UNIVERSITY OF NOVI SAD
FACULTY OF TECHNICAL SCIENCES

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# MODEL OF IMPLEMENTATION OF LEAN CONCEPT IN CLINICAL LABORATORIES

DOCTORAL DISSERTATION

Novi Sad, 2019

UNIVERZITET U NOVOM SADU ● **FAKULTET TEHNIČKIH NAUKA**

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| Menthor's sign |
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# INTRODUCTION

The goal of every company today is to improve business and increase profit through the reorganization and simplification of its processes, decrease of costs and resources utilization, retaining existing and attracting new consumers and employees, etc. Improving the business is usually implemented through different techniques and methodologies that have been developed. Very often we can see that even we already entered into the era of information technology, automation, and modern technology, some companies continue to operate in the traditional way of doing business. The traditional way of doing business can hardly respond to the contemporary requirements (customer requirements are increasingly stringent, there is needed a larger and faster variation of products, economic instability in the world, etc.), which are becoming increasingly demanding and unpredictable. One of the most striking instabilities in the world certainly was the global economic crisis that appeared in the world in 2008. Countries that have managed to recover in a relatively short period were those with highly developed production. Although it is evident that the production is the engine of the economy, service activities have the primacy in the world and this sector is still growing. One of the definitions of services is „*Services are outputs produced to order and which cannot be traded separately from their production. Services are not separate entities over which ownership rights can be established. They cannot be traded separately from their production. Services are heterogeneous outputs produced to order and typically consist of changes in the conditions of the consuming units realized by the activities of producers at the demand of the consumers. By the time their production is completed, they must have been provided to the consumers.*“ (OECD). The influence of services is well known today, and it is important to emphasize that services have great significance in the economic growth, measured by GDP. This is supported by the fact that services in some countries make up a significant share of GDP and thus in France services made up almost 80% of GDP for 2012, while for the same period the average share was 63.6% in all countries. In the same period, the impact of services on GDP in the US was almost 78%, followed by England with nearly 77%, and Germany with some smaller influence of services of almost 71%. In the case of other countries, it is interesting to present Taiwan with approximately 67%, India 66%, etc. (source: IMF). But, in order that services and service systems bring benefits to the wider environment in which they have an impact, they need to be continuously improved. Only in this way services can respond to consumer demands and contemporary changes. One of the imperatives of our time is to improve the quality of service systems, particularly from the perspective of consumers. Service quality is crucial to the success of any service system (Kandampully, 2000; Seth et al., 2005). System for providing services, or service system, is consisted of physical elements and workforce, and it is very important to improve the quality of each segment individually in order to obtain the quality of the service system (Majed et al., 2014). According to Russell and Taylor (1999), a well-designed service system is:

- consistent with the strategic focus on the company, if the company is competitive in speed, then each element of the service process should focus on speed.

- understandable: clear signs and instructions, understandable forms, logical steps in the process, available service providers.
- robust: able to deal with a sudden increase in demand, lack of resources and variable customer expectations.
- easy to maintain: the workers are given achievable tasks and the technology is reliable and convenient.
- effectively related activities of the front and back office.
- cost-effective: do not lose the time or resources, no appearance of inefficiency.
- visible to the customer: the customer should clearly see the value of the provided service.

One of the ways to improve service processes, and health system processes also, is the implementation of the lean concept. Lean concept philosophy first appeared after WW2 in Japan and after the publication of a book titled "The Machine that Changed the World" by Womack & Jones (1990), where authors showed the model which helped the Japanese auto industry to realize incredible resurgence and take over the leadership in the production compared to the American auto industry. Since that, the lean concept seems to be a more and more important worldwide application. Womack and Jones defined lean model like "do more with less - human effort, less equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want". Review of the literature enables us to see that the lean concept in health care organizations represents a growing trend. Authors Kim et al., (2006) describes challenges which may arise during the implementation of the lean concept in healthcare organizations. Hawthorne and Masterson (2013) in their work explain how their health-care organization succeeded to increase the quality and safety of healthcare delivery with the implementation of the lean concept. Dahlgaard et al. (2011) present lean concept which will enable an improvement of the system of the healthcare organization. Womack (2005) in his book "Going lean in health care" describes several ways to reduce wastes in health processes by the implementation of lean tools. One of the very important authors in this research area, Graban (2011), in his book „Lean hospitals Improving Quality, Patient Safety, and Employee Satisfaction", mentioned several benefits which can be achieved by the implementation of the lean concept in healthcare institutions:

- reduced turnaround time for clinical laboratories results by 60% without adding head count or new instrumentation,
- reduced instrument decontamination and sterilization cycle time by over 70%,
- reduced patient death related to central-line-associated bloodstream infections by 95%,
- reduced patient waiting time for orthopedic surgery from 14 weeks to 31 hours,
- increased surgical revenue by 808.000,00 $ annually,
- reduced patient length of stay by 29% and avoided $ 1,25 million in new emergency department construction and
- saved $ 7,5 million from lean rapid improvements event and reinvestment the saving in patient care.

Although it is important to improve processes in health care, it is important to note that this should not be the primary objective of implementing the lean concept in this area. Processes in health systems are specific because they largely include the participation of employees. Therefore, the authors Ballé and Regnier (2007), and Dickson et al. (2008) consider that the implementation of the lean concept can loose its basic sense if it is directed only to the improvement of the process, and not to the employees, that are also a part of the process. Due to this fact, the same authors believe that meaningful education and continuous improvement of employees is much more important when implementing lean concept instead of a simple improvement of each process.

**The goal of the research, with the emphasis on the expected results**

The aim of the research is to develop a methodology that will allow the selection of lean methods and tools that are applicable in the service sector – hospitals and to explore the issues about implementing the lean concept in health institutions in Serbia. Issues are more and precisely defined under the hypotheses. The objective of this research is reflected in the fact that the model for the selection of lean methods and tools that are applicable to healthcare institutions should contribute to the achieving, maintaining and enhancing the competitiveness of those institutions, with the realization of the conditions for business success and consumers' satisfaction. The need for such approach lies in the fact that the implementation of the lean concept in healthcare enables the elimination of all unnecessary processes and thus provides the increase of the efficiency and effectiveness for the implementation process and the system. Through the review of the literature, it can be noted that each institution or company, which implemented the lean concept, did not use one unique method. Each institution used its own implementation approach.

**The hypotheses**

H1: Principles and tools of Lean concept can be implemented in the clinical laboratory.
H2: Implementation of Lean principles and tools in the clinical laboratory will:

- improve clinical laboratory processes and results.
- maximize process flow without adding more resources.
- reduce waiting time for laboratory results.

H3: It is possible to identify factors that affect a patient's satisfaction with the overall work of the laboratory for a blood draw, which can be improved by applying lean principles and tools.

**The expected results**

The research problem in this doctoral dissertation is presented as the development of the framework for the implementation and application of the lean concept in service systems - healthcare institutions, which allow modernization of institutional arrangements, both organizational and managerial. The frameworks will ensure procedures and tools that directly affect the structure of production and service systems in order to increase the effectiveness and efficiency, competitiveness, etc. In other words, the expected results can be presented as:

- Presentation of the impact of individual methods and tools on the increase of the effectiveness and efficiency, as well as their correlations.
- Shortening the flows of business processes.
- The reduction in the number of steps in implementing lean methods.
- Reduction of the time of the process, an increase in the efficiency, reduction of the number of resources.
- Higher satisfaction of the users (patients, doctors, health system)…

The research results will be significant, both for academic and for government and business sectors.

**The plan of the research**

The first and the second part of the research will be related to the introductory considerations – the description of the research, hypotheses, and the theoretical examination relating healthcare institutions and service systems. The next section will deal with the basics of the Lean concept. The special part of the paper will be devoted to the analysis of the latest scientific literature that deals with the application of the Lean concept in healthcare systems. In the end, empirical research with the emphasis on the results and directions for the future researches will be carried out. The work plan has also defined the structure and the content of the dissertation, which includes the following parts (main areas):

- INTRODUCTION, PROBLEM DESCRIPTION, RESEARCH GOALS, HYPOTHESES.
- SERVICE; SERVICE SYSTEMS AND HEALTHCARE.
    - definition of services
    - characteristic of services
    - service classification
    - service systems and processes
- THE SITUATION AND THE IMPORTANCE OF SERVICE SYSTEM
- MEDICINE TROUGH HISTORY
- HEALTHCARE AS A SERVICE
- LEAN CONCEPT.
    - the history of lean

    - lean principles
    - lean concept in healthcare (theoretical background)
- LEAN CONCEPT IN CLINICAL LABORATORIES - THEORETICAL BACKGROUND
- LEAN METHODS AND TOOLS
- THE DEVELOPMENT OF THE MODEL FOR IMPLEMENTATION THE LEAN CONCEPT IN CLINICAL LABORATORIES
- IMPLEMENTATION OF THE MODEL
- SIMULATION
- DISCUSSION OF THE RESEARCH
- CONCLUSION
- LITERATURE

**The methods that will be used**

In accordance with the above-mentioned plan and dissertation goals, the methodology in this dissertation will be related to the descriptive and quantitative dimension. The descriptive section will obtain methods of analysis and synthesis. The theoretical research will encompass elements of description, classification, explanation, and prediction and it shall contain methods used in the implementation of the lean concept. The research results will be presented in the analytical tables and charts, diagrams, and process flows. In addition, the secondary data available from the literature and the internet will be also used. In this doctoral dissertation, the following statistical methods of analysis and data collection will be used: a survey of patients, employees, and doctors in healthcare institutions, data processing will be done by applying statistical methods, to explain the attitudes of the respondents there will be used descriptive methods to verify or discredit the proposed hypotheses.

**The manner of selection, size, and structure of the sample**

Selection of healthcare institutions where will be carried out the testing will be done in relation to the willingness of the management to accept the plan of action which will be presented in detail. Until now, the author of the dissertation has already conducted some researches in the field of Lean concept in healthcare organizations (Clinical Center of Vojvodina – department for clinical biochemistry).

**The possibilities for the implementation of the results**

The expected results will be very useful. Namely, it is expected that the results will be used in healthcare facilities in Serbia and it could be very helpful for any medical organization, planning to start their own lean journey.

# 1. Service, service system, and healthcare

## 1.1 The definition of service

The service industry is a subject of numerous studies. Services as the industry include very large segment from which many scientific disciplines have emerged, such as marketing services (Zeithaml et al., 2006; Vargo & Lusch, 2004; Gummesson & Grönroos, 2012), consumer services (Batt, 2002; Turel et al., 2008; McDougall & Levesque, 2000), etc. Some of the characteristic service industries nowadays are:

- education (elementary school, high school education, university and college education, lifelong learning, training programs, etc.),
- financial services (banking, broker services, insurance, pension funds, etc.),
- business services (consulting, accounting, marketing, etc.),
- logistics (transport of goods and people, maintaining, and security, etc.),
- health services realized in hospitals, clinics, polyclinics, social care institutions,
- state/public services (state defense, court and judicial activities, operations of national security, state administration, etc.),
- telecommunication,
- trade (wholesale and retail trade, sale, trade brokerage, etc.), and
- many others.

When the definition of services is in the question, it can be concluded that there is no single definition that would be acceptable. Due to this fact, some authors stress that although the service area was studied for 25 years period, there is no consensus on the issue of services (Haywood-Farmer & Nollet, 1991). Also, it is very difficult to find a product that "operates" independently without some kind of service. All products are closely related to the various aspects of services which can be represented as advertising, transportation, etc., and therefore services are considered as a very important component in the creation of the entire product or service as a standalone product.

Review of the literature points to the different views on services. Services are "*timely perishable, intangible experience for consumers who participate in the role of co-producer*" (Fitzsimmons & Fitzsimmons, 2006), or service is "*work, process and performance*" (Zeithaml & Bitner, 2002). Vargo and Lusch (2004) define service as "*the application of specialized competencies (knowledge and skills), through deeds, processes, and performances for the benefit of another entity or the entity itself*". According to the ISO standards service is a product that is immaterial, it can represent all or only a part of the whole offer, it is tied to the activities such as sales, handling, delivery, planning, improvement, training for use, maintenance or use of material products (ISO 9001:2015). One of the marketing gurus, Kotler, believes that service is „*any activity or benefit that one party can give to another that is, essentially intangible and does not result in the ownership of anything. Its production may or may not be tied to a physical product*“ (Kotler, 1988). According to Hill, *services are* *defined as changes in the state of personality or state of things* (Hill, 1977). One of perhaps the most commonly used definitions of service is given by the American Marketing Association which presents services as "*activities, benefits, or satisfactions which are offered for sale or are provided in connection with the sale of goods*"AMA (1960).

Although the previously mentioned definitions are from the early period, it should be emphasized that these definitions represent the foundations of today's research. Also, those certainly are not the oldest. The first authors who tried to define the concept of services are Fisher and Collin, who were engaged in the area of services in the thirties of the twentieth century. Fisher tried to split the production into the primary and tertiary, where tertiary production was defined as one that is facing with any new or relatively new consumer demand (Fischer, 1939). A different approach to defining services had Clark who defined service or service industry as a system that includes a large number of different activities which cannot be classified as agriculture or processing industry (Clark, 1960).

With this approach, Clark has extended the concept of services in activities such as maintenance services, transport, etc. Unlike Clark and Fisher, while studying the difference between the primary and tertiary products, Kahn marked tertiary services as those that are primarily intended for the industries (primary and secondary), and which increasingly become important both for the society and for the production. Among others, the definitions of different authors that could also be mentioned are presented in table 1.1.

Table 1.1. Definition of services

| Definition of service | Authors |
|---|---|
| Deed, act, or performance | Berry (1980) |
| An activity or series of activities… provided as a solution to customer problems | Gronroos (1990) |
| All economic activity whose output is not physical product or construction | Brian et al (1987) |
| A time-perishable, intangible experience performed for a customer acting as co-producer | Fitzsimmons & Fitzsimmons (2001) |
| A change in condition or state of an economic entity (or thing) caused by another | Hill (1977) |
| Deeds, processes, performances | Zeithaml & Bitner (1996) |
| Application of specialized competencies through deeds, processes, and performances to benefit another | Vargo & Lusch (2004) |

Source: Maglio, 2007.

By summarizing the various definitions and attitudes it can be concluded that the services, because of the industries which they include, contain certain characteristics accepted by different researchers, which served as the basis for the division on intangibility, the absence of property rights, perishability, etc. Main characteristics of services will be described in more detail in the next section of this thesis.

## Characteristics of services

In order to understand services in a better way it is necessary to identify their main characteristics, which differ from the characteristics of the products (Gronroosu, 1984):

- intangibility (the non-material character of services);
- perishability and volatility;
- heterogeneity;
- simultaneity of production and consumption;
- lack of ownership;

ISO standards emphasize that:

- services are provided in order to meet the demands or needs of the users,
- the customer is usually the participant in the creation and delivery of services,
- the user cannot try out services before buying.

In case of the intangibility of services, as one the most important characteristic, it is important to emphasize the fact that services are intangible forms that are typically expressed as ideas, information, or different processes. Because of intangibility, services are usually invisible and cannot be touched or try before buying and therefore one very important aspect when creating new services or improving old one is the investment in research involving psychological characteristics of consumers such as experience, satisfaction, perceived quality, the satisfaction of consumers, etc. When observing the degree of intangibility, services can be classified into three groups. Different concepts of tangibility in form of groups are more fully disclosed in table 1.2 (Wilson, 1978):

- Group 1 – services of clearly intangible character,
- Group 2 – services which provide added value for tangible products, and
- Group 3 –services that make available a tangible product.

Table 1.2. Concepts of tangibility of services

| The degree of tangibility | Production services | Consumers services |
|---|---|---|
| Group 1 | Security, communication systems, franchise, evaluation | Museums, shareholders, agencies, education... |
| Group 2 | Insurance, contract, consulting, advertising, travel... | Washing, repair... |
| Group 3 | Transport, wholesales, storage, architecture... | Retail, humanitarian aid... |

Source: Wilson, 1978.

Another significant characteristic of services is perishability. Perishability is reflected in the fact that services cannot be stored and therefore it is impossible to ensure the stocks which directly hinders the ability to manage demand. One of the simplest examples of the perishability of services can be presented as a hotel room. When the room is not issued on a given day it represents lost revenue forever, which cannot be compensated nor the lost dates can be stored to be returned or resold later. It is important to mention that when rooms are not issuing all fixed costs (maintenance, electricity, etc.) cannot be eliminated, and those are an additional burden for service providers. Because of these characteristics, services are the subject of the current use, at a specified period of time (hour, day, and month).

The heterogeneity of services is the characteristic which represents the diversity in the quality of services. A variety occurs primarily as a result of the intangibility of services and therefore it is very difficult to measure service as a product. Because of that, services are not always the same and they cannot be repeated. One of the ways to reduce heterogeneity in products is the introduction of standard procedures (standardization) while in the area of service standardization of services can be done usually for smaller systems. For larger service systems, one of the solutions is franchising in order to establish the uniform procedures that would mostly present the uniform quality of service. Since in the process of the provision of services there is a large number of contacts, which can be direct or indirect, between consumers and service providers, special focus and attention should be dedicated to the training of employees. Recruitment and selection of new and qualified staff, as well as continuous training of employees, represents a segment where successful companies perform different and quite sophisticated approaches. One of the examples of the good practices of training of employees can be seen at fast food chains such as McDonald's, which opened the McDonald's Hamburger University in the purpose of training of quality staff and positioning them on their market. This company is characterized by a variety of procedures to ensure quality control, realized through the control teams with the aim of assessing the quality of service, maintenance and cleanliness of the service system.

The control teams come unannounced, to evaluate the top management and the employees individually. On the other hand, the chains of prestigious hotels such as the Holiday Inn educate their future recruits as well as employees at the Holiday Inn University with the aim of creating a brand that is recognized all around the world.

As a result of heterogeneity, intangibility, and perishability the following characteristic is reflected in the simultaneity of production processes and consumption of services. The process of producing and consumption of services largely depends on the distribution channel of a service system. It happens very often that service systems do not have the distribution channels and as a result, there are two-way effects between consumers and manufacturers. The first case represents the situation when a consumer comes for a service in a particular service system, which operations are largely limited to a certain region. Service systems can solve this problem by creating a larger number of smaller service systems located to enable the economical use of time and travel of consumers while reducing distribution costs of the system. An example of such a system can be the opening of different retail chains in the immediate vicinity of the city. The second case is when a manufacturer of services comes to the consumer where the limits in terms of the region do not exist, but the cost of services for the consumer increase. Depending on the quality of a service, a consumer is willing to pay or not for it. An example of such a service is the delivery of services to consumers by the service system (through its own services or by hiring other service systems) at any location on the earth with extra costs included.

One of the main differences between the goods as products and services is reflected in the absence of ownership. When a consumer pays for a particular product he/she becomes the owner of that product (car, telephone, shoes, food, etc.) while on the other hand a consumer who pays for service as a product, it can only be an "illusory" owner in a certain period of time. An "illusory" means that the consumer can only have a certain time to access/use/facilitate the service. In order to describe the absence of property, the best examples are hotels. When a consumer pays for the use of hotel capacity (room) he/she becomes a temporary owner of the room, and he/she has to leave a room after the expiry of a period of service use. All that remains to the consumer of hotel service is a sense of satisfaction and a connection with a service which will be used again in the future. Besides the differences between products and services, which is reflected in the absence of ownership, differences between products and services are shown in table 1.3 below, based on the ISO standards:

Table 1.3: Differences between products and services

| Service | Product |
|---|---|
| Nonmaterial | Material |
| Hardly repeatable | Repeatable |
| Provision and the use of services are usually in the same location | Production and the use of products are usually in different locations |
| Consumer is engaged in the creation and the delivery of service | Consumer usually is not engaged in the creation and the delivery of product |
| Limited presence of the quality function in the service processes | Function of quality is present in production processes |
| It cannot be transported | It can be transported |
| For not-harmonized service only possible solutions are apology, repeating the services or allowances/bonifications | Poor product can be withdrawn, improved or replaced |
| Service cannot be stored, there are no service inventories/stocks | Products can be stored, there are socks of products |
| Control of a service is made by a consumer on the basis of the level of satisfaction of his/her expectations | Control of a product is based on a comparison with the specification and it does not have to be done by consumer |
| It cannot be tried out before buying | It can be tried out before buying |
| In the most cases, it is necessary a direct contact between provider and consumer of services. | There can exist a mediator/agent between a producer and consumer of product |

One more classification of the services and material products is presented by Russell and Taylor (1999) through seven differences:

1. Services are intangible, unlike products.
2. Service output is highly variable.
3. Services have large contact with customers.
4. Services are short-term.
5. Buyers do not separate the service from the delivery of services.

6. Services have a greater tendency to be decentralized and geographically dispersed.
7. Services are frequently consumed than products and they can change easily.

In addition to the ideas of Russell and Taylor, the author of the thesis presented the differences between production and service manufactures by Krajewski and Ritzman (1990), shown in table 1.4.

Table 1.4: Continuum of characteristics of production and service producers

| **More like Service Producer** | **More like Goods Producer** |
|---|---|
| Intangible, perishable product | Physical, durable product |
| Output cannot be inventoried | Output can be inventoried |
| High customer contact | Low customer contact |
| Short response time | Long response time |
| Local markets | Regional, national, or international markets |
| Small facilities | Large facilities |
| Labor intensive | Capital intensive |
| Quality not easily measured | Quality easily measured |

When the characteristics of services are in question, in terms that services are performed in order to meet the demands or needs of the users, it is important to emphasize that services are seen as a set of activities of the working process of the service system, which resulted in an immaterial product, defined to meet the needs of consumers (personalized services or mass services) and for which the consumer is willing to pay (directly or indirectly) (Radošević, 2013**).** Because of this, some authors emphasize that these characteristics represent a challenge in the process of creating new services unlike new material products (Figure 1.1).

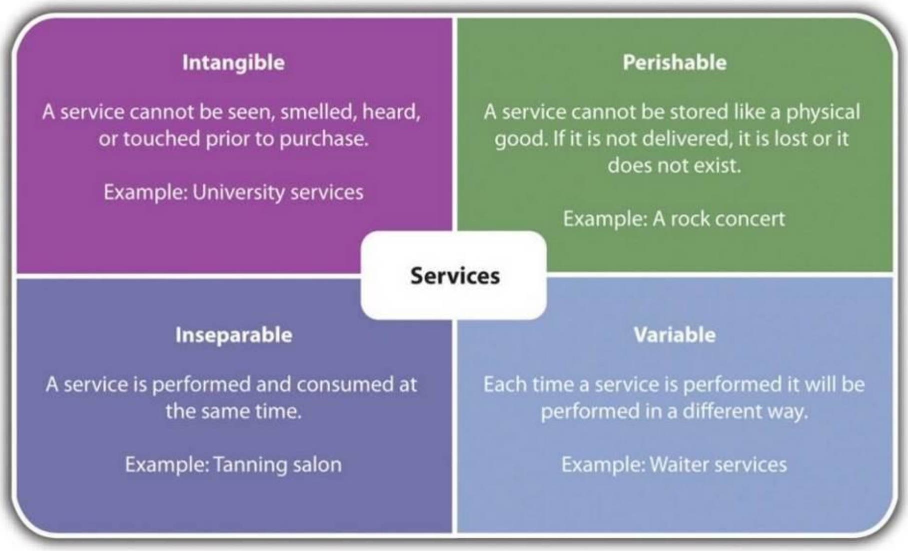



Figure 1.1. Characteristics of services
Source: Dana-Nicoleta Lascu and Kenneth E. Clow, Essentials of Marketing (Mason, OH: Atomic Dog Publishing, 2007), 264–268

Another significant feature of services that largely determines the difference in comparison to the material product is consumer participation in the creation of services. The participation of consumers in service processes consists of two main characteristics. The first is the time that a producer of services consumes dealing with consumers which are presented as a short or long contact with consumers. The second characteristic lies in the place where the contact with customers is made, or the place where the new value is generated: the front office or the back office. Adding together all the characteristics that define the services has led to the creation of the different classifications of services that are the subject of numerous studies today because of the very great importance of services in the market.

## Classification of services

A large number of attempts of classification of services can be found in the literature. One of the initial problems that occurred in classification is the attempt to replicate material manufacturing to services. The problem has arisen in the initial stages since the researchers did not take into account the particular characteristics of services. Morris and Johnston (1984) have emphasized that some authors do not take into account the variability of services resulting from the presence of the consumer in the service system. Therefore, in most cases, the classification of services based on classifiers taken from material production is usually considered impractical or unusable. Subsequent studies have developed many classifications of services which were taking the different basis for classification like inputs of services which are processed, the degree of contact with customers, the degree of interactions, classification depending on the orientation of services, etc. In their work Goodale et al. (2003)

showed in detail some of the most famous classification of services with reference to the basis for the classification and type of services (Table 5).

Table 1.5. Well-known classification of services (Goodale, J.C., Verma, R., Pullman, M.E., 2003)

| Basis for classification | Type of services |
|---|---|
| Inputs that are processed<br>Morris & Johnson (1984) | • Operations of processing customers<br>• Operations of processing information<br>• Operations of processing materials |
| Degree of a contact with a customer in process of service<br>Chase (1978) | • Pure services<br>• Mixed services<br>• Quasi-production |
| Type of the relationship between service organization and customer regarding continental delivery (CD) or discreet transaction (DT)<br>Lovelock (1983) | • „Membership" relations with CD<br>• Informal relation with CD<br>• „Membership" relations with DT<br>• Informal relation with DT |
| Orientation on the people or equipment, length of contact time, the level of adjustment, the level of discretion, added value and orientation on the process or product, or the number of customers processed per day<br>Silvestro (1992) | • Professional services<br>• Service shops<br>• Mass services |
| The degree of the interaction and customization, or the degree of the work intensity<br>Schmenner (1986) | • Professional services<br>• Service shops<br>• Mass services<br>• Service factories |
| The complexity of the service process and its divergence<br>Shostack (1987) | • High complexity, low divergence<br>• High complexity, high divergence<br>• Low complexity, low divergence<br>• Low complexity, high divergence |
| A person to person or person to technology or, delivery at the place of services or delivery at the customer<br>Dabholkar (1994) | • An employee uses the technology in place<br>• The customer uses the technology in place<br>• The customer calls an employee who uses technology<br>• The customer uses technology from home |

One of the major researchers in the field of management services is Silvestro, who based its research on the issue of classification of services on the six most important characteristics of services. These characteristics can be expressed as:

- Orientation for equipment/people;
- Time spent on working with users;
- Level of adjustment;
- Potential for adaptation;
- Place of the creation of the added value;
- Orientation to the product/process.

Based on the different characteristics, Silvestro classified services on three types:

1. Mass services,
2. Service shops, and
3. Professional services.

Under the term of mass services, Silvestro has defined services which have a low level of adjustment with a high level of intensity. This type of service is focused on the broader framework of people, different types of communities such as schools, banks, etc., not individuals. One of the most important characteristics of mass services is the ability to standardize its processes and services while the focus is directed to the equipment and production.

A high level of contact and an ability to adapt, accompanied with a high number of users that are served during the day, with a declining trend in the level of labor intensity are characteristics of services known as service shops. The most important representatives of these services are healthcare institutions and hospitals. This type of service is characterized by the orientation of services to the process-products and to the equipment-users. Services occur in the front office and in the back office working with consumers.

Services that are provided only in the front office with consumers and which are directed only at consumers are defined as professional services by Silvestro. Representatives of these services are lawyers, psychiatrists, etc., and such services are characterized by a very high degree of customization and working activities, a high degree of contact with consumers with a small number of consumers during a specific period of time. More detailed display of characteristics of services according to Silvestro is shown in Figure 1.2.

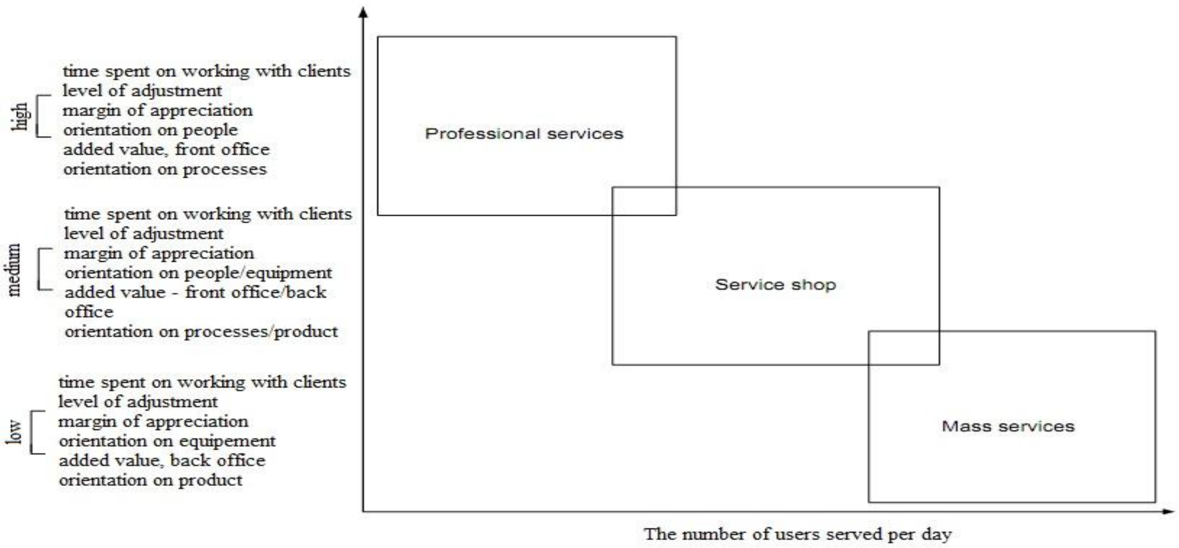



Figure 1.2. Classification of services according Silvestro (1992)

Unlike Silvestro, some authors classify services in relation to the tangibility, market, objectives, level of regulation, etc. Table 1.6 presents the classification system of services by Evans & Berman (1990).

Table 1.6. The classification system of services by Evans & Berman

| | | |
|---|---|---|
| Market segmentation | Organizational consumers | management consulting, plant maintenance, accounting, service… |
| | Final consumers | wardship, taxi, insurance, cleaning… |
| Level of tangibility | Rented-Goods Services | leasing auto, hotel room, office space, wedding items… |
| | Owned Goods Services | auto or computer repairs, lawn care & home care… |
| | Nongoods Services | personal advice, tutor, legal, and accounting… |
| Skills of service provision | Professional | medical services, service, consulting... |
| | Non-professional | security, taxi... |
| Objectives of service provision | Profit | Insurance companies, transporters... |
| | Non-profit | universities, museums… |
| Level of regulation | Regulated | hospitals, mass transport... |
| | Non-regulated | computer time sharing, catering… |
| Level of labor intensity | Technically-based | automated car wash, air transport… |
| | Labor-based | tennis instructor, accounting… |
| Level of contact with consumers | High contact | university, air transport, hotels… |
| | Low contact | arranging grass, carwash… |

Haywood-Farmer (1988) classified services according to the degree of adjustment of services, the degree of labor intensity and the degree of interaction with customers. Depending on three above-mentioned factors they have divided services into 8 areas which are presented in Figure 1.3 as a three-dimensional system of service classification.

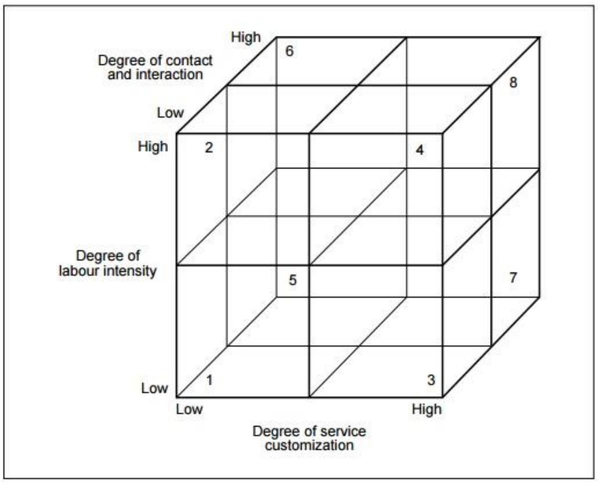



Figure 1.3. The three-dimensional system of service classification according to Haywood-Farmer (1988)

Based on the Silvestro's division of services into three types, as well as division of services depending on the degree of labor intensity, expressed as the relative flow in the period (high or low), and the level of interaction and adaptation – marked as the degree of variation (high or low), Schmenner has defined its own classification of services.

The classifier of services shown in Figure 1.4 is known under the name of "the modified matrix of services" because, instead of Silvestro's division of services on three types, Schmenner modified services in four types:

1. Service shop;
2. Service factory;
3. Mass services, and
4. Professional services.

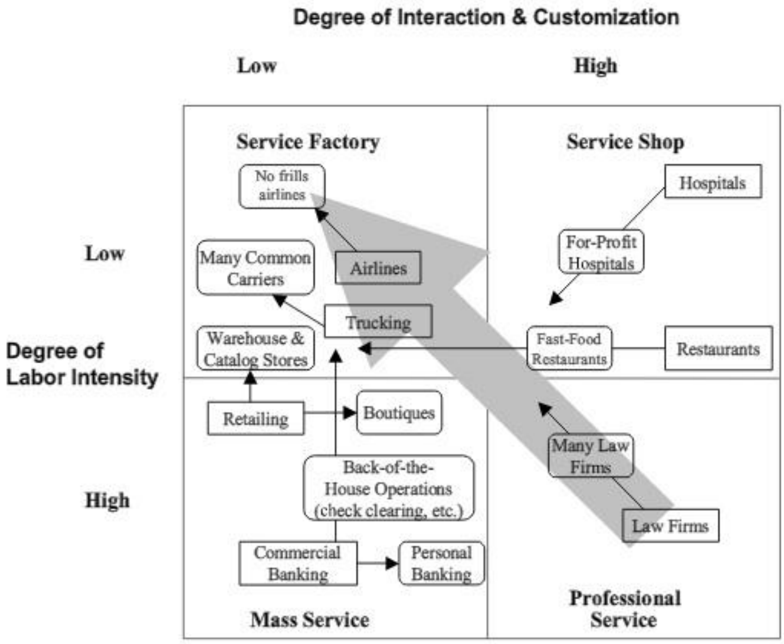



Figure 1.4. The modified matrix of services by Schmenner, R. W. (2004).

Mass service, professional service, and service shop are characterized similarly to Silvestro, but he expanded services to the service factory. As features of service factories, there are emphasized the level of labor intensity, low contact with consumers and low level of customization. Some authors (Nagy, 2013; Lovelock and Gummesson, 2004) did not enter into such a complex classification but they made classification taking into account only certain features of the service and have classified services based on the simultaneity and intangibility (Table 1.7).

Table 1.7. Service classification based on the simultaneity and intangibility

| | | Level of simultaneity | |
|---|---|---|---|
| | | High | Low |
| Level of intangibility | High | Video education | Psychotherapist |
| | Low | Fast food restaurants, Bookshop | Hairdressing salon |

Looy et al., (1998) classify services based on the degree of contact with consumers and customization of service process (Table 1.8)

Table 1.8. Service classification based on the degree of contact with consumers

| | Standardized processes (execution) | Customized processes (diagnosis) |
|---|---|---|
| High contact with the client<br><br>Value is provided during the interaction with the client | Medical nurse<br>(skills: making a comfortable experience for the client, that is focused on the user) | Psychotherapist<br>(skills: timely diagnosis of complex diseases and specific problems) |
| Low contact with the client<br><br>Client focus in on the results | Pharmacist<br>(skills: cost control of rational team) | Neurosurgeon<br>(skills: creative and innovative solutions for solving one of the problems) |

The integration of all the characteristics of services and the classification of services has led to the fact that we can understand service systems in a better way. Service systems today can be much more complicated as opposed to the production systems.

## Service systems and processes

It is well-known that the production processes and systems are relatively older than service systems and that is the reason why they were the subject of earlier studies and researches. Trought the development of production-oriented era by Taylor, Drucker, McCarty via consumer-oriented era until today, which can be presented as the consumer era, service systems were developed also. The materials of Ćosić, Maksimović, and Zelenović were used in order to simplify the representation of production systems and to understand service systems in an easier way. Similarly, as production system is defined by the input values such as material, energy, and labor, on the entrance into the production system, and by the output as a product, at the end, service systems on the entrance to the system have the energy, material (idea), information, while as the output there is a product in the form of service. The authors define production systems as a set of basic technological systems and other information and energy structures, arranged in such a way to ensure the implementation of the objectives and projecting of effects (Ćosić & Maksimović, 2005). Some authors observe service system as the "value co-creation integration of people, technology, the value proposition of the internal and external service systems and shared information such as language, methods, measures, laws" (Maglio & Spohrer, 2008). On the other hand, another group of authors defines "service system as a function of the number and variety of people, technologies, and organizations linked in the value creation networks, ranging in scale from professional reputation systems of a single kind of knowledge worker or profession, to work systems composed of multiple types of knowledge workers, to enterprise systems, to industrial systems, to national systems, and ultimately to the global service system" (Maglio et al. 2006). Deming defined a system as a network of interconnected and dependent components that work in conjunction in order to achieve their goals (www.deming.org). If the characteristics of production and service definitions above are connected to the definition of the system by Deming, a service system could be presented as a network of inter-related components (information, people, technology and organizations) that work in conjunction with the objective of creating new services in order to meet the needs of consumers for which a consumer is ready to allocate certain financial resources.

Regardless of whether it is a production or service systems in question, both are constantly influenced by external factors or external environment in terms of cultural influences, political and demographic influences, etc. (Figure 1.5). In order to explain the characteristics of production and service systems (impacts on the processes within the production and service systems), there have been presented the results of research of author Zelenović published in the book "The design of production systems"**.**

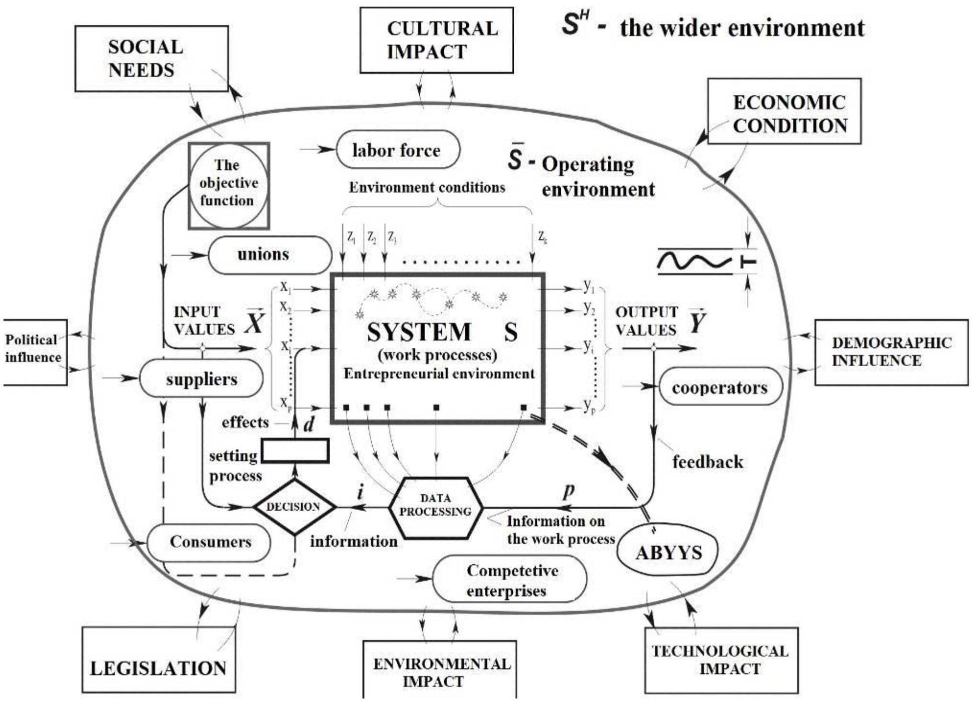



Figure 1.5. The impact of the immediate and wider environment on working processes (Zelenović, 2003)

"Relation between the elements of the program structure ($p_j$) and the quantity of products ($q_j$) presents the basis and dependence that is used during the determination of the type of production system. „This dependence is determined by environmental conditions, the degree of social division of labor and by the organizational level of the economic system." If there is, for example, a given production program structure: $p_1$, $p_2$, $p_3$, . . . , $p_j$ . . . $p_n$ and quantity $q_1$, $q_2$, $q_3$, . . . , $q_j$ . . . $q_n$ (Figure 1.6.)

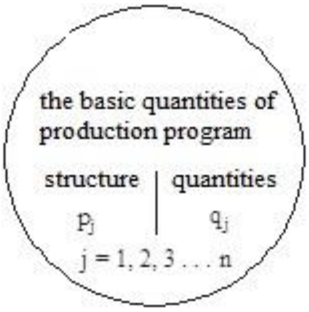



*Figure 1.6. The basic values of the production program*

and if there is a rule that:

$q_1 > q_2 > q_3 > \ldots > q_j > \ldots q_n$

it is possible to present the dependence between the structure and the quantity (Figure 1.7.).

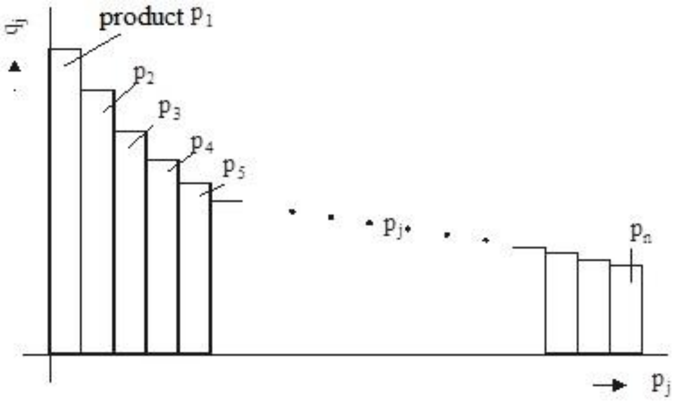



*Figure 1.7. The characteristic dependence of the production program: structure – quantity*

Looking at the dependency of structure and quantity, there can be derived two limits of dependence (Figure 1.8):

1) typical production program with narrow structure (one or a couple of products of similar size and shape) and larger quantity, and
2) characteristic production program with wider structure and unit quantities.

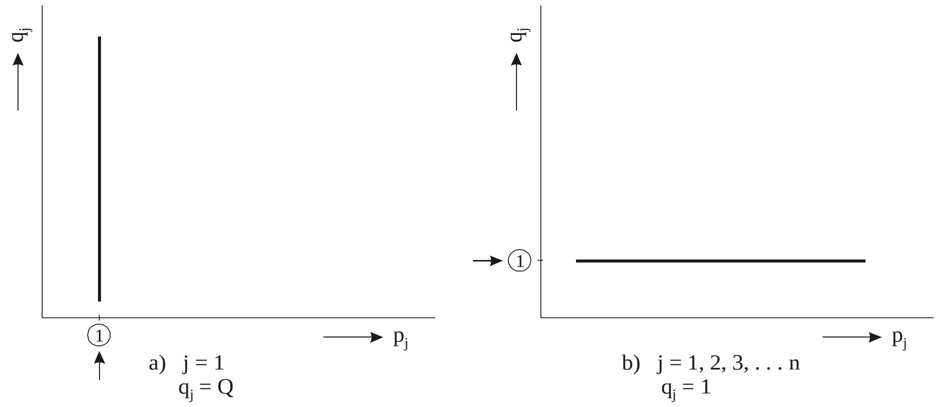



*Figure 1.8. Limit areas of dependence $p_j$ - $q_j$*

The general dependence of $p_j$-$q_j$ (figure 1.9) represents the basic orientation in the consideration of the flows of materials, energy, and information in the system:

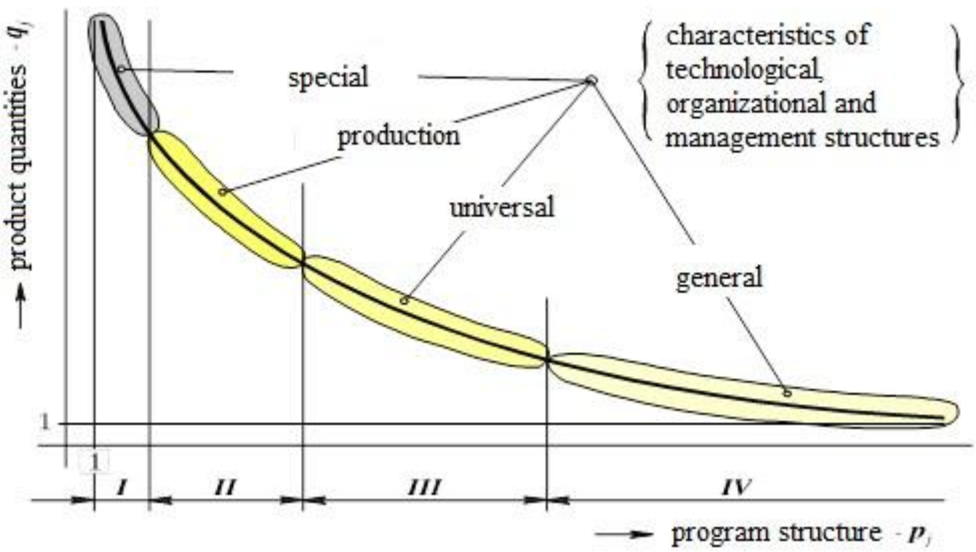



*Figure 1.9. Basic areas of dependence $p_j$ - $q_j$*

- *the area I* – essentially, requires a "faster" technology with technological and spatial structures for specific purposes, a high degree of automation and lower levels of flexibility,
- *area II* – requires the application of the technological spatial structure of the production character, the lower characteristics in terms of performance and increased in relation to the space and a degree of flexibility,
- *area III* – requires the technological and spatial structure of universal character and a high level of flexibility ("slower" technology),
- *area IV* – requires technological systems of a general character with wide possibilities of processing and spatial structure of the unit job.

As noted earlier, within the production systems, and therefore in all areas (from I to IV) of the diagram $p_j$ - $q_j$ there are present transformation processes of inputs (flows of materials, information, and energy) into outputs (such as product or service). “The quantity of products, the relationship structure - quantity, the degree of technological complexity of the working assets and working capacity of the system elements represent the values of particular importance for the development of criteria for the creation of material flows and define the basic parameters of production - service systems. Accordingly, there can be distinguished two types of flows in the system: the interrupted and continuous flows” (Zelenović, 2003), whose characteristics are shown in figure 1.10”.

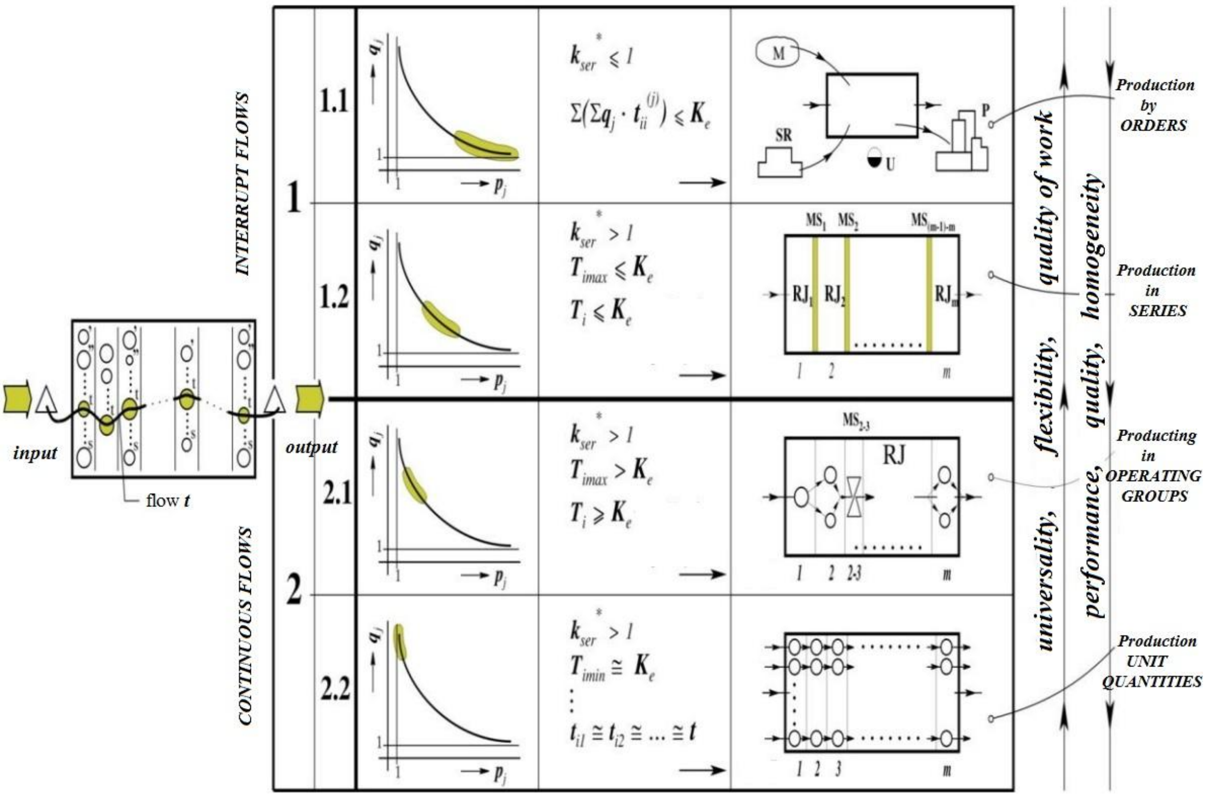



*Figure 1.10. Characteristics of the basic shapes of flows (Zelenović, 2003)*

Since the production cannot be imagined without quality service, a new paradigm, which integrates production and service, is established in the literature as “the production – service systems” (PSS). These systems can be defined as “a marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfillment or economic value” (see Tran and Park, 2014). PSS approach represents the subject of many types of research and a trend in development (for more see Vezolli et al., 2015; Lee et al., 2015; Baines et al., 2007; Morelli, 2006; Aurich et al., 2006). Regardless of the integration of services into the production process, one very important factor of the service systems is quality. The imperative of nowadays is to improve the quality of service systems, particularly from the perspective of the consumer. Service quality is crucial to the success of any service system (Kandampully, 2000; Seth et al., 2005;

Caruana, 2002; Fiedler et al., 2010). System for providing services, or service system, is consisted of physical elements and workforce, and it is very important to improve the quality of each segment individually, to obtain the quality of the whole service system. According to Russell and Taylor (1999), a well-designed service system is:

- consistent with the strategic focus on the company, if the company is competitive in speed, then each element of the service process should focus on speed;
- understandable: clear signs and instructions, understandable forms, logical steps in the process, available service providers;
- robust: able to deal with a sudden increase in demand, lack of resources and variable customer expectations;
- easy to maintain: the workers are given achievable tasks and the technology is reliable and convenient;
- effectively related activities of the front and back office;
- cost-effective: do not lose the time or resources, no appearance of inefficiency;
- visible to the customer: the customer should clearly see the value of the provided service.

## 1.2 The situation and the importance of the service sector

„Services are outputs produced to order and which cannot be traded separately from their production. Services are not separate entities over which ownership rights can be established. They cannot be traded separately from their production. Services are heterogeneous outputs produced to order and typically consist of changes in the conditions of the consuming units realized by the activities of producers at the demand of the consumers. By the time their production is completed, they must have been provided to the consumers.“ (OECD)

A growing trend in the usage of services is certainly related to a trend of globalization. The development of information technology (IT) has led to the provision of services without limits. The exchange and provision of services (various forms of payment, booking, ordering products...) is enabled by the internet, distance learning system allows student to enroll and terminate its desired faculty from other countries with the help of various internet platforms, surgery of patients are possible by using IT where the doctor does not even see the patient. Information technology and the internet today represent a service that keeps primacy and whose influence on the economies of individual countries can be roughly described as "extremely" significant (Figure 1.11).

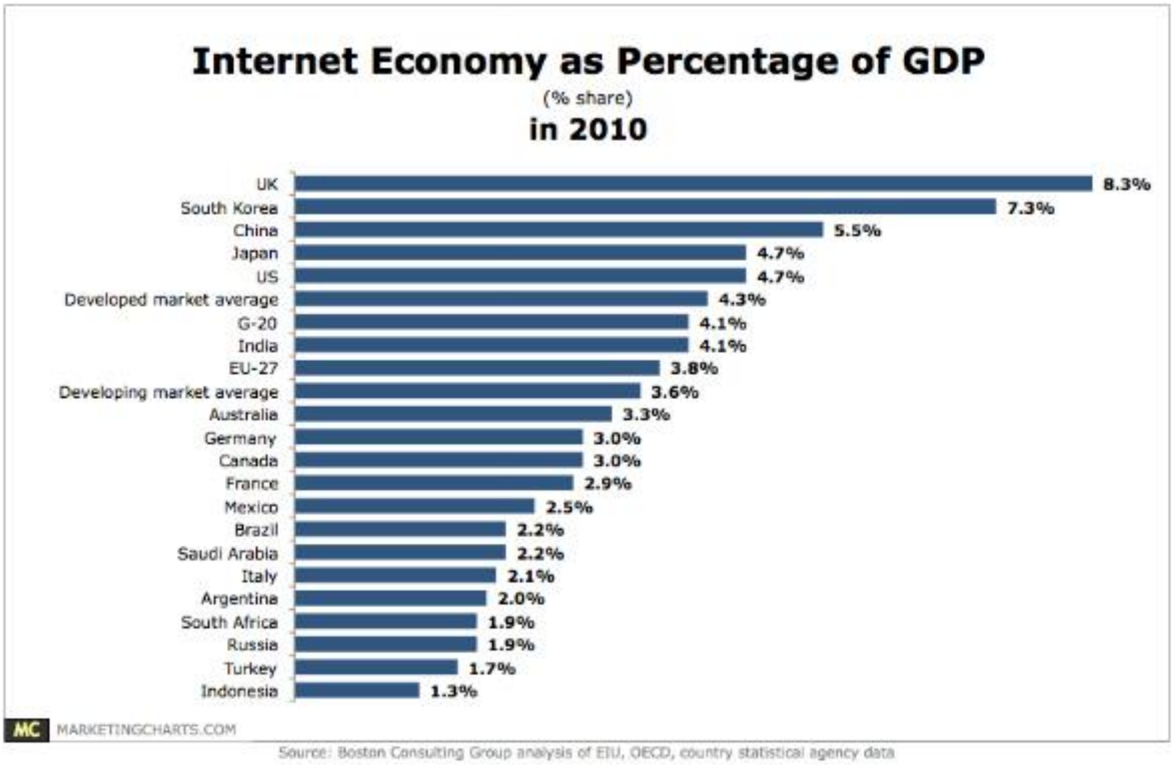



Figure 1.11. The impact of the internet on the GDP of selected countries

In order to realize the importance of services in the continuation of the text, the author presents some of the organizations that deal with statistical measures and data related to services. On October 30, 1947, during the conference of the United Nations (UN) representatives of 23 countries in Geneva signed a document called the GATT (General Agreement on Tariffs and Trade) which later in 1995 was used to establish the World Trade Organization (WTO). Until 1994 128 countries became members of this organization, including Serbia. WTO organization includes goods, services, and intellectual property in its area of business. In addition to the WTO, there is an organization that was formed in 1948 under another name, the European Economic Cooperation (OEEC).

When the US and Canada joined the OEEC in 1960, in 1961 the organization got a new name, under which is functioning even today, the Organization for Economic Co-operation and Development, OECD. The primary activity of the OECD includes data processing of the areas that directly affect the economic growth and financial stability of the country. As known, services have great significance in the economic growth, measured by GDP.

This is supported by the fact that services in some countries make up a significant share of GDP and thus in France services made up almost 80% of GDP for 2012, while for the same period the average share was 63.6% in all countries. In the same period, the impact of services on GDP in the US was almost 78%, followed by England with nearly 77%, and Germany with some smaller influence of services of almost 71%. In the case of other countries, it is interesting to present Taiwan with approximately 67%, India 66%, etc. (source: IMF).

If we look at the situation in Serbia, according to data of the Statistical Office of the Republic of Serbia, we can see from Figure 1.12 the impact of services on national GDP. Services made to 62,2% of Serbian GDP in 2011.

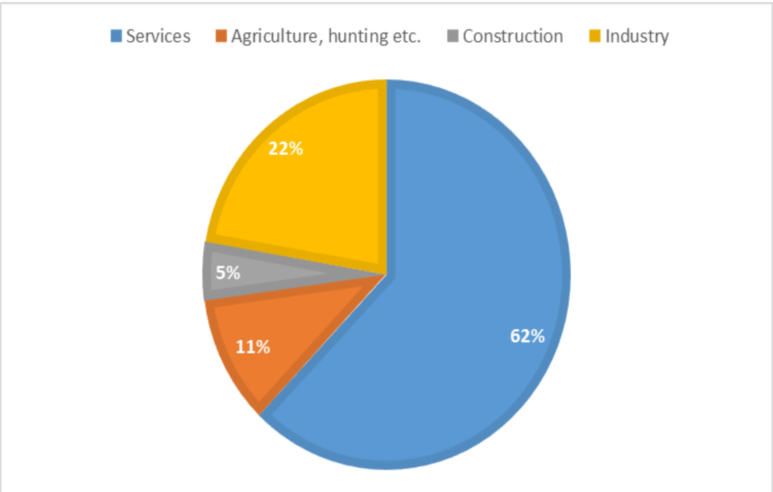



Figure 1.12. Impact of services on national GDP in Serbia
Source: the Statistical Office of the Republic of Serbia (http://webrzs.stat.gov.rs)

In order to explore in detail the state of services in Serbia table 1.9. presents the GVA of the Republic of Serbia by activities and GDP in the period from 2009 to 2011.

Table 1.9. Presents the GVA of the Republic of Serbia by activities and GDP in the period from 2009 to 2011 (http://webrzs.stat.gov.rs)

| Industry | In mil of RSD | | | | Structure in % | | | |
|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | 2010 | 2011 | 2008 | 2009 | 2010 | 2011 |
| Agriculture, forestry and fishing | 195385,4 | 237474,6 | 218005,3 | 245127,5 | 8,58 | 8,92 | 8,01 | 8,5 |
| Mining | 27348,1 | 32910,6 | 36387,6 | 42336,2 | 1,2 | 1,23 | 1,2 | 1,46 |
| Processing industry | 321245,5 | 373645,3 | 370264,3 | 389942,3 | 14,10 | 14,03 | 13,61 | 13,53 |
| Electricity, gas, water | 60786,2 | 69284,7 | 86388,3 | 90119,5 | 2,66 | 2,6 | 3,17 | 3,12 |
| Building and Construction | 99195,8 | 125692,3 | 111747,6 | 114513,5 | 4,35 | 4,72 | 4,1 | 3,97 |
| Wholesale and retail | 230192,0 | 277794,2 | 258486,9 | 267969,6 | 10,10 | 10,43 | 9,5 | 9,29 |
| Transport and storage | 107862,0 | 122502,9 | 126593,4 | 132582,1 | 4,73 | 4,6 | 4,65 | 4,6 |
| Accommodation and food services | 23924,1 | 25612,6 | 27693,2 | 27507,8 | 1,05 | 0,96 | 1,01 | 0,95 |
| Information and communication | 85451,0 | 106128,0 | 114393,5 | 123813,7 | 3,75 | 3,98 | 4,2 | 4,29 |
| Financial and insurance activities | 62911,1 | 77917,4 | 85076,4 | 94803,0 | 2,76 | 2,92 | 3,12 | 3,28 |
| Real estate | 216482,0 | 258029,0 | 297809,0 | 322186,7 | 9,5 | 9,69 | 10,94 | 11,17 |
| Professional, scientific and innovative activities | 93754,0 | 112861,0 | 97084,0 | 97926,6 | 4,11 | 4,24 | 3,56 | 3,39 |
| Administration | 33071,0 | 42224,4 | 39403,9 | 42941,3 | 1,45 | 1,58 | 1,44 | 1,49 |
| Public administration and social insurance | 91494,7 | 91633,2 | 90452,4 | 100137,0 | 4,01 | 3,44 | 3,32 | 3,13 |
| Education | 95432,4 | 114757,2 | 119411,4 | 121467,4 | 4,19 | 4,31 | 4,38 | 4,14 |
| **Health care and protection** | **213330,6** | **144343,4** | **150012,9** | **151009,0** | **9,36** | **5,42** | **5,51** | **5,23** |
| Arts and Entertainment | 18948,0 | 23463,6 | 35035,7 | 38724,8 | 0,83 | 0,88 | 1,28 | 1,34 |
| Other service activities | 20604,2 | 24257,0 | 37779,0 | 37213,7 | 0,9 | 0,91 | 1.38 | 1,29 |
| Activities of households as employers | 2373,2 | 2598,0 | 2468,4 | 2685,1 | 0,1 | 0,09 | 0,09 | 0,09 |
| | | | | | | | | |
| Industries – total | 1933805,2 | 2289884,2 | 2333391,1 | 2476743,2 | | | | |
| FISIM (-) | 43597,5 | 59878,3 | 68726,9 | 76702,3 | | | | |
| GVA | 1890207,7 | 2230005,9 | 2264664,2 | 2400040,9 | | | | |
| Taxes on products | 426929,5 | 482632,9 | 489628,6 | 528754,4 | | | | |
| GDP | 2276886,2 | 2661386,7 | 2720083,5 | 2881891,0 | | | | |

According to the data from Table 1.9. the primary sector (agriculture, forestry, fishing, and mining) in 2008 made up to 9.6% of the gross domestic product. The secondary sector, which includes electric supply, electricity, gas, and water, manufacturing and construction comprised 21.11% of the GDP of the Republic of Serbia in the same year. The tertiary sector, which includes all other service activities in 2008 amounted to 69.29% of the gross domestic product. In 2009, national GDP consisted of 10.15% of the primary sector, 21.35% of the secondary and 68.5% of the tertiary sector. In 2010, the primary sector made up to 9.21%, secondary 20.88% and tertiary 69.91% of national GDP. In 2011 the primary sector made up 9.96%, secondary 20.62% and tertiary 69.42% of national GDP.

When we talk about the number of employees in the service sector, Figure 1.13. gives an overview of some countries in the world based on data from the World Bank. We can see that the highest employment in the services sector is in the United States, with almost 81%. France, whose share of services in GDP is among the highest has fewer employees with approximately 73%. Switzerland recorded a significant drop in employment in the services sector in the period between 2007 - 2008 years for 5%, but from 2008 there is recorded a gradual growth that is now around 72%. Germany and Japan have approximately the same number of employees in the service sector, which is around 70%.

When the situation of employment in the service sector in Serbia is in question, we can conclude that Serbia is lagging behind mentioned countries and in the service industry, Serbia has approximately 56,1% of employees (in 2017). The reason lies in the fact that although Serbia has a significant share of services in GDP (more than 60%), it has a very high rate of unemployment, inadequate development of service sector which employs a large number of people, the slow reform of the State in resolving these problems, etc. (http://www.worldbank.org/)

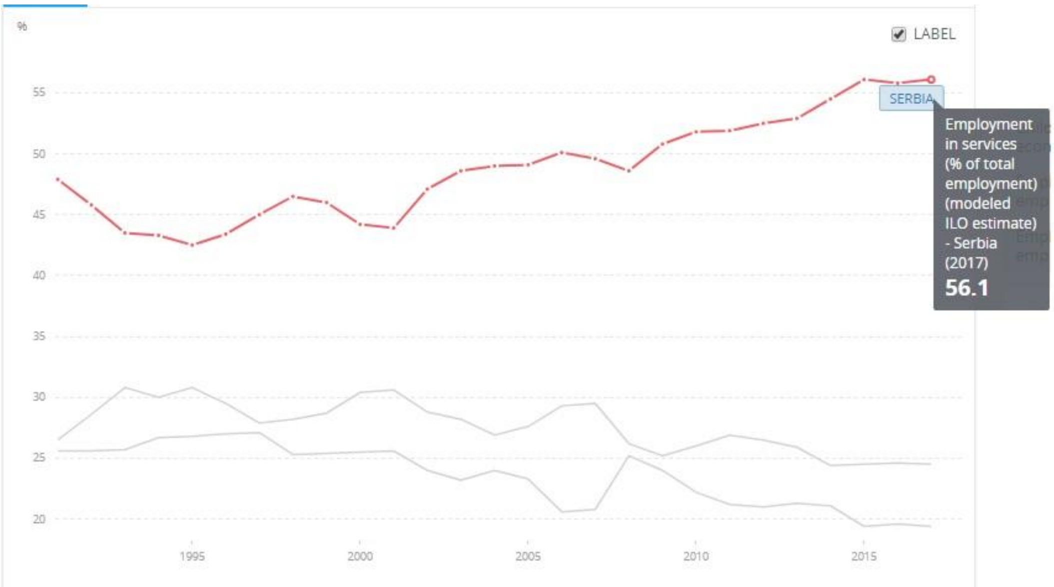



Figure 1.13. World Bank data Employment in services (% of total employment) http://www.worldbank.org/

## 1.3 Medicine trough history

Bona diagnosis, bona curation (good diagnosis, good cure)

Medical maxim

According to the definition of the World Health Organization (WHO) medicine (actually traditional medicine) is „the sum total of the knowledge, skills, and practices based on the theories, beliefs, and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as in the prevention, diagnosis, improvement or treatment of physical and mental illness“. The precise date of the beginning of the development of medicine is not known, but it is known that it began with the development of human consciousness. Some of the stages of development of medicine that can be found in the literature are shown in Figure 1.14.

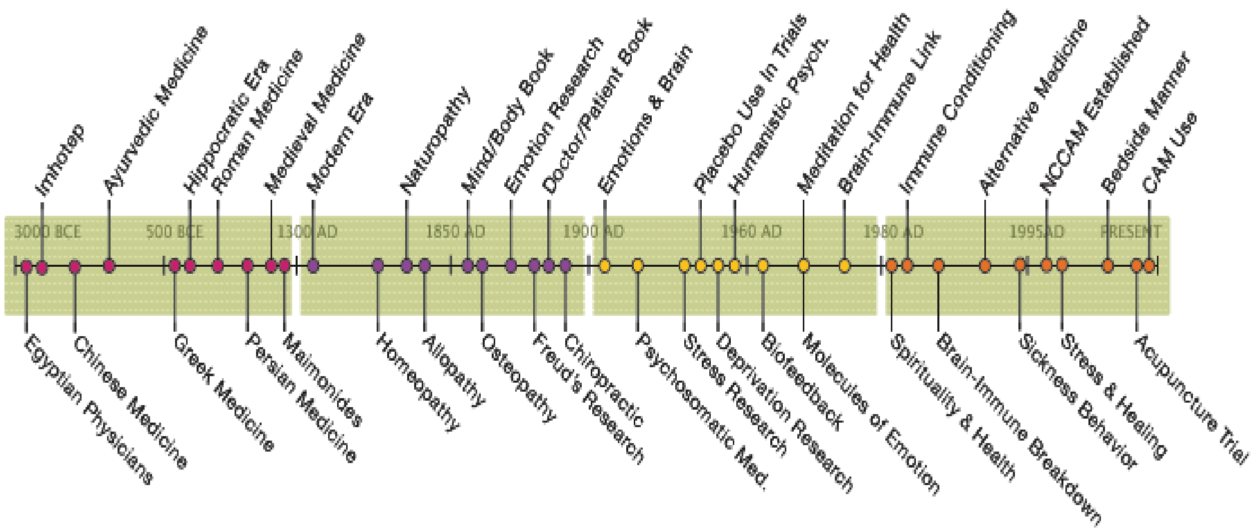



Figure 1.14. Medicine timeline through history (taken from http://www.thenewmedicine.org)

Although the image cannot accurately determine the occurrence of development, it is possible to observe some of the most significant periods of the development of medicine that have been accepted by many researchers. This division can be presented as:

- prehistoric,
- antique,
- Arab medicine,
- medieval European medicine,
- early modern period and
- development of modern medicine (Guthrie, 1945).

In the continuation of the paper, there are presented the beginning of the medicine and the development of medicine in the ancient period. When we talk about prehistoric medicine there is not enough data to explore the same. It is assumed that medical treatments are carried out on the basis of belief in the higher power and that the drugs were based on plants, different types of minerals, animal body parts, etc. The ancient period of development of medicine includes Egyptian, Chinese, Indian, Babylonian (known as Mesopotamian) and Greco-Roman medicine. Some of the earliest saved records that are directly related to medicine are dating from 3000 years BC. Figure 1.15 presents the stone tablets from the period around 2500 (the medicine of Sumerian) BC that contains a record of a medical recipe.

Figure 1.15. Sumerian stone board - recipes 2,500 B.C.

Babylonian or Mesopotamian medicine is less known than Egyptian. Based on the existing records of that time, scientists were able to learn that the Babylonian medicine was divided into two categories, "scientific" and "practical" school of medicine (Magner, 2005). The Babel community was one of the most developed societies, supported by the Babylonian law, known as the Code of Hammurabi. King Hammurabi (1792 - 1750 BC) was the founder of the empire of Babylon, which was located in the southern part of Mesopotamia. In his law, the king was very dedicated to medicine. This is primarily reflected in the cost of treatment as well as penalties, and the doctor-patient relationship.

When speaking about the Egyptian medicine, it is well known that the Egyptian medicine set some of the postulates that still apply in modern medicine. Based on the data of that time scientists have concluded that the first surgery was performed in Egypt around the 2750 year BC. One of the most important "doctor" of the time was certainly Imhotep (Figure 1.16). His period, as well as its impact on the development of Egyptian medicine, can be presented in three stages:

1. in the court of Pharaon Zoser (2630–2611 B.C.E.)
2. a medical demigod (ca. 2600–525 B.C.E.)
3. as a major deity (ca. 525 B.C.E.–550)

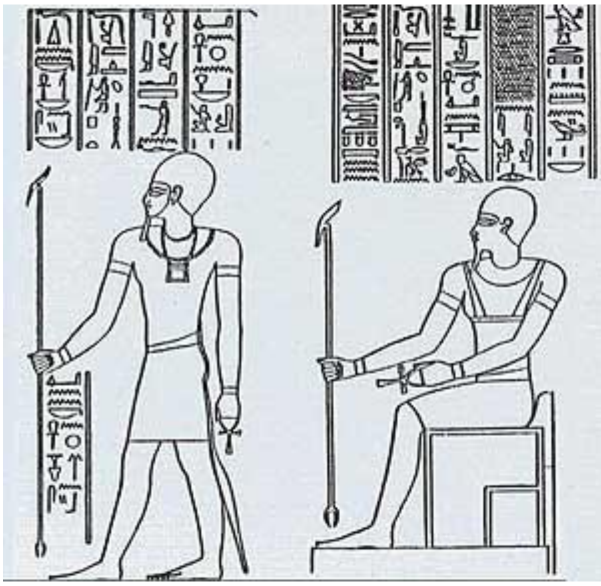


Figure 1.16. Egyptian record on God Imhotep

In the case of the Chinese medicine, the development began from the written data of Chinese history (since 722 BC) and Zhou dynasty (256 BC). In his work Hong (2004) described the development of medicine in China as totally different from the development of medicine of that time in the Western countries. He showed that the Chinese medicine of the time was not so much based on the principles of research. Chinese medicine directed its focus on the concept of "qi and yin-yang" and teaching of the usage of the acupuncture and herbal drugs. Some of the most important documents which are considered as axioms of Chinese medicine are *Huang Di Nei Jing*, *Nan Jing* (1st century BC), *Shang Han Re Bing and Shang Han Za Bing Lun* (1st century BC) and these records are considered to be a unique direction in the development of Chinese medicine. Learning was based on the systems of wu xing and ying yang, and until these days there were no attempts to refute the knowledge based on these systems.

The most famous medicine certainly dates from the period of ancient Greece. The fact probably is that from that time we have the most preserved materials. Some of the known medical facts of Greece are those that the first medical school was opened in 700 BC in Cnidus. The most famous person from the world of medicine originates just from ancient Greece known as Hippocrates of Cos (460-370 BCE), the son of a doctor Heraclides. Besides the fact that Hipotkrat first categorized disease on the chronic, acute, epidemic and endemic, he put the foundations of the rational medicine. The Hippocratic Oath (Figure 1.17) today represents the text that every future doctor should say aloud and as a conscientious doctor and a human being based the oath in medicine since it is considered as the basis for human behavior. It is believed that Hippocrates wrote over 100 medical records that are at a later stage (from the records that have been preserved) served as materials for the book called *"Corpus Hippocraticum"*. In this section, there has been described the works of Hippocrates works which included research related to the diet, head injuries, epidemics, the impact of climate and geographical factors on the body, etc.

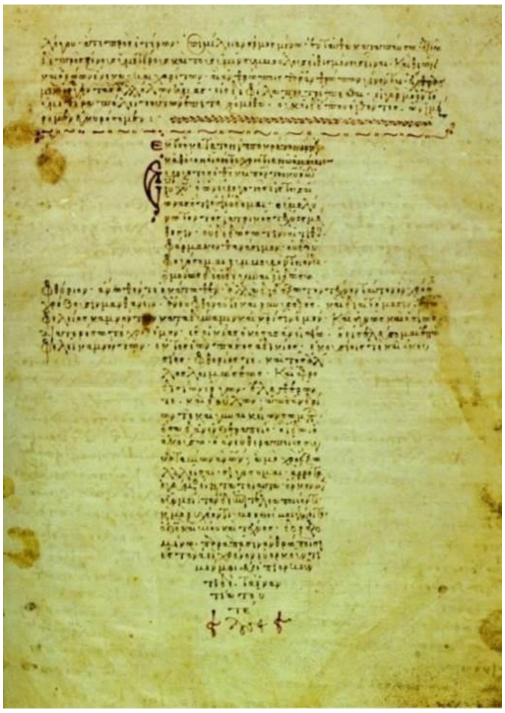


Figure 1.17. The Hippocratic Oath

Beside Hippocrates it is also important to mention other scientists of that time which influenced the creation of modern medicine:

- Herofil (end of 4th century BC), who is considered as the founder of the anatomy;
- Erasistratus (310-250 BC.), anatomist, physiologist, pathologist;
- Galen (129 AD), a doctor in the gladiatorial school and a doctor of the Roman emperor Commodus (more than 400 records in medicine, mathematics, philosophy);
- Aristotle (284 BC), the most significant contribution to Greek medicine was his doctrine of four basic qualities (Hot, Cold, Wet, Dry) ...

A later development of medicine is reflected in the periods known as Arab medicine, the European medieval, early modern period and the development of modern medicine. Modern medicine today, thanks to modern technology, products new knowledge very fast. But although the development of the medicine is rapid, processes that complement that development have shortcomings and special attention should be dedicated to those processes, in order to improve the total process.

## 1.4 Healthcare as a service

Health systems represent one of the most important systems that exist simply because their product is human health. Customer satisfaction depends on the quality of services provided in health systems. Sometimes these institutions make a bad impact on their customers. For example, the author Kohn et al., (2000) publish in their book the fact that in one year in America, due to the poor or inadequate treatment process, dies around 98,000 people. Often the deaths are not attributed to doctors but to the poor processes and complicated bureaucracy that tracks health processes. Although the healthcare industry is one of the strongest that exist in the world, according to research by the US Census Bureau, the annual income of the healthcare industry in the US is 1,668 trillion, but it is still considered that the health is on the quite low level of quality. In his speech, at the second annual convention of the Medical Committee for Human Rights in 1966, Martin Luther King emphasized, and this fact was not significantly changed even today, that the impact of inequality and injustice in health care is the most shocking and inhumanely.

The share of different health services in total earnings is shown in table 1.10. Besides this financial turnover, some experts believe that health care in America is at the very poor level, where the primary focus is on the earnings, and then on the quality. This fact is undermined by the increasing influence of the pharmaceutical industry in the world which dictates the pace and manner of treatment with the purpose of achieving the greatest possible profits.

Table 1.10. The share of different health services in total earnings in the USA (source: http://www.statisticbrain.com/health-care-industry-statistics/)

| **Health Care Industry Sales Statistics** | **Annual Revenue** | **Percent of Industry** |
|---|---|---|
| Health Care Industry Annual Revenue Total | $1.668 Trillion | 100 % |
| Patient Care | $1.068 Trillion | 64 % |
| Inpatient skilled nursing services and rehabilitation | $74.8 Billion | 4.49 % |
| Dental non-surgical intervention services | $49.6 Billion | 2.98 % |
| Contributions, gifts, & grants by the government | $44.9 Billion | 2.69 % |
| Appropriations from general government | $40.2 Billion | 2.42 % |
| Other | $389 Billion | 23.36 % |

One of the indicators of the quality of health care in some countries is certainly the allocation of the expenses for medical services per capita as well as the total costs spent on health care. Data from Figure 1.18 present the comparative analysis of costs per capita and total health expenditures shown through the share of health in GDP of America and certain European countries, while the overview of the total expenditure on health (% of GDP) in

Serbia and Lybia is given in figure 1.19., where it is presented that in 2014 the total expenditures on health were 10,36% of GDP in Serbia and 4,96% of GDP-a in Lybia.

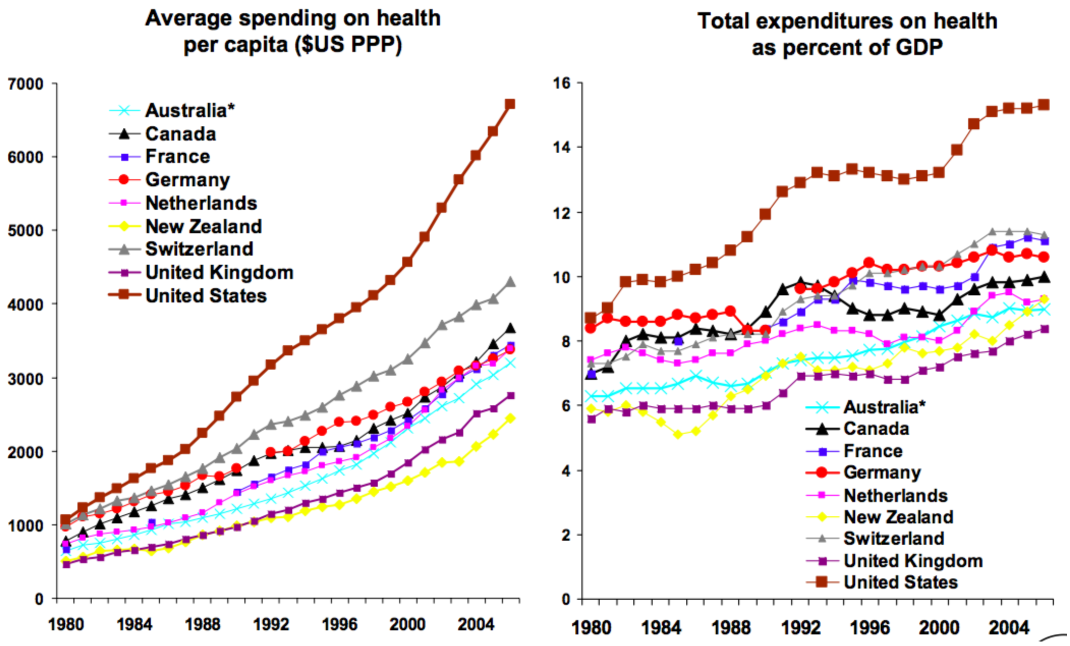



Figure 1.18. Comparative analysis of costs per capita and total health expenditures (source: https://epianalysis.wordpress.com/2012/07/18/usversuseurope/)

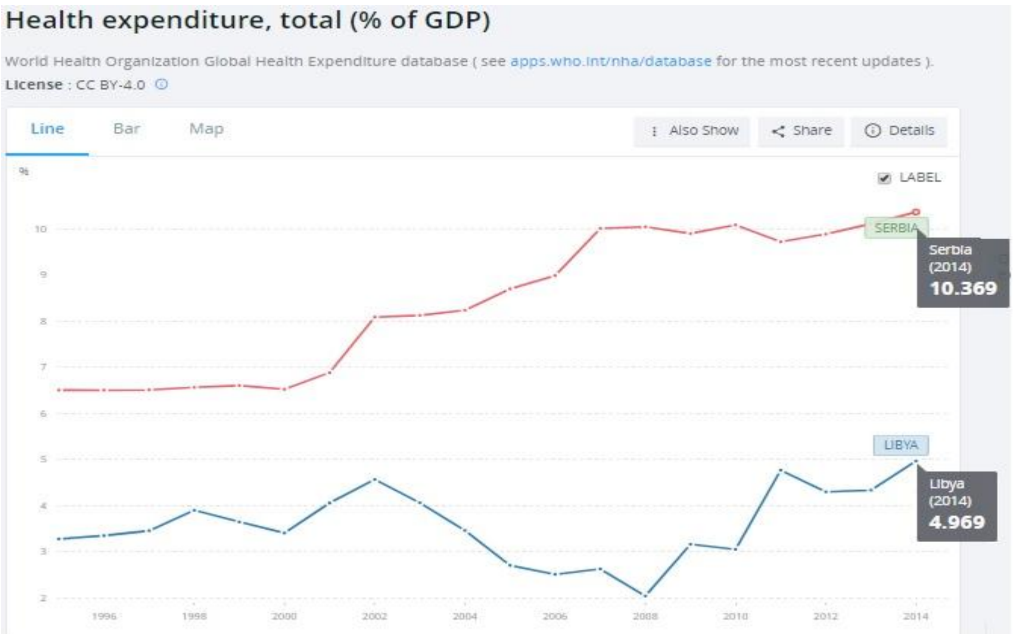



Figure 1.19. Total health expenditures as a percent of GDP in Serbia and Lybia (source: https://data.worldbank.org/indicator/SH.XPD.TOTL.ZS?locations=LY-RS)

A more detailed presentation of costs in health care is made by the OECD in a report from 2014 (OECD Health Statistics). There has been pointed to the fact that health expenditures in OECD countries can be divided into two periods. The first period is considered to be until the beginning of 2009 when the global economic crisis had the biggest influence. By that time, in almost all OECD countries, the cost of health care was in constant increase. During the crisis, there was obviously a significant stagnation but in the period after the biggest "impact" of the economic crisis, consumption is increasing again, but the rate of growth especially in the European countries is now significantly lower than the pre-crisis period. According to available data from the OECD, the increase in health spending in the percentage of GDP for 2011 was 9.2% and for 2012 there was a small increasing trend of 9.3% of GDP.

The year when the crisis had the highest negative impact was 2010. Consequently, the largest increase in costs in the reporting period was in America, where costs were even 17.6% of GDP. Following countries in health spending were the Netherlands (12% of GDP) and France and Germany with 11.6%. Figure 1.20 gives an overview of the average annual growth in health spending across OECD countries in real terms for period 2000-2011. Since Serbia and Libya are not members of the OECD organization, it is not possible to find the data on the average annual growth in health spending in real terms in 2000-2011.

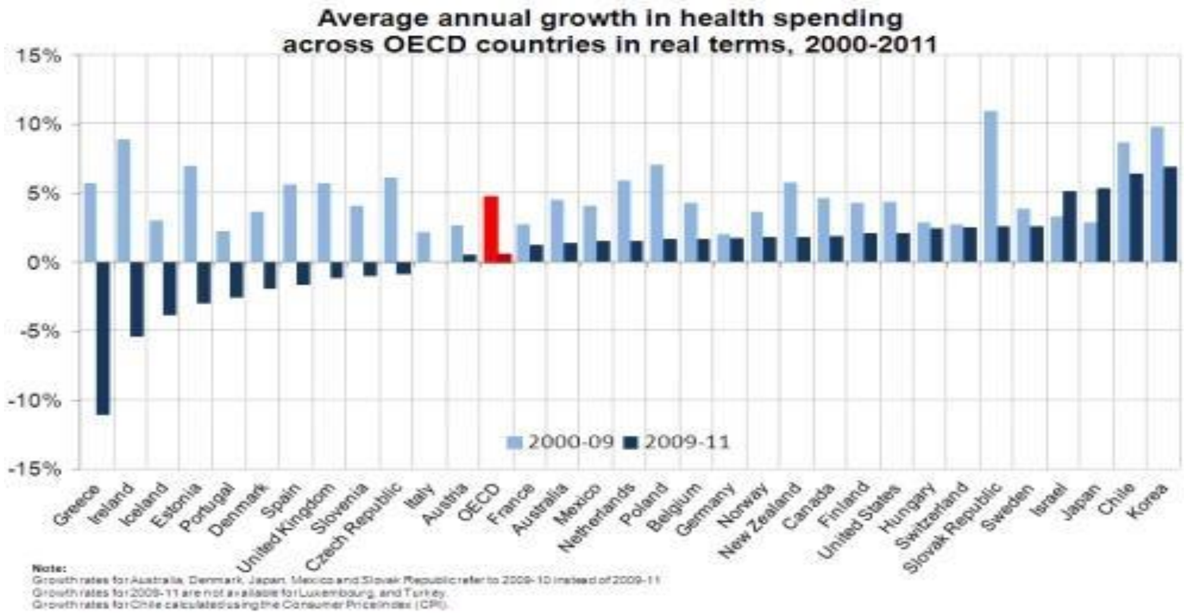



Figure 1.20 Average annual growth in health spending across OECD countries in real terms for period 2000-2011 (source: OECD)

As we have observed the state of health in the world, in the continuation of the paper we will present the state of health care in Serbia with an emphasis on the need for development and improvement of these activities as one of the most significant, both globally and in Serbia.

According to data from the National Statistics Office of the Republic of Serbia from 2012, the health system employed 113,068 people, while according to the data of the Institute for Public Health "Dr Milan Jovanovic Batut" the number of employees was estimated at 112,587 which indicates to the inconsistency of the accuracy and validity of the data. The structure of employees in health care, according to the National Statistics Office of the Republic of Serbia is shown in Figure 1.21.

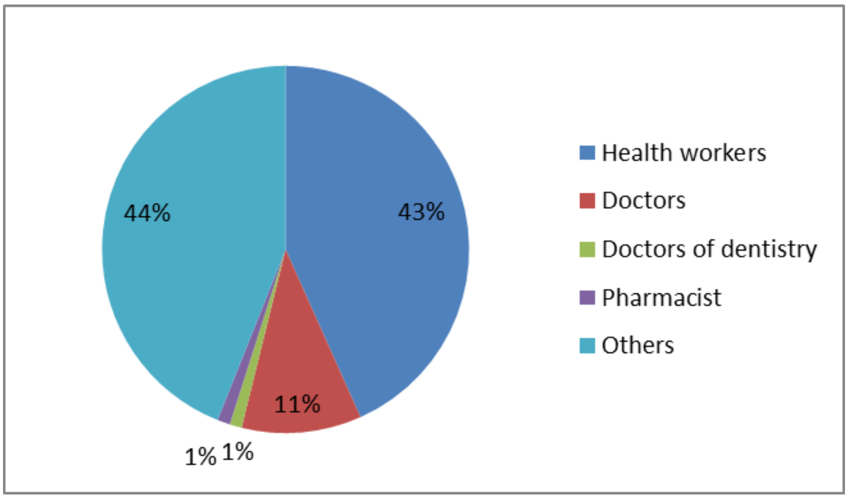



Figure 1.21. The structure of employees in health institutions in Serbia (source:http://webrzs.stat.gov.rs)

Healthcare capacities of the Republic of Serbia include 355 healthcare institutions (according to the Institute Batut). Table 1.11 presents the health institutions according to the network plan in the Republic of Serbia.

Table 1.11. Number of healthcare institutions in the Republic of Serbia (http://www.batut.org.rs/)

| Health care institutions | Number of institutions |
|---|---|
| Pharmacy | 35 |
| Health center | 158 |
| Institute office | 25 |
| General hospital | 41 |
| Special hospital | 36 |
| Clinical-hospital center | 4 |
| Clinical center | 4 |
| Clinics | 7 |
| Institute | 16 |
| National Institute of Public Health | 25 |
| Military medical institution | 4 |
| TOTAL | 355 |

Within the health care system, there is 41,111 available hospital accommodation. Although the Republic of Serbia stands solidly with the capacities in terms of institutions, the fact is that the number of citizens per one physician in 2011 was 344 and the number of citizens per hospital accommodation amounted to 177, which indicates a lack of capacity and manpower. Accommodation capacity of health care institutions has constantly upward trend but the problem of physicians per population lies in the fact that Serbia has a negative population growth, which is shown in Figure 1.22, as well as an increase in the "brain drain" of young professionals from the country.

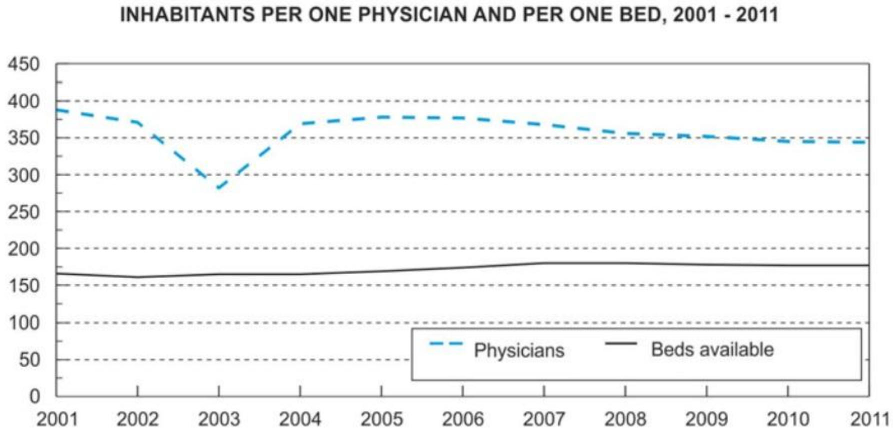



Figure 1.22. Inhabitants per one physician and per one bed in Serbia
(source: http://www.batut.org.rs/)

In 2010 Serbia had a balance of trade in service exports of 274,486.9 million RSD while imports were 273,779.5 million RSD but the impact of the health services on the value of imports and exports was not specifically outlined. It is only known that the health activities, together with the social protection, had an impact on GDP in the amount of 117,831.2 million RSD in 2010, which makes about 15.5% of the total revenue. The real growth rate of this sector in the same year had a decrease of -1.8 compared to the year 2009 when the health care services recorded an increase of 0.8%. According to the statistical data, in 2010 revenues of the budget beneficiaries of health and social protection in the Republic of Serbia amounted to 202,488,994 thousand RSD. 164,964,979 thousand RSD of that sum was obtained from healthcare activities, 102,732,280 thousand RSD was obtained from medical and dental practice while other forms of health care made 8515339 thousand RSD. Other income includes the incomes of social protection. The impact of human health and social work activities to GDP (income) is shown in Figures 1.23.

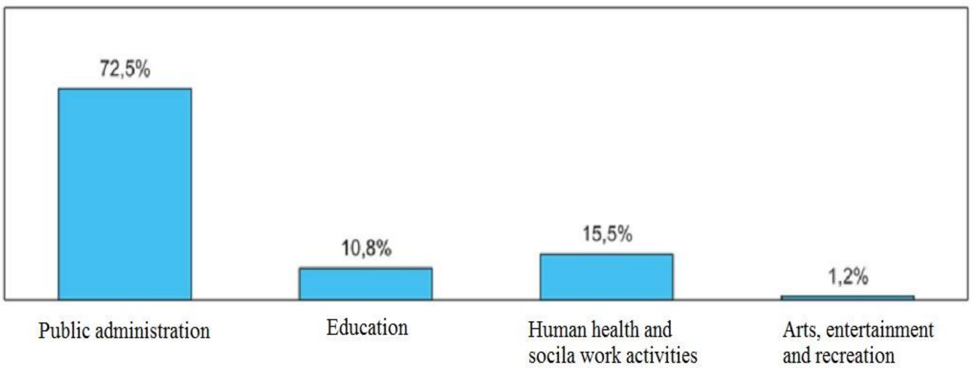



Figure 1.23. Revenues share by activities in total revenues
(source: http://webrzs.stat.gov.rs/WebSite/ , 2010)

On the other hand, the expenditures for the health and social protection in 2010 amounted to 201,910,734 thousand RSD. 164,346,390 thousand RSD of that sum was spent on health activities, 102,025,359 thousand RSD was allocated to the activities of hospitals, 53,812,280 thousand RSD was spent on medical and dental practice, while other aspects of healthcare worn 8,508,751 thousand RSD. Other expenses obtained social protection. Although according to the National Statistical Office, we can conclude that health and social protection are not a non-profit activity – in reality, the situation is different. From Figure 1.24 we can see that the total costs of health and healthcare account for 19.6% of the GDP which is for 3.9% higher than revenues. The impact of human health and social work activities to GDP (expenditure) is shown in Figures 1.24.

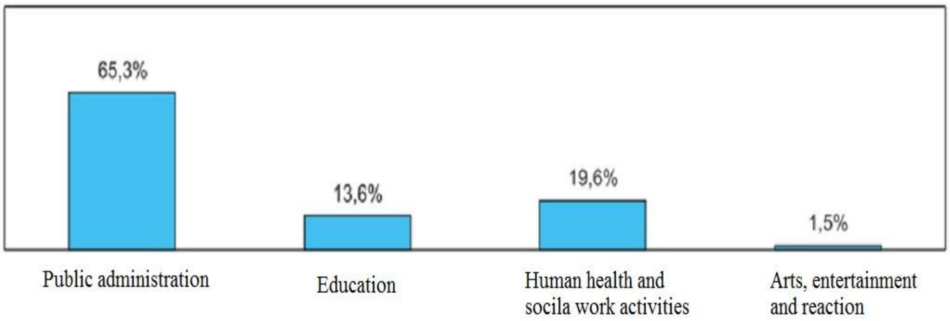



Figure 1.24. Expenditures share by activities in total expenditures
(source: http://webrzs.stat.gov.rs/WebSite/ , 2010)

On the basis of the figures 1.23 and 1.24, it may be concluded that human health and social work activities are national costs of the GDP of the Republic of Serbia due to the higher expenses than revenues. The data shown in previous figures and tables pointed to the need for improving both, individual processes within the health care institutions and health care in general.

# 2. Lean concept

## 2.1 The History of Lean

The term “lean” first appeared in the book "The machine that changed the world" (Womack et al., 1990) where the authors showed differences between the Japanese production methods and traditional mass production from the West. The book discussed approaches which the Japanese automobile industry used to take the precedence over the American automotive industry (Melton, 2005). In table 2.1 the authors Womack et al. show the comparison between these two approaches in production. The same authors have defined this approach as *lean*, under the definition that lean:

“*provides a- way to specify a value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less—less human effort, less equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want*”.

Womack and Jones (2003)

Table 2.1. The differences between lean and mass production (retrieved from Melton, 2005)

| | Mass production | Lean production |
|---|---|---|
| Basis | • Henry Ford | • Toyota |
| People–design | • Narrowly skilled professionals | • Teams of multi-skilled workers at all levels in the organization |
| People–production | • Unskilled or semi-skilled workers | • Teams of multi-skilled workers at all levels in the organization |
| Equipment | • Expensive, single-purpose machines | • Manual and automated systems which can produce large volumes with large product variety |
| Production methods | • Make high volumes of standardized products | • Make products which the customer has ordered |
| Organizational philosophy | • Hierarchical—management take responsibility | • Value streams using appropriate levels of empowerment—pushing responsibility further down the organization |
| Philosophy | • Aim for ‘good enough’ | • Aim for perfection |

The first pioneers of the lean concept are considered to be Eiji Toyoda and Taiichi Ohno who, after the Second World War (WW2), after several visits to Ford, which was considered then as the most successful automotive industry, gained an insight into the way of doing business as well as their mistakes. After the defeat of Japan in the WW2, car company Toyota, which was established by Sakiichi Toyoda, operated in very difficult conditions. In addition to the poor economic situation of the state, Toyota had approximately 300 employees, with no facilities needed for the realization of the production, and one more problem was the lack of resources for production (http://www.strategosinc.com/). After the visit to Ford Company, Kiichiro Toyoda and his colleagues implemented several innovative ideas in order to make improvements in the production cycle.

They provided processes that functioned on the principles of continuous flows, succeeded to reduce production costs and provided a range of different products in different variations (http://www.leaninstitute.in/). On the other hand, there are attitudes of different authors in this area who claim that lean concept did not originate from the development of the Toyota Company. Those authors emphasize that the roots of the process improvement go back many years, since the time of Eli Whitney, who dealt with the issue of interchangeable parts in 1850, Fredrick Taylor, who studied time and work standards, Frank and Lillian Gilbreth, who studied the movement and the elimination of losses, and many others (Figure 2.1).

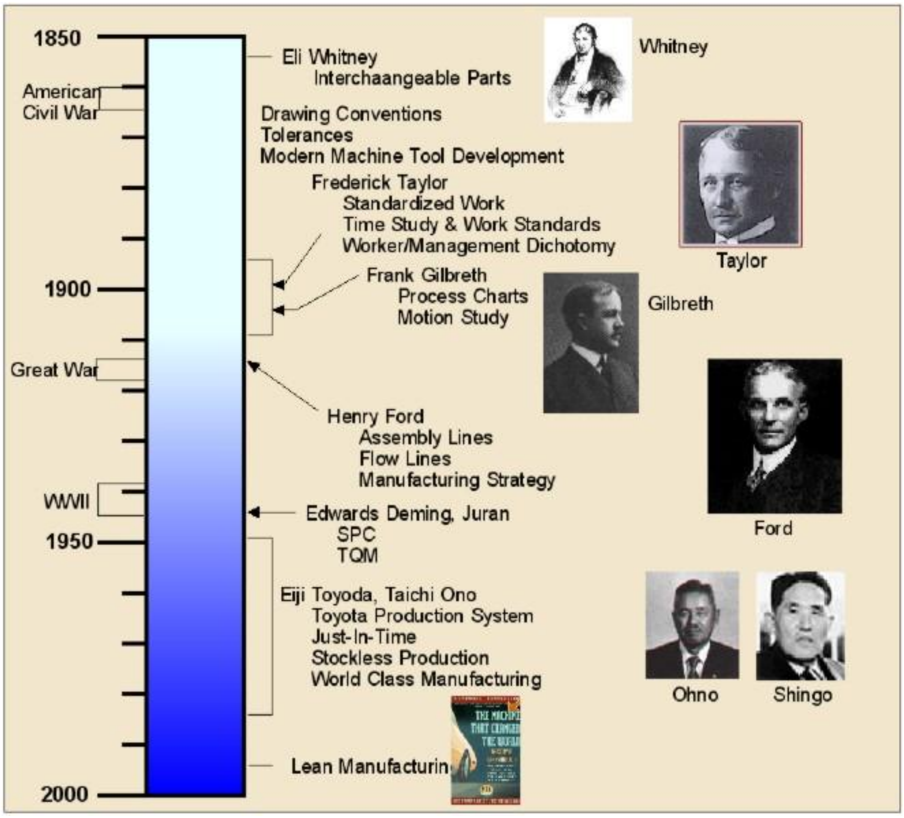



Figure 2.1. The history of Lean Manufacturing
(source: http://www.strategosinc.com/lean_manufacturing_history.htm)

One of the basic principles that guided the employees in Toyota Company during the improvement process was the elimination of "muda". "Muda" is the Japanese word for waste, in the sense of wasted effort or time (Hines et al., 2004). Through the improvement of production processes in Toyota, Toyota's experts were able to define the various types of waste that could be grouped into seven "deadly" loss of production (Hicks, 2007). The first identification and classification of seven wastes in manufacturing have been done by Taiichi Ohno, who is considered as the most important fighter against the wastes.

Taiichi's seven wastes are described in detail in his book "The Toyota Production System: Beyond Large-Scale Production" while the authors Womack and Jones (1996) defined the eighth waste that occurs in the production:

1. Transport (moving products that are not actually required to perform the processing);

2. Inventory (all components, work in process, and finished product not being processed);
3. Motion (people or equipment moving or walking more than is required to perform the processing);
4. Waiting (waiting for the next production step, interruptions of production during shift change);
5. Overproduction (production ahead of demand);
6. Over Processing (resulting from poor tool or product design creating activity);
7. Defects (the effort involved in inspecting for and fixing defects);
8. Manufacturing goods or services that do not meet customer demand or specifications;

- and also we have untapped human potential.

Beside “muda”, which represent activities that spend resources and do not add value, in production, there are also “mura” and “muri”. “Mura” represents the variations that occur within operations that are not caused by the end user while “muri” represents an overload of employees, machines and entire enterprise caused due to the “muda” and “mura”. Author Womack (2006) emphasizes that all three types of waste affect and cause each other.

## 2.2 Lean principles

The goal of each company today is to improve the business and increase profit through the reorganization and simplification of its processes, decrease of costs and resources utilization, retaining existing and attracting new consumers and employees, etc. Improving the business is usually implemented through different techniques and methodologies that have been developed. Very often we can see that even we already entered into the era of information technology, automation, and modern technology, some companies continue to operate in the traditional way of doing business. The traditional way of doing business can hardly respond to the contemporary requirements (customer requirements are increasingly stringent, there is a need for larger and faster variation of products, economic instability in the world, etc.), which are becoming increasingly demanding and unpredictable. The reason why a company should abandon its traditional way of doing business and improve its business processes regarding lean concept is vividly demonstrated by Kilpatric (2003) in its work. The author shows the differences between the business in accordance with the lean concept and traditional business, considering processes, people, labor costs, quality, etc. (Table 2.2).

Table 2.2. The differences between the lean and traditional concept of business

| Concept | *Traditional Organization* | *Lean Organization* |
| --- | --- | --- |
| **Inventory** | An asset, as defined by accounting terminology | A waste – ties up capital and increases processing lead-time |
| **Ideal Economic Order Quantity & Batch Size** | Very large – run large batch sizes to make up for process downtime | ONE – continuous efforts are made to reduce downtime to zero |
| **People Utilization** | All people must be busy at all times | Because work is performed based directly upon customer demand, people might not be busy |
| **Process Utilization** | Use high-speed processes and run them all the time | Processes need to only be designed to keep up with demand |
| **Work Scheduling** | Build products to forecast | Build products to demand |
| **Labor Costs** | Variable | Fixed |
| **Work Groups** | Traditional (functional) departments | Cross-functional teams |
| **Accounting** | By traditional FASB* guidelines | "Through-put" Accounting |
| **Quality** | Inspect/sort work at end of process to make sure we find all errors | Processes, products, and services are designed to eliminate errors |

**Financial Accounting Standards Board (FASB)*

In order to gain success in the implementation of the lean concept, it is not enough simply to apply different methods and tools for process improvement. It takes a lot more than that. It is necessary that the entire enterprise, from the lowest level to the highest levels accept the "philosophy" and that the company and all employees start to "live" in accordance with the principles that define lean philosophy. Lean principles are first defined by the authors Womack & Jones (2003) in their book, and they are presented as:

1. ***VALUE*** – This principle is commonly seen as the starting point defined by the consumer – end user. This value is expressed through the satisfaction of consumer's needs with the product or service with appropriate quality, price, and availability in a defined period of time and location. Very often companies are difficult to determine the exact value of the products and in this step, it is very important to involve consumers and to "listen" their demands. Only in this way a company will be able to produce a product which has appropriate performance and quality, appropriate price while improving its processes and further operations on the market.
2. ***VALUE STREAM*** – This principle includes a set of steps that includes the production of a certain product or group of products. Very often, Value Stream principle points to excessive amounts of losses in the process. Womack and Jones emphasized that the analysis of this principle if it is done properly, can define three "actions" within the company, as follows:
    a. *steps within a process that are creating value for the product (VAT - value added times);*

   b. *steps within a process that do not add value to the product, but without them, it is impossible to achieve the process (NNVAT - Necessary non value added times);*
   c. *steps within processes that do not add value to the product and that can be immediately eliminated (NVAT - non value added time).*
3. ***FLOW*** – After defining values defined by consumers and defining value stream in order to eliminate unnecessary time, pull principle tends to create a continuous flow of the steps that add value to the products. Only continuous flows can contribute to the creation of the value in each step of the process. Womack and Jones consider this principle as the most difficult to achieve. In order to achieve this principle, it is important to “reorganize the mindset of employees”.
4. ***PULL*** – This principle provides consumers to withdraw a value (product/service) from an enterprise. A company will, through the first three principles, define the value of its products and define and improve flows within the process by which it is possible to achieve a defined value. But the production will not be started until consumer asks for the product or service. In other words, production is initiated at the request of the consumers. This principle can greatly reduce stocks of finished products as well as the stocks of necessary raw material and provide easier production management and production planning.
5. ***PERFECTION*** – When the value and value stream are defined, continuous flows are achieved, production is realized with less required resources with the realization of appropriate quality, the idea of perfection still is not discarded. In such defined company all employees will start to look for perfection and to continuously improve both processes and products that will meet all demands of consumers.

## 2.3 Lean concept in healthcare systems (theoretical background)

Four main differences between production and service processes are explained by Chikan (2003). He describes them as:

- the outcome of service is not tangible,
- the outcome of service cannot be stored,
- the customers take part in the process,
- a certain part of the processes takes place under the eyes of the customers, whereas another part remains invisible to him.

Chikan (2003) emphasizes that the previous division primarily relates to a “clean” service and production processes. He also believes that the processes covered by health are “par excellence, pure services”. Taking into account the researches of many authors in this field, on the basis of the characteristics of the health services it is possible to largely accept his attitude:

- a result of health services is not the product, it is the service aimed at people (Bertrand & de Vries, 2007);
- it is very difficult to determine accurately and in advance the "final state" as a result of services (Bertrand & de Vries, 2007);
- health organizations must be prepared for the unpredictable business because demand for health services is not always possible to predict (Ghosh & Sobek, 2006);
- changes that deviate from the normal routines of work are frequently occurring, which further burdens the employees (Fillingham, 2007);
- in the health process, the subject of transformation are people, who have "feelings" as opposed to mere material products (e.g. car) (Fillingham, 2007);
- healthcare requires special knowledge and skills (Mills et al., 1983) and employees are a key factor of services (Bertrand & de Vries (2007).
- within teams of people who provide services in health care, there is no exact shared responsibility of each individual. Every individual is able to change or discontinue the flow of services, because of their responsibilities (anesthesiologist may terminate, or accelerate, or shorten an operation) (Ahlström, 2004).

Although specialized people work in health systems, those systems are not perfect in their operations. A large number of studies indicate shortcomings that occur within health care processes (Kondrup et al., 2002; Leggat et al., 2008; Thurman, 2001; Bacigalupe et al., 2010; Goldberg et al., 2002). One of the very important authors in this research area, Graban (2011, page 1), in his book „Lean hospitals Improving Quality, Patient Safety, and Employee Satisfaction", explained in detail the need for implementation of the lean concept in health care systems:

*"Hospitals do many wonderful things but some people say that hospitals have world-class doctors and treatment but completely broken processes".* According to his opinion lean can help hospitals not to improve quality by asking people to be more careful, but to help hospitals to be more organized and managed. Lean is a method that allows hospitals to improve quality of care for patients by reducing errors and waiting times. Lean is a system for strengthening hospitals organizations for long-term reducing costs and risks while also facilitating growth and expansions.

Graban (2011) has also mentioned several benefits which can be achieved by the implementation of the lean concept in healthcare institutions:

- reduced turnaround time for clinical laboratories results by 60% without adding head out or new instrumentation,
- reduced instrument decontamination and sterilization cycle time by over 70%,
- reduced patient death related to central-line-associated bloodstream infections by 95%,
- reduced patient waiting time for orthopedic surgery from 14 weeks to 31 hours,
- increased surgical revenue by 808 000 $ annually,

- reduced patient length of stay by 29% and avoided $ 1,25 million in new emergency department construction, and
- saved $ 7,5 million from lean rapid improvements event and reinvestment the saving in patient care.

Graban (2011) also points to some problems which occur in healthcare, such as:

- disrespect of procedures,
- delays due to poor procurement system,
- minor injuries and injuries that are not reported,
- employees are having trouble with handling with new equipment,
- protective equipment is not used.

Sometimes these shortcomings, mistakes, broken processes or whatever we call them, according to Graban, can lead to the great damage because a result is not a scrap product but health of people, which may be threatened in the sense of permanent damage or even death. The rate of such deaths in certain countries in the world exceeded the number that could be acceptable to common sense. With the development of the lean concept as a business philosophy, authors Womack and Jones (1996) stressed that the lean concept can be implemented in all organizations, and even in healthcare systems. Figure 2.2 shows the way of implementation of the lean concept in healthcare organizations throughout history. The first scientists who have implemented the lean concept in healthcare organizations are considered to be Heinbuche (1995), Jacobs and Palfrey (1995) and Whitson (1997). But the first successful result of the implementation of lean in hospitals has been achieved by Bushell and Shelest (2002) by improving the patient flow in a hospital in the USA.

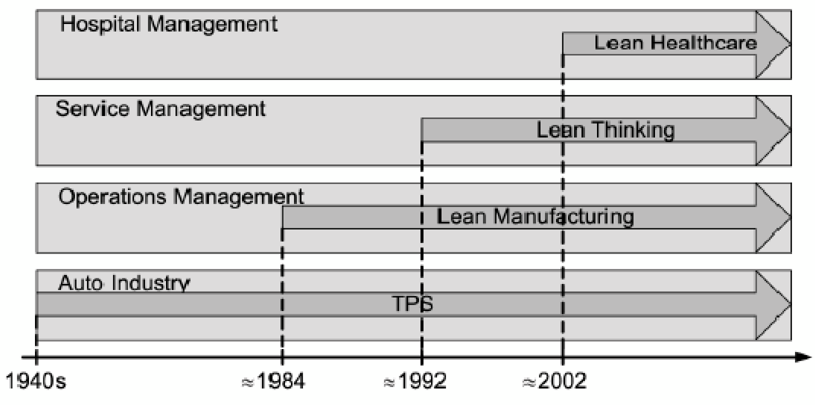


Figure 2.2. The evolution of lean (Laursen et al., 2003)

Although it is important to improve processes in health care, it is important to note that this should not be the primary objective of implementing the lean concept in this area. Processes in health systems are specific because they largely include participation of employees. Therefore, the authors Ballé and Regnier (2007) and Dickson et al. (2008) argue that the unilateral focus of lean concept on the processes can lose the main perspective if it is dedicated only to the improvement of processes and not on the improvement of employees who need to manage these processes. Due to this fact, the same authors believe that meaningful education and continuous improvement of employees is much more important when implementing lean concept instead of a simple improvement of each process. Many authors believe that the successful implementation of lean concept primarily requires the understanding of all those who are involved. The lean concept is not just a set of tools, it is a system that includes all the elements that should function as an integrated unit (Kim et al., 2006; Mann, 2005; Ballé & Regnier (2007).

The review of the literature points to the conclusion that there is a “unique” accepted approach of implementation of lean concept in health institutions which is accepted by many authors (Ben-Tovimet al., 2007; Manos et al., 2006; Bahensky et al., 2005; Fillingham, 2007; Jimmerson et al., 2005; Spear, 2006; Dickson et al., 2008; Raab et al., 2006). This approach can be represented by the following steps:

- Realization of training and education of employees about the lean concept
    - the first phase involves training of employees which essentially represent the principles of lean concepts, the fundamentals of lean concepts and lean methods and tools for process improvement. At this stage, training of employees may be collective or for specific groups of employees who will represent lean leaders for other employees who will be trained and who will spread lean concept through the process and organization (Jimmerson et al., 2005)
- Initiating changes and projects
    - The second phase involves tests of ideas of trained staff, who are often integrated into cross-functional teams to analyze different processes, find out problems and identify value-added times (VAT) and non-value added times (NVAT). The aim of this way of solving problems is to enable employees to find quick solutions for improvement and it is usually implemented at the same time immediately after the first phase with the most recent knowledge and information (Papadopoulos & Merali, 2008; Dicson et al., 2008; Kim et al., 2006)
- Implementation of projects by using the lean concept
    - the last phase, known as the process of solving problems, fully engages all employees. Most often there are created smaller teams of people (5-10 employees), who possess various specialties, from different organizational levels. Sometimes this phase is known as RIE – Rapid Improvement Event (Papadopoulos & Merali, 2008).

A review of the literature enables us to see that the lean concept in health care organizations represents a growing trend. Authors Kim et al., (2006) describes challenges which may arise during the implementation of the lean concept in healthcare organizations. Hawthorne and Masterson (2013) in their work explain how their health-care organization succeeded to increase the quality and safety of healthcare delivery with the implementation of the lean concept. Dahlgaard et al. (2011) present a lean concept which will enable an improvement of the system of the healthcare organization. One of the gurus of lean concept Womack (2005) in his book "Going lean in health care" describes several ways to reduce wastes in health processes by the implementation of lean tools. Questions and observations that often occur during the implementation of the lean concept in health care are described by the authors Joosten et al., (2003) while the authors Kollberg et al., (2006) in its work describe the most important issues regarding the measurement of lean initiatives in health care.

A literature review of researches in the field of application of the lean concept in health gave authors Mazzocato et al., (2010) and Poksinska (2010). Of course, beside successful practices of implementing lean concept in healthcare that have been published by many authors, when the application of lean concept in health care is in question (Fillingham, 2007; Waring & Bishop, 2010; Jimmerson et al., 2005; Fine et al., 2009; Robinson et al., 2012; Burgess & Radnor, 2011; Burgess, 2012) there are some critical views of individual researchers (Young and McClean, 2008). Burgess & Radnor (2010) research whether the lean concept is only a paradox and whether lean can help a health care system and their findings suggest that lean implementation in English hospitals tends to be isolated rather than system-wide. In contrast to these critical views of mentioned authors, De Souza & Pidd (2011) highlighted some problems and barriers to implementing the lean concept in health care, based on their experience of applying lean thinking in the UK's National Health Service. The authors conclude that lean approaches do offer ways to improve health care. It is very difficult to find a negative attitude when it comes to the application of lean in healthcare. One of the papers which emphasized that the lean concept cannot always fulfill the expectations is described by the authors Radnor et al. (2012). The authors in their work investigated the extent to which lean concept was successfully implemented in four health institutions, with a specific focus on those segments that were successful and those which were not, and the reasons why this happened. The paper does not mention the exact systems and subsystems of health care in which lean was implemented. It is important to note that health and production systems are composed of subsystems integrated as a whole, for example, one medical institution – hospital consists of different objects (depending on the application), laboratories, operating rooms, room for viewing, storage rooms, rooms for waste removal, etc. In each of these locations, there are processes that can be improved by applying lean concepts

Since the aim of this doctoral thesis is the application of the lean concept in clinical laboratories, the focus of further research will be related to the implementation of the lean concept in this sector of the health system. Clinical laboratories mainly serve as the backbone for the other processes in the health sector. Those processes could not be implemented without these clinical laboratories. In other words, clinical laboratories are indispensable units that make specific health processes a whole. For example, some doctors cannot bring the appropriate conclusions about the patient's condition until he receives the results of blood, smears on the results of various bacteria, etc., from clinical laboratories. In order to perform certain surgical procedures, preliminary results of the various laboratory tests are usually required in order to avoid possible errors or incorrect treatment of the patient. That fact tells us about the importance of clinical laboratories within the healthcare process, and the importance of improving clinical laboratories to a higher level in order to remove the possibility of any fault. Errors occurred in clinical laboratories often may have disastrous consequences for the patient in terms of poor and improper treatment, for a doctor or his reputation, as for a reputation of the whole organization. In the literature, there can be found a significant number of studies dealing with lean in different laboratories. Buesa (2009) shows the influence of lean in laboratories of histology, in the laboratory of cellular therapy (Hollyman et al., 2014) or laboratories of molecular diagnostics (Cankovic et al., 2008). To provide a contribution to the field of implementing the lean concept in medical laboratories, in the following section, the author will present the research part of the work in detail, which includes the presentation of principles and tools of lean management that can be implemented in the clinical laboratory. In addition to the methods and tools, there will be displayed the implementation of lean principles and tools in the clinical laboratory which will improve clinical laboratory processes, maximize process flow without adding more resources, and reduce waiting time for laboratory results. The focus of the work will also be placed on identifying which factors sustain positive changes and which factors can hinder the delivery of high-quality results achieved by implementation of lean principles and tools, how to take control on this factors and ensure the further improvement of achieved results.

# 3. Lean concept in clinical laboratories (theoretical background)

*"Lean is a way of thinking – not a list of things to do"*
*Shigeo Singo*

As previously mentioned, the literature review shows that the lean concept in healthcare facilities represents a trend that is increasing. Implementation of the lean concept is not related just to the improvement of a medical institution as a whole, but to the implementation of lean concepts in each subsystem of a medical institution. When speaking of "subsystems" of a medical institution that is primarily related to clinical laboratories, nursing, primary care, perioperative service, emergency department, anatomic pathology, etc. The authors Plyutiuc et al. (2013) conducted a systematic literature review of the lean in the healthcare sector with the aim of pointing out the poor relations of research and the area that is rich for further research. In their work, the authors pointed out the most important pattern of citation that is most common in the literature that is dealing with lean healthcare infection (Figure 3.1).

The authors identified six most important groups in relation to specific colors:

- purple – NHS UK,
- dark gray - lean in pathology laboratories,
- black - Reduction of variability and Six Sigma,
- red – Lean in laboratories,
- dark green - Lean in the pathology laboratory and emergency department,
- light green Lean, Lean Six Sigma and emergency departments (Plyutiuc et al., 2013).

Since the subject of research in this doctoral dissertation is the implementation of lean concepts in clinical laboratories, the theoretical focus of further research will be in that direction. The keywords that authors Plyutiuc et al., found in the literature review regarding the lean labs are: laboratory; phlebotomy, blood draw; lean six sigma; radiology; NHS; Pathology laboratory; autopsy; implementation methods. The significance of the keywords that are emphasized by mentioned authors will be described in more detail in the continuation of the dissertation.

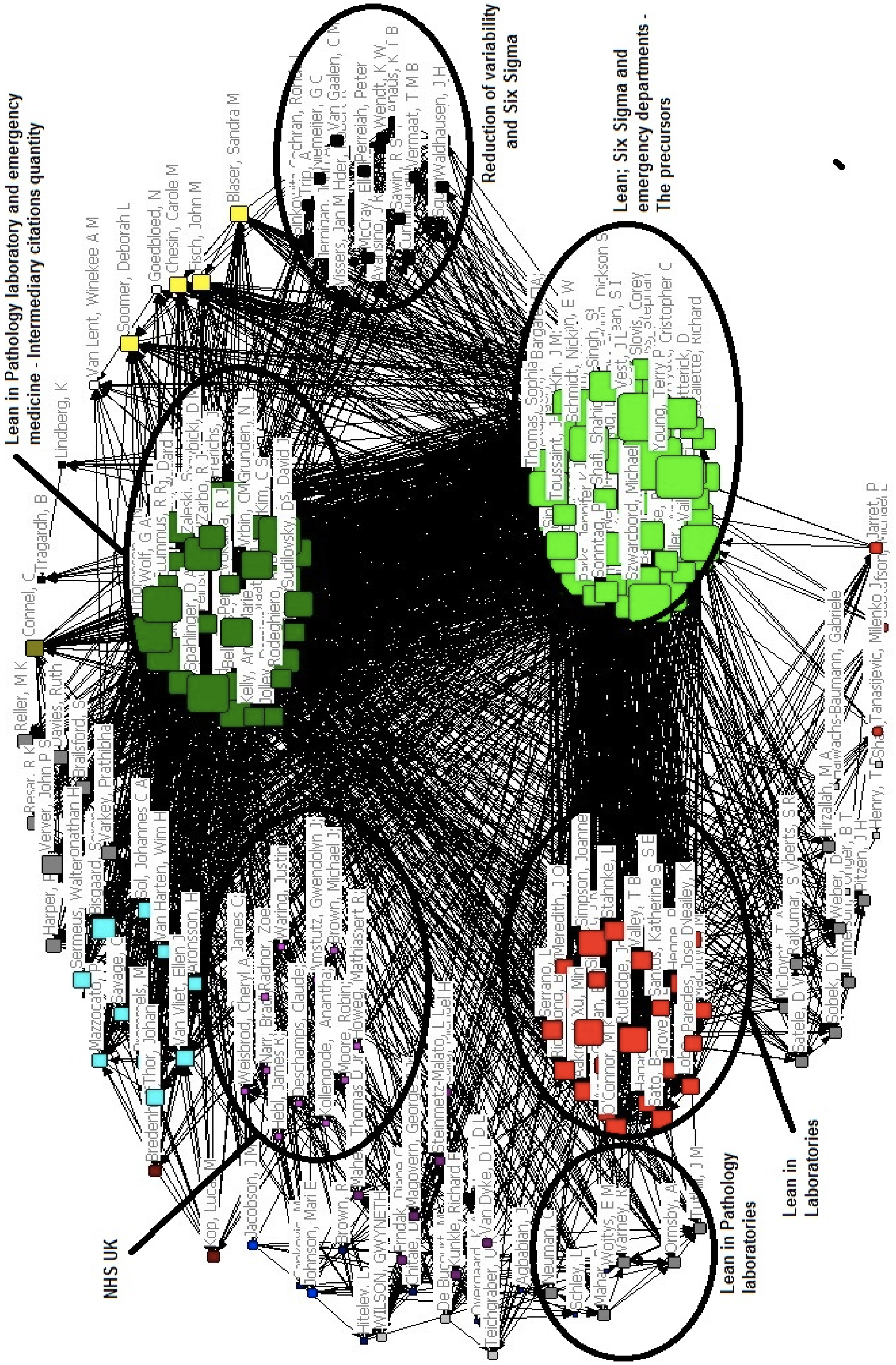



Figure 3.1. The pattern of citation in lean healthcare literature (Plytiuc et al., 2013)

*What are the lean laboratories?*

In recent time, all clinical laboratories are faced with requirements to reduce the cost of procedures while providing faster and more accessible services, processing a wider range of parameters and higher frequency of samples (Halwaschs Bauman, 2010). In addition to these requirements, the laboratory should work on improving the effectiveness and efficiency of the process and satisfaction of patients, quality management, research, and development, etc. In order to perceive the implementation of lean concepts in clinical laboratories in the right way, it is important to note what do not represent lean labs. Authors Jones & Mitchell (2006) argue that lean laboratory does not represent a reduction in staff in laboratories but to do more with the already existing capacities while increasing patient care. Authors Jones & Mitchell (2006) claim that lean labs, in essence, have a holistic view. According to them, the decisions taken on the basis of strategic planning must be primarily of long-term nature and based on information from the external environment, because only then the idea of lean labs will not be misunderstood. Borget (2006) explains that the essence of lean labs is not in forcing employees to work harder and faster, but just the opposite. The lean laboratory should provide employees with moderate and comfortable work without stress and pressures. Some of the most important types of waste (see Stanković, 2008; Coons, 2007) in the laboratory are presented by the author Graban & Padgett (2008) in the table below:

Table 3.1. Types of waste in the laboratory (source: Graban & Padgett, 2008)

| Type of waste | Definition | Example |
|---|---|---|
| Defects | Errors or problems that require inspection or rework | Mislabeled or hemolyzed specimens |
| Overproduction | Doing work earlier than necessary of more than is required by customs | “Just in case” tubes that are drawn but not needed; drawing specimens faster than they can be accessioned |
| Transportation | Unnecessary distance traveled by patients or specimens | High volume chemistry analyzer located far from tube station |
| Waiting | Idle time for specimens or employees | Specimens waiting because of batching; employees idle due to uneven workloads |
| Inventory | Excess or wasted inventory | Expired tubes or reagents; increased cost from high inventory level |
| Motion | Unnecessary walking or exertion by employees | Employee walking due to poor layout and laboratory design |
| Processing | Performing work that does not add value | Running calibrations or quality control more frequently that required by rules and manufacturer |
| Talent | Not utilizing employee creativity and potential | Medical technologists, before Lean, saying they are like “robots” because they are not involved in improvement efforts |

A review of the available literature showed different focuses of researches when it comes to the lean concept in clinical laboratories. The authors Rutledge and Simpsons (2010) explored the improvement in clinical laboratories by applying lean tools. The authors have defined the new design of the laboratory and tried to secure the improvements that are reflected in a reduced TAT - turnaround time (reduced from 54 to 23 minutes) with increased testing volume (20%), monetary savings (4 full-time equivalents), decreased variability in TAT, and better space utilization (25% gain).

The author Halwasch-Bauman (2010) pointed to the influence of the laboratory which has been based upon the lean principles of the organization of work, and its efficiency and effectiveness. The authors Persoon et al. (2006) investigated the improvement of a preanalytical process by using lean principles. By applying lean principles the authors successfully reduced the preanalytical process time from 29 to 19 minutes. At the same time, the laboratory achieved the goal of creating 80% of the reports of chemical analysis of samples within an hour in the following 11 months.

The authors Knowles & Barnes (2016) in their critical paper tried to draw attention to the need that clinical laboratories do more with fewer resources by analyzing the best practices from other industries. An interesting study was made by the authors Yerian et al. (2012) that determined the lost time that employees lose because of leaving the workplace in order to perform its task. In the initial stage of the recording process in clinical laboratories, it has been detected that of 664 tasks 251 of them (38%) require that the technologist leave the job position in order to perform the task. After the reconfiguration of jobs, the authors have succeeded that in only 59 (9%) cases (out of 664) the technologist has to leave the job position to complete the task. They managed to reduce the leaving from the workplace for 3.4 times, while the times spent when leaving the workplace ranged from 8 to 70 seconds.

One more comprehensive study was made by the authors Amirahmadi et al. (2007) from the Mayo Clinic - Mayo Medical Laboratories department (see also AHRQ Publication No. 13 (15), 2014) who showed the possibility to apply innovation in clinical laboratories such as the application of lean principles. The main objective of the authors was to show that the application of lean principles in laboratories ensures:

- improved operational performance (faster testing turnaround time, decrease in costs and improved quality),
- reduced variability in operational performance
- operations management approach as an end-to-end discipline
- improved patient and employee safety
- improved employee morale
- reduction in development time for new tests
- reduction in testing defects and errors during new test development and implementation.

while the concrete results of the implementation were:

- reduced batch sizes,
- staffing schedules matched to sample arrivals,

- standardization of work processes with visual cues to help people stick with the standard,
- reduced set up time for testing,
- root cause analysis and mistake-proofing to reduce defects due to human error
- improved operational tracking management (Amirahmadi et al., 2007).

Table 3.2. shows an overview of some literature with an emphasis on the field of the researches of different authors with the paper titles of the researches.

Table 3.2. Overview of some literature with an emphasis on the field of the researches (source: the author)

| Filed of research | Authors | Title |
|---|---|---|
| Literature review | - A. D'Andreamatteoa, L. Iannia, F. Legab, M. Sargiacomoa (2015)<br>- R. Holden (2010)<br>- P. Mazzocato, C. Savage, M. Brommels, et al. (2010)<br>- A. Cherrafi, S. Elfezazi, A. Chiarini, A. Mokhlis (2016)<br>- Zidel, T. (2011)<br>- Arthur, J. (2006) | - Lean in healthcare: A comprehensive review<br>- Lean Thinking in Emergency Departments: A Critical Review<br>- Lean thinking in healthcare: a realist review of the literature<br>- The integration of lean manufacturing, Six Sigma, and sustainability: A literature review and future research directions for developing a specific model<br>- A lean guide to transforming healthcare: How to implement lean principles in hospitals, medical offices, clinics, and other healthcare organizations<br>- Lean Six Sigma for hospitals: Simple steps to fast, affordable, and flawless Healthcare |
| Specimens handling | - E. Yücel, F.S. Salman, E.S. Gel, E.L. Örmeci, A. Gel (2013)<br>- J. Sugianto, B. Stewart, J. Ambruzs et al. (2017)<br>- Mulder, S. (2012)<br>- I. Litchfield, L. Bentham, A. Hill, R. McManus (2015)<br>- C. Sheppard, N. Franks, F. Nolte, C. Frantz (2008) | - Optimizing specimen collection for processing in clinical testing laboratories<br>- Applying the Principles of Lean Production to Gastrointestinal Biopsy Handling…<br>- Towards a lean blood testing process in Campbelltown hospital<br>- Routine failures in the process for blood testing and the communication of results to patients in primary care…<br>- Improving Quality of Patient Care in an Emergency department Laboratory Perspective |
| Reducing times and errors,<br>flow reduction | - B. White, J. Baron, A. Dighe, C. Camargo Jr., D. Brown (2015)<br>- Novis D. (2008)<br>- Sirvent, M., Gil, M., Alvarez, T., Martin, S. et al. (2016) | - Applying Lean methodologies reduces ED laboratory turnaround times<br>- Reducing Errors in the Clinical Laboratory: A Lean Production System Approach<br>- Lean techniques to improve the flow of critically ill patients in a health region with its epicenter in the intensive care unit of a reference hospital |
| process change;<br>frontline providers;<br>patient satisfaction | - E. Dickson, S. Singh, D. Cheung, C. Wyatt, A. Nugent (2007) | - Application of lean manufacturing techniques in the emergency department |

| Filed of research | Authors | Title |
|---|---|---|
| laboratory improvement | - René J. Buesa (2009)<br>- C. Michael, K. Naik, M. McVicker (2013)<br>- N. Dundas, M. Ziadie, P. Revell, E. Brock, M. Mitui, K. Leos, B. Rogers (2011)<br>- S. Agarwal, J. Gallo, A. Parashar, K. Agarwal et al. (2016)<br>- C. Krittanawong, T. Kitai, T. Sun (2016) | - Adapting lean to histology laboratories<br>- Value Stream Mapping of the Pap Test Processing Procedure - A Lean Approach to Improve Quality and Efficiency<br>- A Lean Laboratory - Operational Simplicity and Cost-Effectiveness of the Luminex xTAG™ Respiratory Viral Panel<br>- Impact of lean six sigma process improvement methodology on cardiac catheterization laboratory efficiency<br>- Time to start implementing Lean and Six Sigma in the catheterization laboratory |
| simulation | - S. Robinson, Z. Radnor , N. Burgess, C. Worthington (2012) | - SimLean: Utilising Simulation in the Implementation of Lean in Healthcare |

By summarizing all the above mentioned papers, and starting from the keywords proposed by the authors Plyutiuc et al. (2013), when it comes to research in the field of lean laboratories (and in other defined categories by the author Plyutiuc et al.), we comes to the conclusion that there are not so many researches that are closely linked to the essence of lean concept – satisfaction of doctors and patients as end users. One of the researches that are dealing with patient satisfaction after the application of the concept of lean in the laboratory is shown in the work of Melanson et al. (2009). The authors of the mentioned research presented the implementation of lean principles with the aim of improving phlebotomy patient satisfaction and workflow where user satisfaction was investigated with a questionnaire of 5 questions survey. The results of the research was a reduction of average patient wait time from 21 to 5 minutes, with the goal of drawing blood samples within 10 minutes of arrival at the phlebotomy station met for 90% of patients.

Authors Umut and Sarvari (2016) investigated the application of lean tools in clinical laboratories to reduce turnaround time (TAT) for blood test results. In their study, the authors have focused on shortening the time required for the analysis of blood samples using the layout laboratories in U-form which reduces the overall operating distance of 650 miles / year with the assumption of increasing the satisfaction of the patients, which will occur with the reduction of the waiting time without specific testing the opinions of patients.

The influence of the lean methodology in health institutions, particularly in clinical laboratories, in terms of improving the capacity and workflow, and an increase of customers' and patients' satisfaction have been explored by Morón-Castañeda et al. (2015). The authors pointed out a reduction in the flow of patients, from the moment of entering the clinic until the moment of departure for 17 minutes, and a decrease of 60% in complaints of delay in care, high staff turnover and 38% increase in the number of patients seen.

Improvement of the flow of patients has been examined by the authors Chan et al. (2014). Namely, the admission of waiting time emergency medical ward (EMW) was significantly decreased by using the lean technique from 54.76 minutes to 24.45 minutes.

Through the review of the literature, it can be noted that there are a very few studies that focused on the direct impact of the lean concepts to the satisfaction of the patients in the true sense of that word, especially when it comes to the “lean” services in clinical laboratories. The literature usually only emphasizes the specific process improvements that are obtained by applying lean concepts with conclusions that those improvements automatically lead to patient satisfaction as end consumers of clinical services. The available literature is dating mainly from the recent period, which points out that the area of researches of lean concept in clinical laboratories and its impact on patient satisfaction is one of the trends that is increasing. Based on these facts, it can be concluded that there is an available study area defined as the study of the impact of implementing the lean concept in medical laboratories and its direct impact on the level of satisfaction of end consumers - patients. The need for research lies in the fact that the implementation of the lean concept in healthcare enables the elimination of all unnecessary processes and thus provides the increase of the efficiency and effectiveness for the implementation process and the system. In addition to the improvement of the work processes, an even more, important aspect of the need for research in this doctoral dissertation is certainly the research of the impact of the process improvement in clinical laboratories by applying lean concepts to the satisfaction of the patients as end-users. Exploration of the elements that influence the degree of patient satisfaction allows us significantly to define a unified methodology for process improvement in the clinical laboratories by applying lean concepts.

A detailed analysis of previous studies, given in Table 3.3, provides a summarized view of lean methods and tools that have been implemented by several authors in their research, regarding the implementation of the lean concept in clinical laboratories. Special emphasis was directed to the target area and the achieved results.

Table 3.3 An overview of implemented lean methods and tools by different authors with a focus on the target area and the results achieved

| **Authors** | **tools/methods** | **Target area** | **Results** |
|---|---|---|---|
| | | | |
| J. Sugianto, B. Stewart, J. Ambruzs et al. (2017) | Kaizen, VSM, Kanban, SIPOC* | Specimens obtained at a 487-bed tertiary care pediatric hospital | Process cycle efficiency of 29%. Implementation of a revised-state value stream resulted in a total process time reduction to 238 minutes, of which 89 minutes were non-value-added, and an improved process cycle efficiency of 63%. |
| Umut and Sarvari (2016) | Lean six sigma, 5S, change management, heijunka, pull, mistake proofing, single piece flow, JIT, layout change. | urgent cardiac catheterization with dominance coronary angiography, coronary angioplasty, peripheral angiogram, and other heavier procedures | A number of blood test delays was 97 before the improvement and reduced to 29. Especially creatinine test was varying between 180 to 210 minutes and after implementation 90 mins. |
| Chan et al. (2014) | re-design process, priority admission triage (PAT) program | evaluate the current patient flow in ED, to identify and eliminate the non-valued added process, and to modify the existing process | The admission waiting time of emergency medical ward (EMW) was significantly decreased from 54.76 minutes to 24.45 minutes after implementation of PAT program |

| Authors | tools/methods | Target area | Results |
|---|---|---|---|
| | | | |
| Coons, 2007 | VSM, Workplace Organization (5S), Batch Size Reduction, Standard Work, Root cause analysis | Explores Lean tools that can be implemented within the healthcare setting | 25-50% improvement in turnaround time<br>20-50% improvement in tests verified for morning rounds<br>10-35% improvement in the productivity measure<br>5-15% improvement in staff and patient satisfaction |
| Melanson et al. (2009) | Kaizen event, statistic | Phlebotomy, Specimen collection, Process Improvement, Clinical Laboratories | reduction of average patient wait time from 21 to 5 minutes, with the goal of drawing blood samples within 10 minutes of arrival at the phlebotomy station met for 90% of patients. |
| Yerian et al. (2012) | Kaizen, Laboratory design, Standard work, Temotoko | lost time that employees lose because of leaving the workplace in order to perform its task | After improvement, only 59 (9%) cases (out of 664) the technologist has to leave the job position to complete the task.<br>They managed to reduce the leaving from the workplace for 3.4 times, while the times spent when leaving the workplace ranged from 8 to 70 seconds. |
| Amirahmadi et al. (2007) | VSM, 5S, change management, Pull/Kanban, flow layout | continually optimizing quality, patient care, and employee and patient safety. | Reduced batch sizes, Staffing schedules matched to sample arrivals, Standardization of work processes with visual cues to help people stick with the standard, Reduced set up time for testing, Root cause analysis, and mistake-proofing to reduce defects due to human error, Improved operational tracking management |
| I. Litchfield, L. Bentham, A. Hill, R. McManus (2015) | VSM, process improvement strategies | patients and staff across four primary care practices, the process of testing and result management, improve quality, productivity and patient experience within phlebotomy, | delay in phlebotomy,<br>lack of a fail-safe to ensure blood tests are returned to practices and patients,<br>difficulties in accessing results by telephone<br>role of nonclinical staff in communicating results,<br>routine communication of normal results,<br>lack of a protocol for result communication. |
| Stanković, 2008 | Six Sigma, Kaizen Blitz, VSM, 5S, Specimen Management System | discusses Lean and Six Sigma strategies as well as their application for the clinical laboratory, specifically utilizing lean tools | With Lean and Six Sigma, labs are able to recognize waste (streamline), reduce variation for consistent<br>results, and error-proof operations-all of these translated into enhanced quality and efficiency (turnaround time). |
| Rutledge & Simpsons (2010) | work cell, visual controls, single piece flow, standard work, 5S | increased clinical demands of hospital expansion, improve quality and reduce<br>costs, tertiary care, pediatric core laboratory | reduced TAT - turnaround time (reduced from 54 to 23 minutes) with increased testing volume (20%), monetary savings (4 full-time equivalents), decreased variability in TAT, better space utilization (25% gain). |
| Persoon et al. (2006) | TPS, 1-piece flow, Baseline Cycle Time Study, VSM | improvement of a preanalytical process | reduced the preanalytical process time from 29 to 19 minutes<br>laboratory achieved the goal of creating 80% of the reports of chemical analysis |
| B. White, J. Baron, A. Dighe, C. Camargo Jr., D. Brown (2015) | Lean-based reorganization, process flow | laboratory process flow, turnaround times (TAT) and reduce waste | screening test: troponin T TAT was reduced by 33 minutes (86 to 53 minutes) and urine sedimentation TAT by 88 minutes (117 to 29 minutes) |

| Authors | tools/methods | Target area | Results |
|---|---|---|---|
| | | | |
| J. Sirventa, M. Gil, T. Alvareza, S. Martina, N. Vila (2016) | VSM, survey | the flow of critically ill patients in a health region with its epicenter in the intensive care unit | Demographic No. patients admitted before 697 and after 691<br>EMS transfer due to lack of beds No. transfers/total requested before 10/22 and 3/21 after |
| Novis D. (2008) | VSM, process flow analysis, | Reducing Errors in the Clinical Laboratory | patients demanding better job reducing errors in laboratories,<br>medicare no longer reimburse hospitals for medical errors,<br>Third-party payors and state hospital associations have followed suit |
| E. Dickson, S. Singh, D. Cheung, C. Wyatt (2007) | VSM, 5 days Kaizen | healthcare, process change, frontline providers, patient satisfaction | Patient visits increased by 9.23%<br>length of stay LOS decreased slightly and patient satisfaction increased significantly without raising the cost per patient |
| René J. Buesa (2009) | 5S, Six Sigma, Just-In-time, First-in-first-out, Workflow analysis | histology laboratories, discontinuous workflow, lack of "pulling" between steps, accepting unavoidable waiting times | largest productivity increase (2.4 times), the highest sigma value (4.8), TAT reduction (5 days), pathologists were able to sign 60% of the cases the same day |
| C. Michael, K. Naik, M. McVicker (2013) | VSM, TPS, lean management | Pap Test Processing Procedure | PT for 1,355 samples averaged 31 hours,<br>17 accessioning errors were detected on a review of 385 random requisitions (4.4%),<br>no labeling errors were undetected |
| Morón-Castañeda et al. (2015). | lean methodology | specimen handling, patient satisfaction | reduction of the flow of patients for 17 minutes, decrease of 60% in complaints of delay in care, high staff turnover and 38% increase in the number of patients seen |
| S. Agarwal, J. Gallo, A. Parashar, K. Agarwal et al. (2016) | Lean six sigma, Kaizen, Genchi Genbutsu, Waste reduction | Operational efficiency of our catheterization laboratory (Cath Lab) | The percentage of cases with optimal turn-time increased from 43.6% to 56.6%,<br>The percentage of cases with an aggregate on-time start increased from 41.7% to 62.8%<br>Manual sheath-pulls performed in the Cath Lab decreased from 60.7% to 22.7% |

** SIPOC – A type of process map used to define the various aspects of a process. SIPOC stands for suppliers, inputs, process steps, outputs, and customers.*

Table 3.3 presents a summarized view of lean methods and tools that have been implemented by several authors in their research, regarding the implementation of the lean concept in clinical laboratories. Based on the data in table 3.3, different authors made their researches in different clinical laboratories such as laboratory of a pediatric hospital, phlebotomy, PAP test laboratory, catheterization laboratory, histology, etc. Since the subject of research in this doctoral dissertation is the study of the implementation of lean concepts in clinical laboratories for biochemistry, researches that are most closely related to the processes of the laboratory for clinical biochemistry are presented in the works of following authors Chan et al. (2014), Coons (2007), Yerian et al. (2012), Amirahmadi et al. (2007), Litchfield et al.

(2015), Stanković, (2008), White et al. (2015), Novis (2008), Dickson et al. (2007), and Morón-Castañeda et al. (2015).

By summarizing the research results of these authors, it is possible to notice the "pattern" of the results or the unique results of the process improvement after the implementation of the lean concept within the clinical laboratory process. The unit results are first of all viewed in:

- *improvement of the work processes*: admission waiting time of emergency medical ward (EMW) was significantly decreased from 54.76 minutes to 24.45 minutes (Chan et al., 2014)) 25-50% improvement in turnaround time (Coons, 2007);
- *productivity improvement*: 10-35% improvement (Coons, 2007); reduced set up time for testing and batch sizes (Amirahmadi et al., 2007); screening test: troponin T TAT was reduced by 33 minutes and urine sedimentation TAT by 88 minutes (White et al., 2015);
- *improvement of patient satisfaction*: 5-15% improvement (Coons, 2007); patient satisfaction increased significantly without raising the cost per patient (Dickson et al., 2007); decrease of 60% in complaints of delay in care (Morón-Castañeda et al., 2015);
- *reducing employee departure from workplace*: reduction of leaving from the workplace for 3.4 times (Yerian et al., 2012);
- *standardization of the process*: standardization of work processes with visual cues to help people stick with the standard (Amirahmadi et al., 2007);
- optimization of inventory
- improving communication and patient scheduling systems
- *reduction of errors*: mistake-proofing to reduce defects due to human error (Amirahmadi et al., 2007); reducing medical errors (Novis, 2008);
- *increase in the number of patients served*: 38% increase in the number of patients served (Morón-Castañeda et al., 2015);

By summarizing the above improvements obtained in researches of various authors, it is possible to define several KPIs that define process indicators that need to be monitored and improved in order to monitor the success of the implementation of the lean concept in clinical laboratories, which can be defined as:

- reducing lead time,
- reducing process time,
- improvement patient satisfaction,
- reducing employee departure from workplace,

- reducing the number of all activities,
- inventory turn over,
- reducing the number of errors and
- increase number of patient served.

By implementing the lean tools in departmental processes in clinical laboratories that are supported by the software package for simulation, attention will be paid to the above results, as a source for benchmarking, as well as to all other improvements that will be gained in the research process. The author used the above mentioned KPI's in order to gain an insight into the main and most important improvements that are and should be gained during the implementation of the lean concept in clinical laboratories. Of course, some of the results in the research in this doctoral thesis will be different from previous researches due to the different environment and working system in Serbia.

# 4. Lean methods and tools

As previously stated, the lean concept is, in fact, a set of principles, methods, and tools which combined provide continuous business improvement. Lean manufacturing, as business philosophy, primarily is the approach that largely depends on the organization of the workplace as well as its flexibility, but it is an excellent starting point for companies that want to improve their processes. During the process improvement, companies use lean tools and methods in order to eliminate all unnecessary steps in their processes, reduce unnecessary time, and reduce necessary resources to the needed level. Production approach known as the "smaller is better" best describes the lean concept in every aspect. In other words, it is the production with the usage of a smaller number of resources, fewer people, fewer steps in the process, fewer unnecessary times, etc., and with a higher quality of products or services, delivery exactly on the location where customer wants it, the maximum satisfaction of the consumers' needs, and increased revenue. All this can be achieved only if lean philosophy and principles are accepted at the level of the whole enterprise, thereby referring to the employees from the lowest level to the top management. But in order to complete lean concept, it is very important to include and integrate consumers in the process because without knowledge of consumers' demands we can often lose the essence of lean philosophy, which puts a consumer in the first place (Figure 4.1).

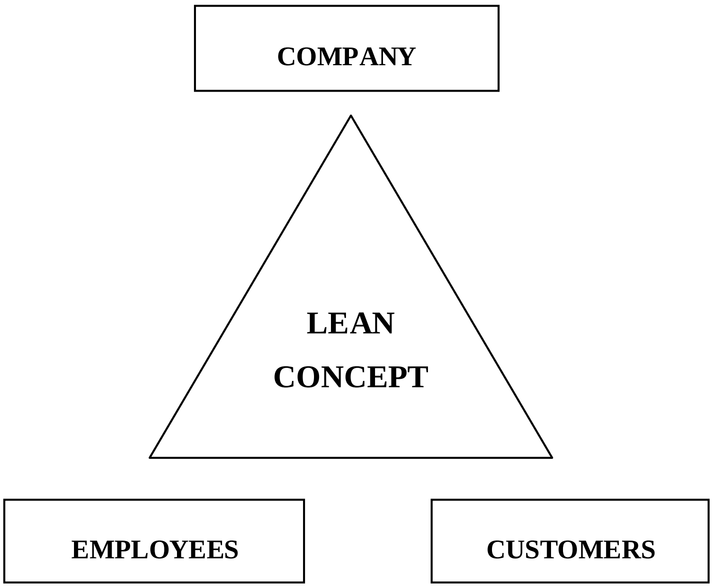



Figure 4.1. The integration of the company, employees, and consumers inside the lean concept

In the following of the thesis, the author gives an overview of some of the most important lean methods and tools which are used in the improvement of both, manufacturing and service jobs, processes and systems.

## 5S

One well-known tool of the lean concept is certainly 5S (Michalska & Szewieczek, 2007; Bayo-Moriones et al., 2010). Very often this tool is confused with an ordinary cleaning and maintenance of the workplace but this tool is definitely much more than that. One of the highest quality characteristics of this tool is that it can be implemented in every workplace, process, independently of the industry. The lean 5S tool is a combination of five Japanese words, where each word begins with the same letter "S" (Jimenez et al., 2015) as follows:

1. SEIRI,
2. SEITON,
3. SEISON,
4. SEIKETSU,
5. SHITSUKE.

The first step in the implementation of 5S is *SEIRI*, which translated means: *sort*. The aim of this step in the workplace is the elimination of anything that is not needed in a particular workplace. It is necessary to leave only the resources that are necessary to a certain position to function on a necessary minimum. Benefits that this step brings to the workplace are higher equipment availability rate and new team working mentality.

The second step is called *SEITON*, i.e. *organization of the workplace*. After rejecting all unnecessary things from a workplace that are not needed, at this stage it is necessary to organize and label all the resources that are needed in the workplace. Organizing and labeling need to be done so that employees who use a given position can easily and readily use tools. Good organization of the workplace provides better working conditions for employees, reduce possible occurrence of injuries, facilitates work on the given position, and thus the efficiency of employees. Benefits that this step brings to the workplace are higher quality and lower maintenance costs.

*SEISON* is the third step, and in translation means *cleaning of the workplace*. Cleaning of the workplace must be done daily. In handing over work-shift employee has to leave the workplace clean and tidy for another worker. At this stage, all employees must be involved, without exception. Only on the clean workplace workers can see any irregularities that show that something is wrong or that some elements do not belong to the proper position. Benefits that this step brings to the workplace are optimized workspace and visual control.

The fourth step is called *SEIKETSU*. Seiketsu means *standardization*, standardization of all procedures which are performed in the workplace. Standardization of work in the workplace provides respect to the work process, as well as the reduction of the possibility of occurrence of waste and workers injuries. Benefits that this step brings to the workplace are improved safety and decreased inventory.

The last phase of the 5S tool is called *SHITSUKE* which means *maintenance*. Term maintenance does not present the cleaning and maintenance of the workplace, but a kind of discipline of all those who are involved in continuously repetition and improvement of previous steps. The benefit that this step brings to the workplace is self-discipline. To represent 5S steps, Figure 4.2 gives a simple example of applying 5S tools.

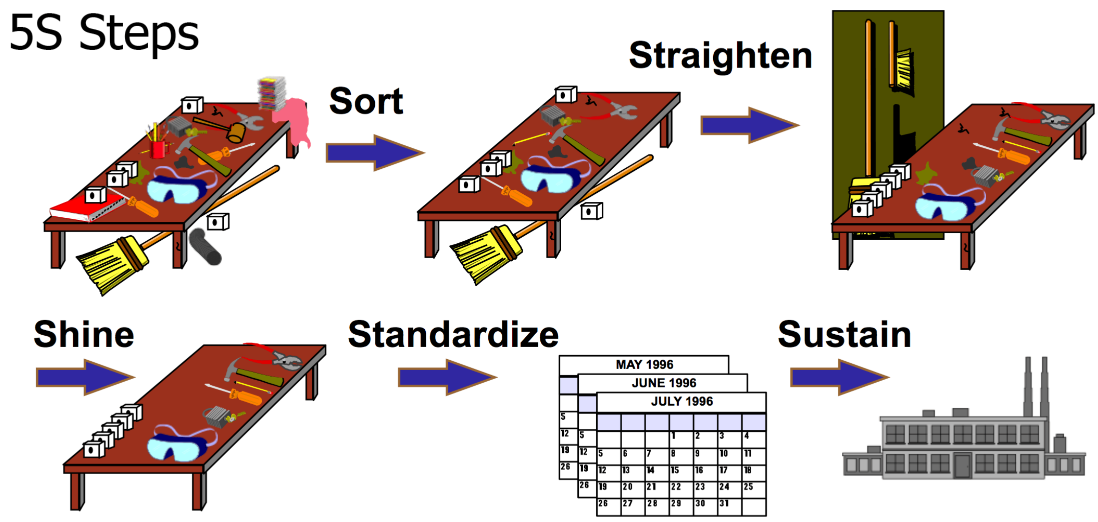



Figure 4.2. The order of steps in the 5S tool (example)

## VSM – Value stream mapping

Next most popular lean tool is VSM - Value stream mapping. The usage of this tool started after the publication of the book of the authors Rother & Shook (1999) entitled "Learning to See: Value Stream Mapping to Add Value and Eliminate Muda". VSM essentially represents a mapping of the entire process with all the elements involved in its operation. Rother & Shook presented mapping process as "wherever there is a product for a customer, there is a value stream". According to the authors, value stream is a set of all actions (value-added as well as non-value-added) required to produce a specific product or group of products that use the same resources through the main flows, starting with raw materials and ending with the customer (Rother and Shook, 2003). These actions consider the flow of both information and materials within the overall supply chain. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try to eliminate these wastes (Rother and Shook, 2003; Abdulmalek & Rajgopal, 2007). The review of the literature (Tyagi et al., 2015; Abdulmalek & Rajgopal, 2007; Morlock & Meier 2015; Rohac & Januska, 2015; Venkataraman et al., 2014) leads to the conclusion that there exists a consensus about the phases of the implementation of VSM lean tool. Those phases can be presented as:

1. Initiating changes,
2. VSM current state map,
3. VSM future state map,
4. (Simulation) – optional, not obligatory,
5. Implementation.

In the first phase, it is necessary to initiate a desire for change by both, employees and top management. After starting the changes, it is important to create VSM of the current state, which is usually referred to as “AS IS”. To create the simplest VSM of the particular process it is required only a pencil, paper and knowledge of a process with all its elements. VSM is essentially composed of certain symbols that define certain elements within the system (Figure 4.3).

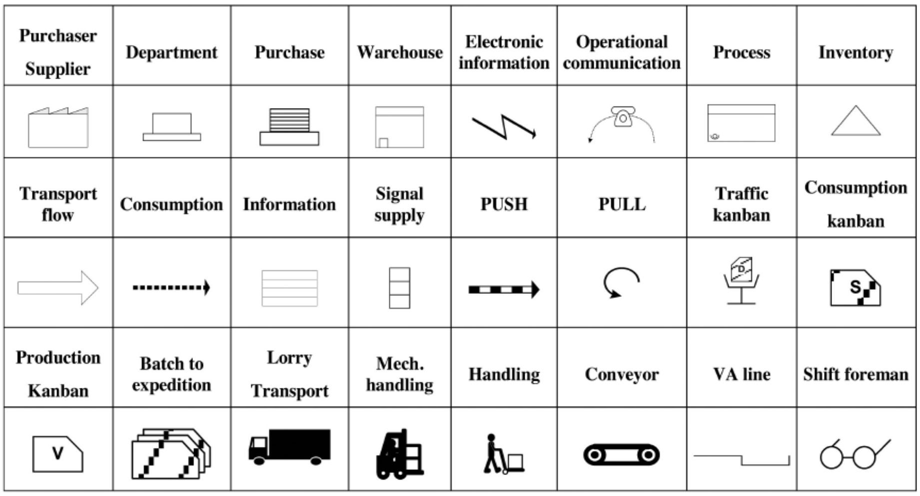



Figure 4.3. Icons used for the creation of VSM (retrieved from Rohac & Januska, 2015)

Today there are more modern methods of creating VSM with the help of various software solutions that simultaneously allow simulation of the current situation (AS IS), determination of the correctness of input data and simulation of the future conditions (TO BE), and handle with more precise data before implementation. Figure 4.4 gives an overview of the case “AS IS” – current state map of a certain process.

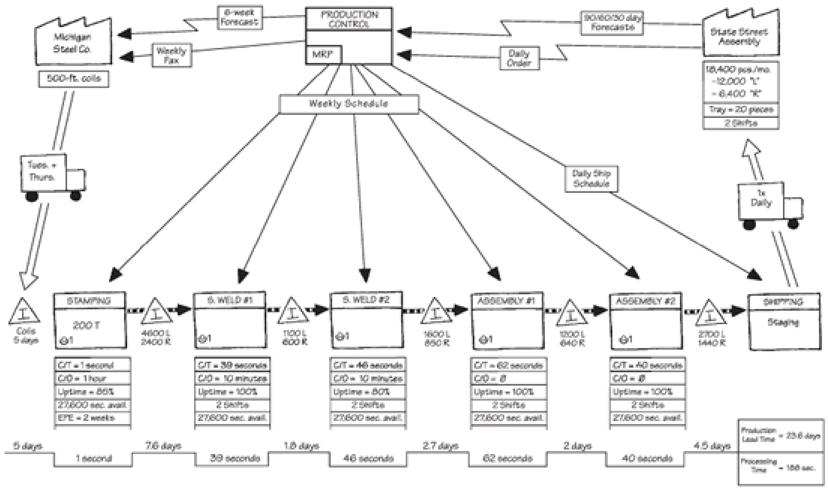



Figure 4.4. VSM of current state example
(source: https://www.lean.org/lexicon_images/363.gif)

After creating the VSM of current state of the system, usually companies create teams of experts, who share ideas in order to eliminate unnecessary steps in the process, to integrate the individual steps into a single, to change working mode, to eliminate reverse steps that occur within the process, to shorten the process and so on. When all this is finished a new map of the system or VSM of future state will be created (Figure 4.5), and this step represents the third phase of implementation of VSM tools.

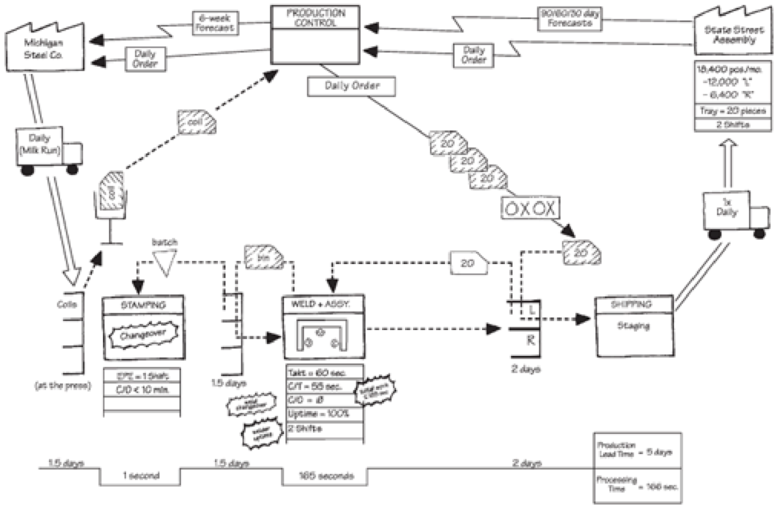



Figure 4.5. VSM of future state example
(source: https://www.lean.org/lexicon_images/363.gif)

An optional step in applying VSM tool is a simulation of the operation of a new system, which is used more and more today (Abdulmalek & Rajgopal, 2007; Lian & Van Landeghem 2007; Lian & Van Landeghem, 2002; Solding & Gullander, 2009). Today's software packages enable us to simulate the results of this new system and to reach a conclusion about whether the new draft system is justified or not before the final step of implementation of the final solution. VSM tool is a very effective tool that allows us to get information on wastes (muda) that occur within the system and to eliminate these wastes easier and as soon as possible.

## KAIZEN

Kaizen in the simplest translation means *continuous improvement*. The word Kaizen was first introduced by the author Masaaki Imai in his book "Kaizen: The Key of Japan's Competitive Success in 1986". Term Kaizen is composed of two words of the Japanese language (Figure 4.6), KAI (which means *change*) and ZEN (which means *good*). It means a good change, better change, but the generally accepted translation in the world is continuous improvement.


Figure 4.6. Kaizen (retrieved from http://www.kaizen.com/)

Kaizen is the continuous improvement in the sense that it does not meet the current "best" solution, rather fostering the view that the perfection does not exist, and that it can always be better in order to achieve the "perfection". The aim of Kaizen is to make even the smallest possible process improvements, or work improvement, every day. According to the philosophy of Kaizen, changes do not always have to be huge, but the collection of small changes can lead to major improvements. This does not mean that Kaizen represents a small change, but sometimes it is impossible to make excessive changes which will cause continuous improvement and great results. It is often necessary to make small steps to cross a long way to the improvement.

One of the pioneers of Kaizen, Masaaki Imai, explains that each improvement can be divided into two parts: Kaizen and Innovation. Unlike Kaizen, an innovation is inclusion of significant investments in equipment and technology with the aim of achieving drastic changes and improvements. Figure 4.7 gives a view of an improvement divided on innovation and Kaizen, as well as of segments that they cover (Imai, 1997).

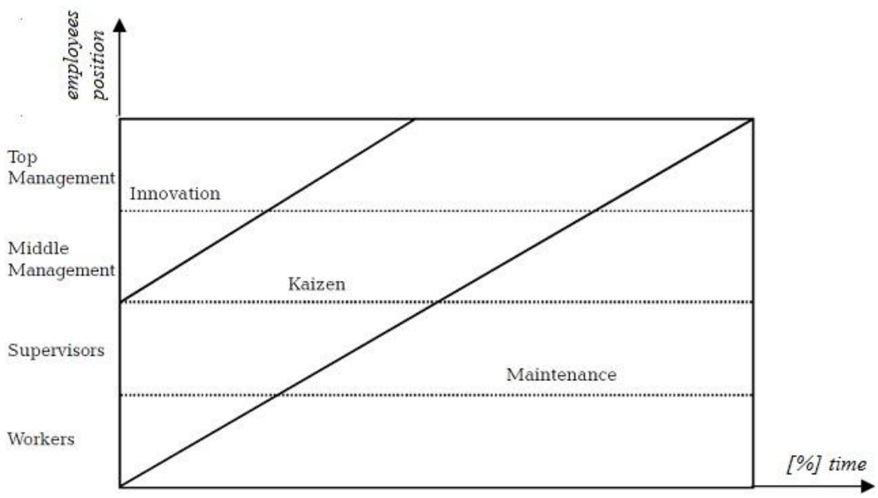



Figure 4.7. Improvement divided on innovation and kaizen (Imai, 1997)

Imai also assumes that Kaizen is the philosophy which uses certain tools like JIT – just in time, Kanban, TPM, Poka-Yoke, and many others. All those tools are covered by so-called Kaizen umbrella (Figure 4.8).

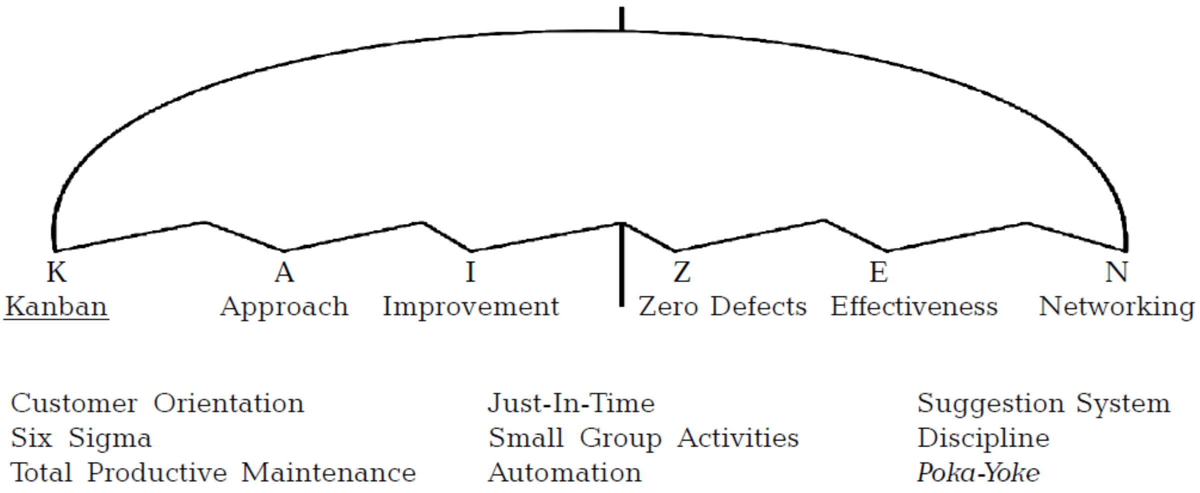



Figure 4.8. Kaizen umbrella (Imai, 1986)

It is important to mention that there are different Kaizen activities with the aim of elimination of waste and improvement of a system. Kaizen events are presented in the continuation of text, with definitions of different authors:

1. **Kaizen event** - "*a focused improvement event during which a cross-functional team of operators, engineers, etc. spends several days analyzing and implementing improvements to a specific work area*" (Kirby & Greene, 2003, p. 2),
2. **Gemba kaizen** – *according to* Imai (1997) *gemba presents "location where things happen" or translated by business vocabulary "the shop floor" (*Suárez-Barraza et al., 2012*). According to* Ohno (2007*), gemba is "workplace where a company adds value",*
3. **System kaizen (jpn. Kaikaku)** – *"Kaikaku means radial improvements that are conducted infrequently, involve some fundamental changes within the production, cause dramatic performance gain, and are often initiated by the top or senior management"* (Yamamoto, 2010),
4. **Kaizen blitz** – *"Kaizen blitz may take one week, but it takes several weeks to prepare and continue the kaizen journey"* (Charavorty & Franza, 2012),
5. **Kaizen super blitz** – "*kaizen super blitz is kaizen event that takes a place immediately upon detection of a detect for a process, equipment of product and is of limited duration – hours*". (Burton & Boeder, 2003)

Some authors believe that the concept of continuous improvement was developed in America (Bhuiyan & Baghel, 2005) and that after the Second World War was "adopted" in Japan. In Japan, it was accepted by Japanese companies as Kaizen (Yokozawa et al., 2012). One of the most famous students of the so-called "American school" was Dr. J.Edward Deming, considered as the guru of the quality. His technique for improving a quality, known as Deming cycle – PDCA (Figure 4.9), is a framework used to manage employees while implementing Kaizen activities.

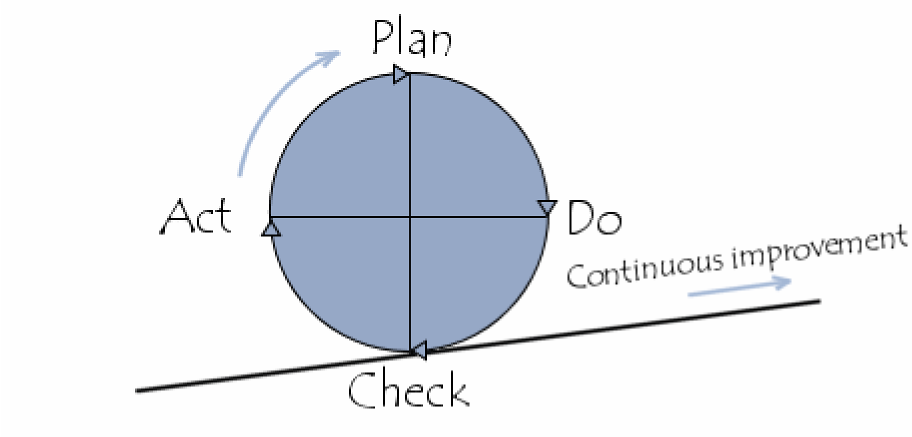



Figure 4.9. PDCA – Deming cycle

But, regardless of the location where this philosophy was created, America or Japan, it is more than obvious that the Japanese industry, since Kaizen has become a part of it, has achieved huge success which caused a great impact on the global industry (Ashmore, 2001).

## JIT – Just in Time

Ohno (1982) defined Just in Time - JIT as the company's ability to obtain an appropriate amount of resources just in time. Fullerton & Watters (2002) defines JIT as an approach which is based on excellence that is achieved through continuous improvement in all phases of the production cycle. A simple definition gave the authors Wu et al., (2012) who observed JIT as "*practices to reduce and eliminate waste*." The review of literature points that there is one common attitude on JIT, so JIT is defined as a methodology, philosophy, strategy, concept, approach, practice, and system (see Alcazar et al., 2014).

The fact that JIT approach is very important and commonly used in the world is described by Teeravaragrup et al. (2011), where they presented the benefits of the implementation of JIT in the period of 26 years. They included researches of 35 authors who managed to classify the 22 most significant benefits that JIT contributes to organizations. The most important benefit is certainly an increase in productivity while the second is a reduction of total production costs. In addition to these two most significant benefits, there were also observed an improved relationship with suppliers, an increase of quality and innovation, increase of motivation of employees, reduction of a number of activities and administrative work and many others.

Besides, the term “Total JIT” is also familiar in the literature. Total JIT integrates different parts of JIT (Green et al., 2014):

- JIT production – this approach is usually based on the Kanban production technique, such as reduced manufacturing lot sizes, reduced manufacturing lead times, and enhanced quality assurance programs, required to implement flexible manufacturing processes (Dong et al., 2001, p. 472).
- JIT purchasing – JIT purchasing, on the other hand, refers to those practices, most notably the frequent deliveries of small lot sizes, that facilitate inventory reduction of raw materials (Dong et al., 2001, p. 472).
- JIT selling strategies – “*exhibits the ability to build value throughout the selling process based on organizational capabilities to deliver zero-defect quality, zero variance quantity, precise on-time delivery and the ability to minimize total waste and total cost throughout the production and marketing processes.*” Green et al. (2008).
- JIT information – this approach is the youngest in this group and it is an important competence in the implementation of JIT. Information structure is very important for collecting and processing data in order to eliminate waste, process management as well as improving effectiveness and efficiency of a process (see Phan & Matsui, 2010; Green et al., 2007).

To make JIT functional it is necessary to establish the “pull” principle. There are usually two types of production systems in manufacturing. One is called “pull” and the other “push”. The main difference between these two types is reflected in the fact that the “push” production (Figure 4.10 and 4.11) “forces” production without quality monitoring of market demands. Very often such kind of production leads to the accumulation of finished products in the workplace and in the warehouse, which directly leads to the “capture” of capital and increased costs for the company. Kumar & Panneerselvam (2007) point out that this approach, because of the unpredictability of customers, creates variation in the production plan and it is very difficult to define the required safety stock level. Figure 2.11 shows the push system which produces a certain quantity of product. At each workstation (WS) it is produced a certain amount and sent to the next, without any order until the final product is produced, which is stored then.

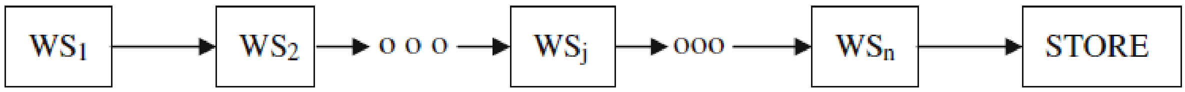



Figure 4.10. Push system (retrieved from Kumar & Panneerselvam, 2007)

On the other hand, “pull” system is functioning on a totally different approach (Figure 2.12). According to Hopp & Spearman (2004) pull system is “*one that explicitly limits the amount of work in process that can be in the system*”.

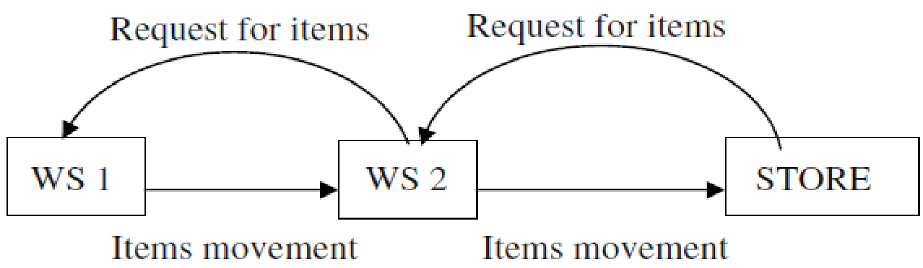



Figure 4.11. Pull system (retrieved from Kumar & Panneerselvam, 2007)

In "pull" systems workstations produce a certain amount of product and when a particular workstation notes a need for a product, usually via Kanban cards it signals the previous workstation to delivers necessary elements or parts. This way of operating enables the elimination of variations in the production plans, ensures the delivery of products right on time while maintaining minimum stocks of raw materials and finished products.

## Kanban

Kanban is the Japanese word which can be translated as a "card" or "visual signal" (www.leankit.com), "visible records" or "visible parts" (Rahman et al., 2013). There are different definitions of Kanban. Some authors observe Kanban as "on-demand" concept which "*maximizes the value flow of the systems*" (Turner & Lane, 2013). "*Kanban, meaning "signboard", is a system that allows for the management of the overall supply chain by strategically and operationally linking production demands and the management of supplies*" (Aguilar-Escobar et al., 2015). The authors Junior & Filho (2010) observe Kanban as a sub-system which is used for "*control of inventory levels, the production, and supply of components, and in some cases, raw material*". Although definitions vary depending on the authors, we can conclude that Kanban with its characteristics is a key element for the functioning of JIT. Some of the most significant benefits that a company can gain by implementing Kanban are a reduction of wastes that may occur by excessive production, reduction of logistics costs and waiting times, reduction of inventory levels and overhead costs, etc. (Rahman et al., 2013). A review of the literature suggests that there are two types of Kanban that are used most often. Those are Kanban Production Order (POK) and Withdrawal Kanban (WK). In addition to these two types of Kanban, there are also Express Kanban, Emergency Kanban and Trough Kanban (www.beyondlean.com). Kanban systems can operate using a single card system, dual or semi-dual card system (Chan, 2001; Horng & Cochran, 2001). Figures 4.12 and 4.13 present single and dual kanban systems.

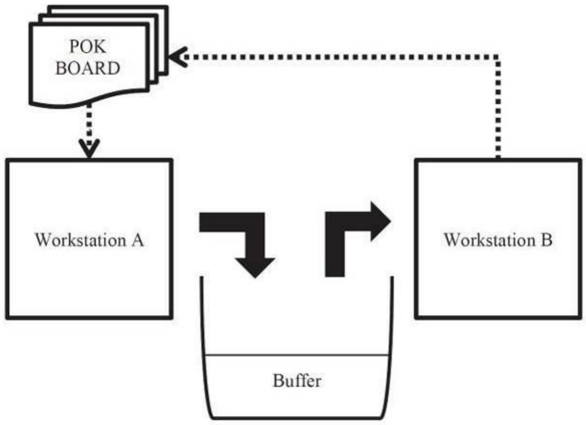



Figure 4.12. Scheme of single card system (retrieved from Giordano & Schiraldi, 2013)

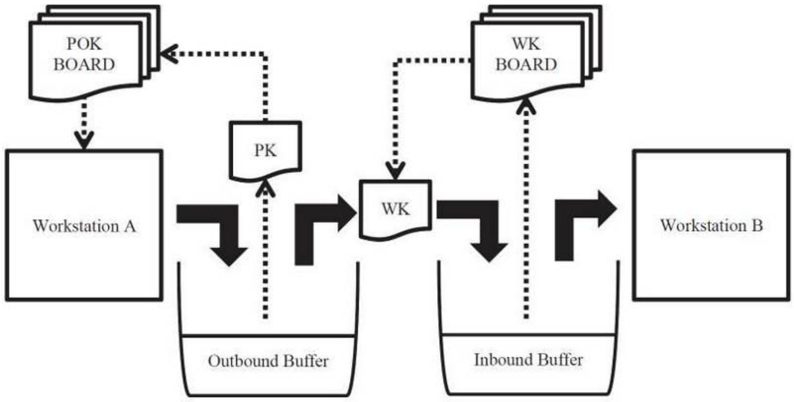



Figure 4.13. Scheme of dual card system (retrieved from Giordano & Schiraldi, 2013)

To make a system functional by using the Kanban system there should be determined a sufficient quantity of Kanbans within the system. The formula to calculate Kanbans is also called the Toyota Formula (Kumar & Panneerselvam, 2007), and it is presented as:

$$K \geq \frac{D\,L(1+\alpha)}{C}$$

Where:

- K is the number of kanbans,
- D is the demand per unit time,
- L is the lead-time,
- α is the safety factor, and
- C is the container capacity.

Lin et al. (2013) emphasize three principles of Kanban: visualize the workflow, limit work in progress (WIP) at each workflow state, and measure the lead time (i.e., average time to complete one item) while Ahmad et al. (2013) note two more principles: to make process policies explicit and improve collaboratively.

## TPM

"Father" of the approaches inside the lean concept known as Total Production Maintenance (TPM) is Seiichi Nakajima. Seiichi (1988) defined TPM as an "*innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce*". The same author emphasize the word "**Total**" which contains three segments of this approach and those are:

1. ***Total*** effectiveness indicates TPM's pursuit of economic efficiency and profitability.
2. ***Total*** maintenance system includes Maintenance Prevention (MP) and Maintainability Improvement (MI), as well as PM. Basically, this refers to "maintenance-free" design through the incorporation of reliability, maintainability, and supportability characteristics into the equipment design.
3. ***Total*** participation of all employees includes Autonomous Maintenance (AM) by operators through small group activities.

There are other definitions of TPM also. McKone et al., (2001) explain TPM as an approach which "*provides a comprehensive company-wide approach to maintenance management, which can be divided into long-term and short-term elements*". Gupta & Garg (2012) observe TPM as "*a proven and successful procedure for introducing maintenance considerations into organizational activities*", while Swanson (2001) claim that TPM is an "*aggressive strategy focuses on actually improving the function and design of the production equipment*". In his work, Swanson explains three different maintenances in more details:

1. reactive (breakdown) maintenance,
2. proactive maintenance including preventive and predictive maintenance,
3. aggressive maintenance.

In order to meet TPM objectives, Nakajima defines 5 pillars of TPM, while contemporary researches find eight pillars which are presented graphically in figure 4.14.

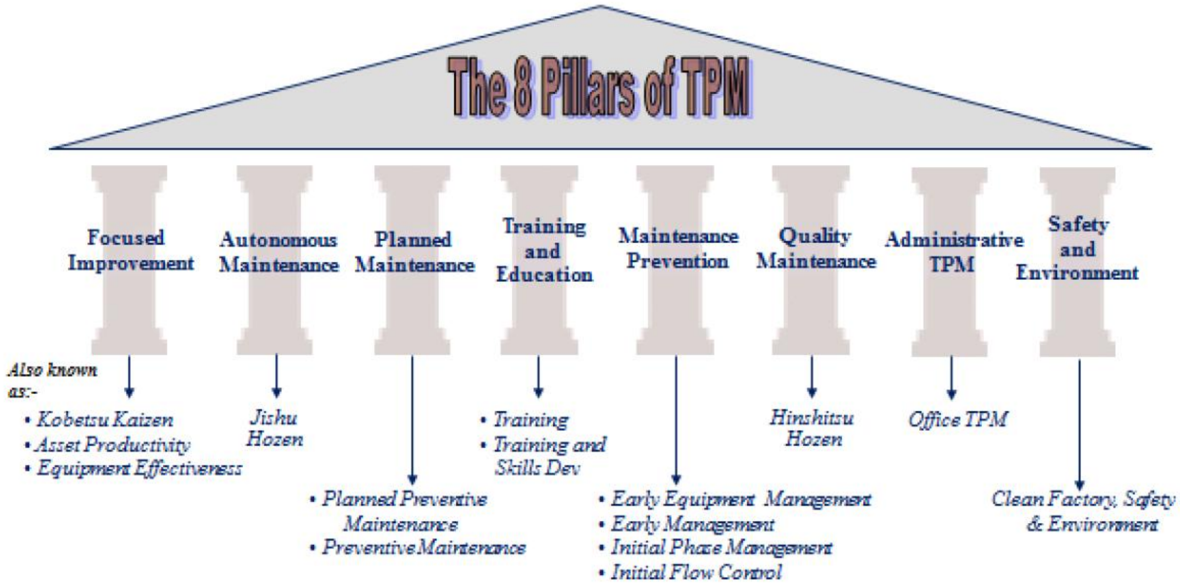



Figure 4.14. Eight pillars of TPM (retrieved from Renganathan, 2014)

It is important to note that a basis of TPM home, from figure 2.15, is the 5S lean tool that has already been described in detail (for more see Singh et al., 2013). Only with a tidy workplace using the 5S, it is possible to achieve high-quality maintenance. With the quality integration of all pillars in the implementation of TPM, it is possible to achieve significant results in production (Ahuja & Kumar, 2009). In their paper, the authors have shown that the benefits that certain companies achieved are the following:

- 92% improvement in productivity,
- 59% improvement in overall equipment effectiveness,
- 63% reduction in equipment breakdowns and failures,
- 85% reduction in customer complaints,
- 22% improvement in delivery compliance,
- 140 times enhancement in operating profits,
- 80% to 90% reduction in rejections,
- 80% reduction in minor accidents etc.

Although TPM can bring very significant improvements, sometimes it fails. Rodrigues & Hatakeyama (2006) considered that the success of TPM is directly linked to the employees and their management. They assume that high pressure when introducing TPM results in increased productivity, but also in waste as well as in increased costs which are indicated in a very short period of time. The authors define factors that directly influence the failure of TPM implementation, such as:

- Increasing the daily rhythm of production, with the same team,
- Lack of time for autonomous maintenance,
- One single operator commands more than one machine at the same time,
- Work stress,

- The operators are given the idea that they must produce and not make maintenance,
- TPM implementation in a quick way omitting some consolidation steps,
- Lack of personal training and others…

## Visual management

Visual management can be described as the "ability to see the process". This tool is essentially composed of different images, diagrams and boards, lights, displays, markings on the floor (Figure 4.15 and 4.16), and serves as a particular form of communication between processes and employees in order to achieve a smooth functioning of a process (Patty & Turner, 2006).

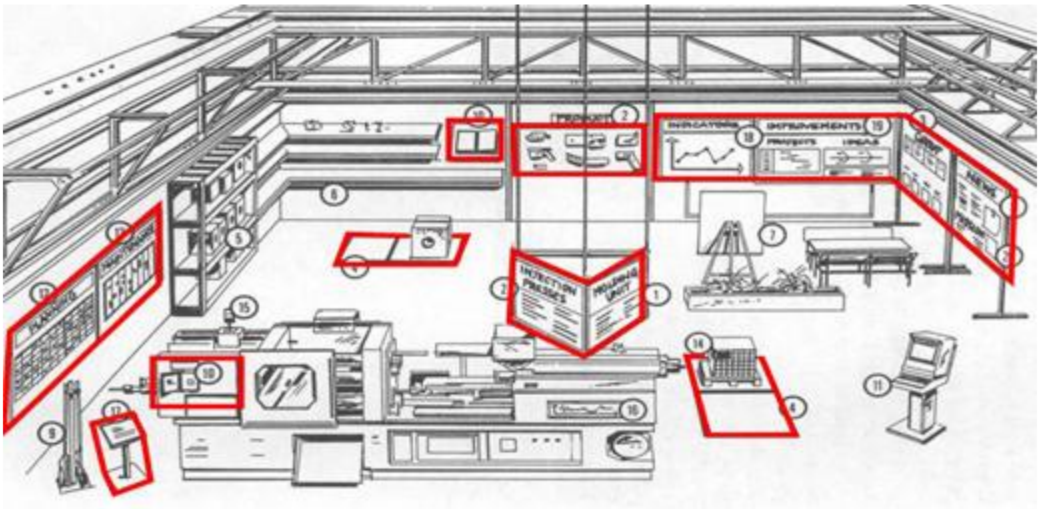


Figure 4.15. Examples of visual management (www.letsworktogether.us)

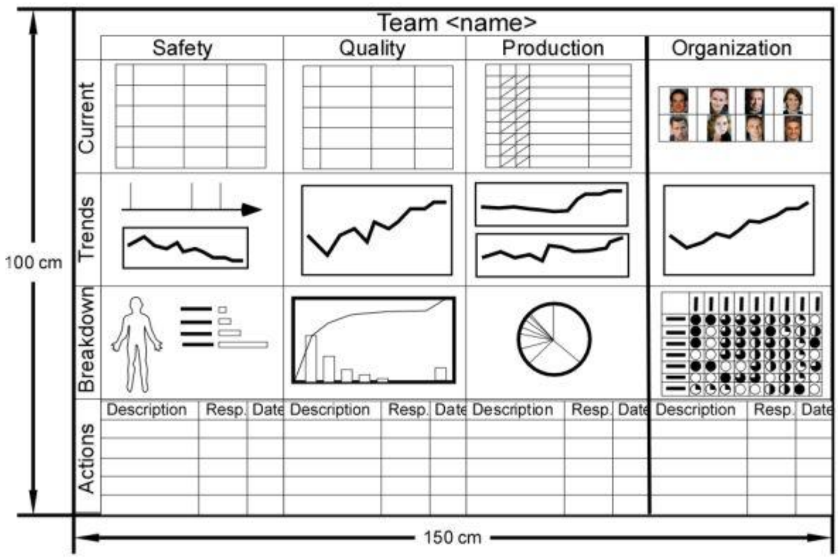



Figure 4.16. Visual management boards – example (www.pinterest.com)

This tool, although looks to be pretty simple, actually plays an important role in business systems. With the help of visual management, workers can be informed about possible necessary details related to the performance monitoring, KPIs - key performance indicators, a number of injured employees in a given time period, a number of rejects produced (see Mignon, 2013; De Koning, 2006; Liqueur & Morgan, 2006). One of the most famous examples of visual management is light displays known as *Andon lights* (Figure 4.17). According to Mejabi (2003), Andon represents "*simple and highly graphical communication of key process status attributes to provide an intuitive understanding of inner workings of the process and ensure quick adaptations to both foreseen and unforeseen process changes*".

Figure 4.17. Andon lights – example (www.leanworkshopgroup.com)

Andon lights are defined in the form of traffic lights located on each machine. Depending on the light that is illuminated an employee is notified and certain information can be delivered to him. Greenlight informs worker that everything is in order, yellow light shows that a machine has a problem, and in the case of the red light, an employee receives information that there is a standstill of the machine or that the entire line of production is stooped.

## Takt time

The design of a lean operation starts with the takt time (Liker & Burr, 1999). The word "takt" comes from the German language and it is associated with the music. It presents a certain interval of time, repetition (Simons & Zokaei, 2005). In order to meet the demands of consumers, it is necessary to determine a takt time at which a particular product will be produced in certain amounts at a particular time. A takt time can be used to regulate and synchronize production with consumer demands in order to eliminate overproduction as one of the basic waste in the production (Womack & Johnes, 1996). Authors Pattanaik & Sharma (2009) described takt time as "*the rate at which work progresses through the shop floor is called Takt. It is a time–volume relationship calculated as the rhythm, beat, or cadence for each process of a flow line and used to establish resource definition and line balance. The* *flow of the product is achieved by causing all of its work tasks to be grouped and balanced to a calculated Takt time*". The formula for calculating takt time is:

$$\text{Takt-time} = \frac{\text{Production time available}}{\text{Customer demand}}$$

Takt time is calculated by dividing the total available production time with consumer demands. In order to accurately explain the formula above, a simple example has been given below:

*Example:* A production line works with three shifts per day, with breaks of half an hour per shift. Consumer demands are 1800 parts per one week. Takt time for the given data is calculated using the following formula:

| | |
|---|---|
| Production time available | = 3 x 8h x 60 min/day |
| | = 1440 min – 3 x 3 x 30 min (breaks) |
| | = 1170 min |
| Customer demands | = 1800 parts per-week (5 working days) |
| | = 1800/5 |
| | = 360 parts per day |
| Takt time | = 1170 / 360 |
| | = 3.25 minutes |
| | = 195 sec |

Takt time, in this case, is 3,25 minutes. This means that if we want to fulfill the required expectations of consumers of 1800 parts per week, we have to produce one product on the production line every 3.25 minutes.

## Work Standardization

A lean tool used for uniform and constant work of the employees is called *work standardization*. After continuous improvement of a particular job or process, it is necessary to define all possible procedures for employees to hold such a workplace without any possibility of returning to the previous stage. It is a known fact that employees easily return to old work habits or to make certain working steps on their own, even those are precisely defined. With the application of good work standardization, it is possible to inform employees and even to train them how to do certain operations or procedures. The aim of work standardization is the elimination of wastes in production, providing a takt time required for a particular operation, reduction of possible injuries of employees, providing a possibility of finding the “guilty” if there have been produced scrap products or employees’ injuries. In order to ensure standardization of work it is necessary to implement three standard forms for processes within the company:

- Sample process capacity sheet,
- Standardized work combination table and
- Standardized work chart.

Figure 4.18 gives a simple view of continuous process improvement by applying Kaizen and work standardization.

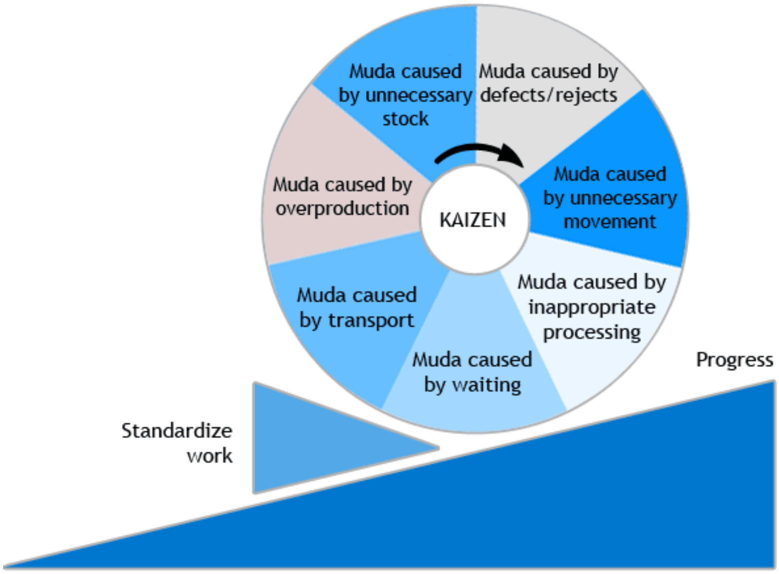



Figure 4.18. Work standardization and Kaizen

Although it is very important and popular, this tool is not used to a great extent in practice. Some of the benefits that this tool can bring to the organization are (http://www.lean.org/Workshops/WorkshopDescription.cfm?WorkshopId=20):

- “*Documentation of the current process for all shifts, reductions in variability, easier training of new operators, reductions in injuries and strain, and a baseline for improvement activities.*
- *Standardizing the work adds discipline to the culture, an element that is frequently neglected but essential for lean to take root. Standardized work is also a learning tool that supports audits, promotes problem-solving, and involves team members in developing poka-yokes*”.

## SMED

SMED – Single Minute Exchange of Dies is a tool developed by Shigeo Shingo as a response to the request for a reduction in the time for tool changes on the machines. The first improvement of the tool change Shingo applied to a press where the time for tool change was reduced from the required two days to 16 minutes only. Shingo explains in his book that SMED means the replacement and adjustment of tools on the machine as soon as possible, such as e.g. 10 minutes (Shingo, 1985). Shingo divided methodology for tool replacement in two phases

- Internal setup –the replacement and adjustment of tools when the machine is off;
- External setup – the replacement and adjustment of tools while the machine is working.

According to Cakmacki (2009), it is possible to divide SMED into three steps which are explained in detail in figure 4.19:

1. Separating the internal and external setup,
2. Converting the internal setup to external setup,
3. Streamlining all aspects of the setup operation.

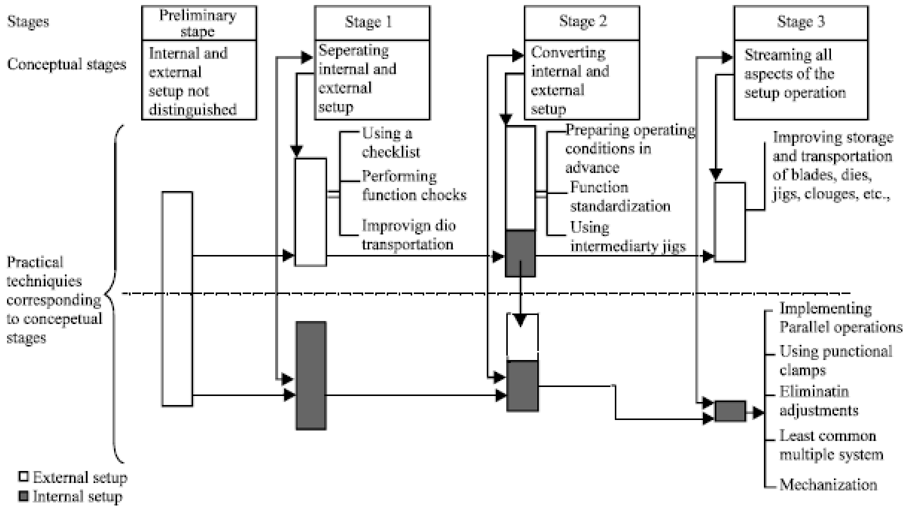



Figure 4.19. SMED conceptual stages and practical techniques (taken from Ulutas, 2011)

The aim of SMED is a reduction of steps and standardization of procedures during tool replacement. Ulutas (2011) emphasize that implementation of SMED enables an increase of the efficiency of the time for tool adjustment from 25% to even 85%, with a significant increase of flexibility at the same time. The authors Alves et al. (2011) showed that SMED influenced a reduction of the change over time (for 40%) and improvement of machines performance.

## Poka Yoke

In the book "Zero Quality Control: Source Inspection and the Poka-Yoke System" author Shingo (1986, p.42-45) described his visit to the company Yamada Electric from Nagoye. The problem within the company occurred during the production of simple push-button devices that are manufactured for the company Matsushita Electric from Kyusku. Often an individual employee, while assembling the device, forgets to incorporate the spring into the product. This caused scrap products and complaints from customers with direct impact on the reputation of the company as well as the increase in costs. Noticing the problem that workers assemble the product without an established sequence, he introduced a "device" which enabled the assembly sequence. The spring was placed first and then everything else was done. This approach fully eliminated errors that occurred during the assembly process. These devices which are able to eliminate the errors the author called Poka Yoke. Rough translation of the word Poka Yoke means "mistake-proofing" because these devices are used for the prevention (Yoke - proof) of unintentional errors (Poka - mistake). Later there were other definitions, but all definitions indicate that Poka Yoke devices are used for eliminating defects and achieving goals that Shingo marked as "zero quality control". For example, Middleton (2001) defines "*poka-yoke as the systematic practice of eradicating errors, by locating their root cause*", or ", *poka-yoke is a quality improvement methodology to prevent mistakes from happening to minimize the negative consequences*" (Krajewski et al., 2001) etc. One of the main characteristics of Poka Yoke devices is that they can be very simple and cheap, and they can be placed in the locations where the errors occur. Figure 4.20 gives an illustration of some individual solutions of poka-yoke, which can prevent the occurrence of errors.

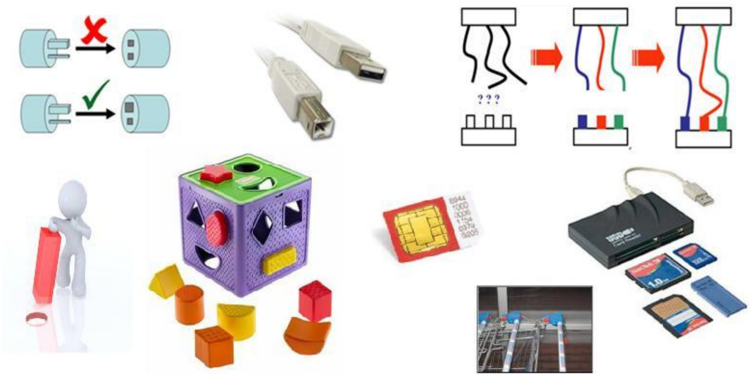


Figure 4.20. The illustration of certain Poka Yoke solutions (www.produktivne.sk)

The importance of introducing poka-yoke is the elimination of errors that can occur by employees who are considered to be the weakest link in the process. Poka Yoke devices can be divided into two basic categories (www. faculty.cbpa.drake.edu):

1. Prevention device - make errors impossible;
2. Detection device - make errors visible to the operator.

Some authors emphasize that the employees cannot be trusted when it comes to the manufacturing products of good quality since they are still possible errors of employees which must be prevented (Pettersen, 2009).

## Jidoka

When we talk about the Toyota Production System (TPS), machines are designed so that they are able to recognize and signal all kinds of abnormalities that occur during operations. Jidoka is often translated in the literature as "*quality at source*". The signaling is realized since the machine automatically stops when there are any abnormalities in its functioning (Jongyoon & Greshwin, 2005; OSONA et al., 2008). Due to the ability of machines to detect abnormalities and to stop their work, some authors often view Jidoka as "automation with a human brain" (Ohno, 1988; Danovaro et al., 2008). It is important to note that Jidoka is used to detect abnormalities, but not to remove them. That is why this tool is also very connected with human resources within a company.

After machines sign that something is wrong, employees must eliminate a problem as soon as possible and, if necessary, define new operating procedures, in order to avoid the same mistakes in the future. Jidoka consists of five basic steps (Grout & Toussaint, 2010):

1. detect the problem,
2. stop the process,
3. restore the process to proper function,
4. investigate the root cause of the problem and
5. install countermeasures.

Shingo (1989), who invented Jidoka system in 1930, also considers that Jidoka can enhance productivity while increasing the quality (http://www.leanuk.org). An increase of quality comes with every machine down or process stop because problems are solved by employees who can learn and improve their knowledge during problem-solving. Jidoka and Just in Time are often seen as the two pillar of TPS house (see Figure 4.21) on which lies quality objectives, time, security, delivery (Kurdve et al., 2014).

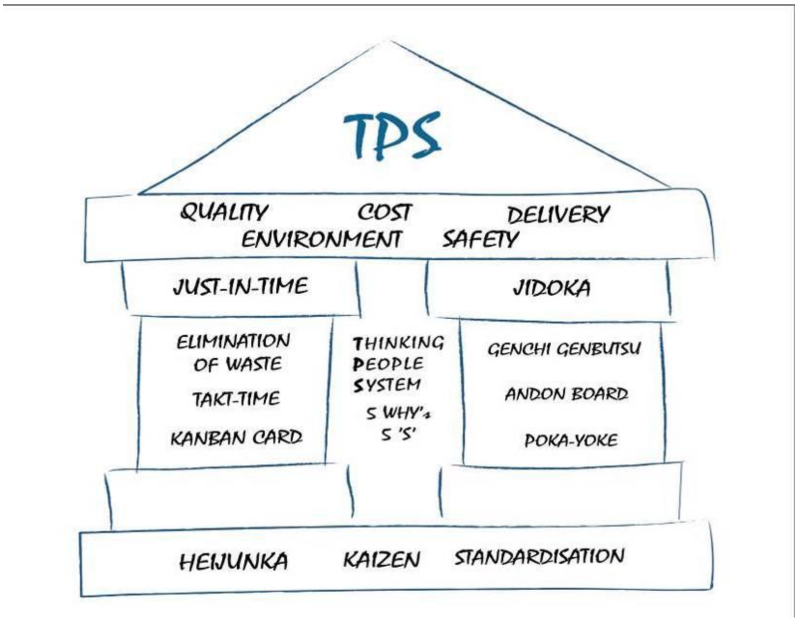



Figure 4.21. JIT and Jidoka pillars of TPS house
(source: http://leanmii.blogs.upv.es/2017/04/12/kaizen-limpieza-y-cultura-de-empresa/ )

In some cases, Jidoka can provide quality on the sources that can ensure production and 100% defect-free products, which is also called "ryohin". Because of the possibility of production without defects, companies use it very often to promote their brand while defining their production conditions which Toyota calls the "ryohin joke". Takami (2014) defines Ryohin joken as "*manufacturing conditions that will always produce defect-free products. It also means breaking away from the intuition and innate skills of workers and concretely quantifying the manufacturing conditions that were previously known only as implicit knowledge. To accomplish this goal, it is important to master measuring technologies, clarify and quantify the relationship between forging conditions and manufacturing quality, and then create standard conditions*".

In order to fulfill the requests of the ryohin joken concept, a company needs to realize the following activities (figure 4.22).

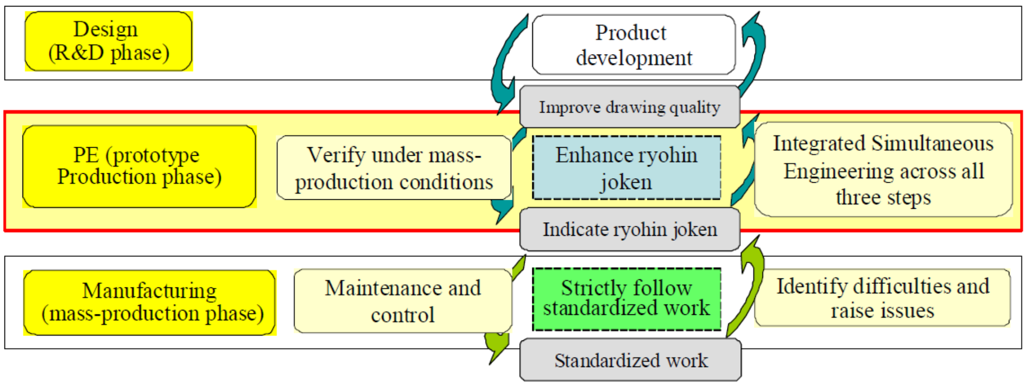



Figure 4.22. The concept of ryohin joke activities (retrieved from Takami, 2014)

## Heijunka

Heijunka means *leveling and bringing to an exact level*. In lean systems, in order to reduce the wastes, it is necessary to have a high level of process control and one of the tools that allow this is Heijunka (Abdullah, 2003). Some authors believe that Heijunka tool is the key element of Toyota's production system (Furmans, 2005). The same author defines heijunka as "*it is used to level the release of production kanbans in order to achieve an even production program over all possible types of products thus reducing or eliminating the bullwhip effect*". On the other hand, Hüttmeir (2009) note that heijunka "*protects the producer from variability in the sequence of jobs to be processed, in which production is scheduled such that the production line produces the same sequence of products throughout a given time period, with that sequence alternating between demanding and less demanding products. The objective of heijunka is to avoid peaks and valleys in the production schedule*". In other words, heijunka is a tool which enables "production Kanbans" in manufacturing in order to provide uniform product quantities for production in time. Customers' orders are often unpredictable and in certain periods there are too many of them and in some too little. Heijunka allows the unification of all customer requirements in a continuous stream where the requirements will enter into a process, and the production process will work continuously without interruptions. Based on the aforementioned, customers will be informed exactly when their ordered products will be produced and delivered to them. According to Reyner & Fleming (2004) heijunka enables the following benefits:

- Converts uneven customer pull into even and predictable manufacturing process,
- It is used in combination with other key Lean principles to stabilize value flow
- It is a core concept that helps bring stability to a manufacturing process.

## Nagara

One of the most important elements, which enables successful implementation of lean concept within the company, is definitively human capital. Nagara roughly means "while doing something else" (Polyglot, 2014). From the standpoint of lean concept, that would essentially mean the possibility of realization several operations by workers in one motion. For example, one worker may work with two or more machines. The aim is to make the Nagara system that aims to educate employees in order to increase the interdisciplinary among them (Maric et al., 2014). The interdisciplinary of workers enables a rotation of workers in the workplace, avoiding a monotony of the workplace, faster identification of problems in a given workplace by more employees, balancing a distribution of work, an increase of the economy of the production process, increasing efficiency and functionality, etc. In addition, with the help of Nagara companies can also reduce the workforce and achieve some savings (but this reduction should not create the overburdening for remaining workers). In the end, we must remember that the lean concept does not mean to satisfy consumer demands only, but all people involved in the lean concept.

## Hoshin Kanri

Hoshin Kanri presents the planning technique developed by Yoji Akao in Japan in 1950, under the auspices of JAST – the Japan Association of Science and Technology, which quickly became one of the basic criteria for the annual evaluation of the companies that apply for the Deming Award (Tennant & Roberts, 2001). The same authors in their other research have defined Hoshin Kanri as an organizational framework when making strategic decisions within the company with the aim:

- *"To provide a focus on corporate direction by setting, annually, a few strategic priorities;*
- *To align the strategic priorities with local plans and programmes;*
- *To integrate the strategic priorities with daily management;*
- *To provide a structured review of the progress of the strategic priorities".* (Tennant & Roberts, 2001).

The Hoshin Kanri tool is essentially a document that is otherwise known as the X matrix (figure 4.23). The aim of this document is to summarize all the goals, the strains of an enterprise, or the determination of long-term business plans that will be addressed by the annual goals that are aimed at improving top-level activities / priorities that directly affect more annual goals or long-term plans, along with application of certain tools with clearly defined human potential, i.e. with precisely defined roles of employees who are responsible for certain improvements.

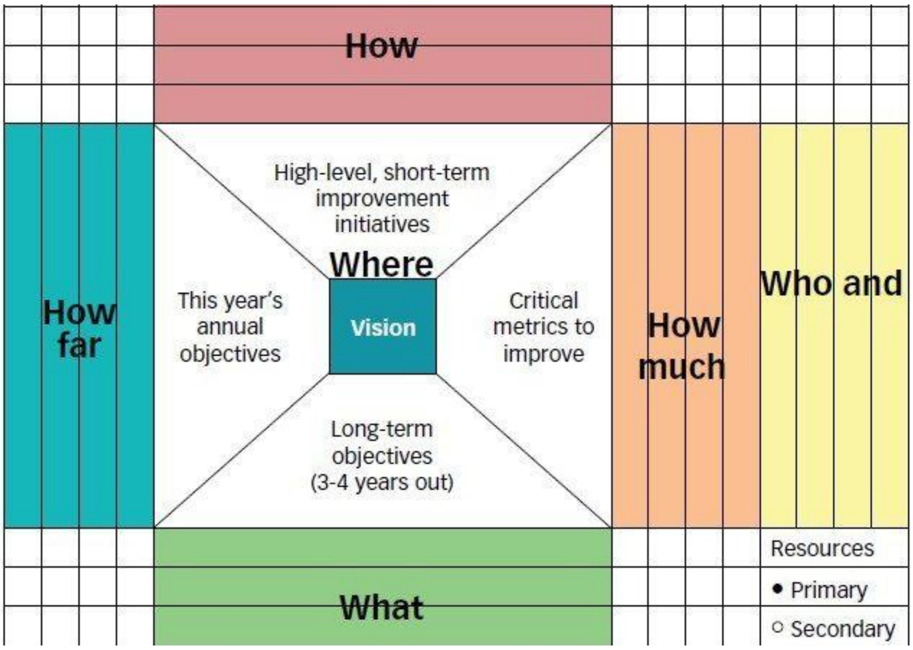



Figure. 4.23. Hoshin Kanri X matrix (source: https://www.leanmanufacturingkaizen.com)

# 5. The development of the model for implementation of the lean concept in clinical laboratories

Based on the literature review it can be concluded that there is no presented one specific model that researchers followed in the implementation of the lean concept. From the research papers, it is only possible to extract the information about lean tools that were implemented, so it can only be concluded which lean tools are being used for implementation inside clinical laboratories. One of the goals of this doctoral dissertation is certainly the development of a model that will allow easy access to implementation of the lean concept within the clinical laboratory processes, where the benefits of implementing the lean concept are well known (for more see Graban 2011), which will provide the improvement of the work of clinical laboratories while creating well-design service system (according to Russell and Taylor, 1999), primarily related to processes that are:

- consistent with the strategic focus on the company,
- understandable,
- able to deal with a sudden increase in demand,
- easy to maintain,
- effectively related activities of the front and back office,
- cost-effective, and
- visible to the customers.

In order to create a well-designed service system, a well-designed clinical laboratory, it is necessary to initially create a model based on the improvement of clinical laboratories by applying a lean concept. Creation of a model in this doctoral dissertation aims to solve problems that would be identified within the clinical laboratory process by using lean methods and tools, in several steps. The first step, which also represents the initial step in modeling, is to examine the attitudes of clinical laboratory stakeholders in terms of their expectations. In this sense, in the initial phase of the research, a questionnaire for the examination of patients' opinions was used to explore the subjective feelings and the expected subjective time and to compare it with real-time measurements by using statistical methods. A survey of employees was also carried out aiming to collect the attitudes of employees. In addition to patients and the staff, directors (doctors) from different departments were also examined in order to collect data and create a more precise image regarding the expectation of the stakeholders. The questionnaire data will be processed by using appropriate statistical methods, which will be presented in more detail in the doctoral dissertation. The significance of this phase is in defining of KPI's based on stakeholder attitudes that represent the input parameter in the next step of the model as well as other parameters defined in the doctoral dissertation. After collecting stakeholder attitudes and defining KPI's, the next step in the model is a determination of the long-term and short-term goals of the organization based on the identified KPIs, as well as a determination of steps that need to be implemented in order to improve defined KPI's. Hoshin Kanri matrix was applied for this purpose, as the second step in the model. After collecting stakeholders' views, defining KPI's and creating the Hoshin Kanri matrix, the third step represents the mapping of the process by using the VSM lean tool. The task of this step is to identify all sites within the process where there are losses or discrepancies within the work of clinical laboratories. Well-defined sites where losses occur within the work of clinical laboratories is the basis for creating the next step in the model. The next step of the model is to define which lean methods and tools need to be applied with the aim of improving the defined "gaps" within the system. For the purposes of defining lean tools that need to be applied to improve the site that creates a problem within the process and which needs to be improved, the gaps-lean methods and tools matrix will be applied with a direct overview of the impact of these improvements on the defined KPI's. The fifth step in the model is the introduction of a new upgraded system with well-defined ways to solve various problems, displaying different solutions in terms of equipment for work, displaying different information solutions, etc. All of these solutions, as well as the places where these solutions are implemented, are shown through the kaizen stars (activities/states that need improvements) within the process. For the purposes of displaying the future state of the system, the VSM lean tool for process mapping will be applied, while for the display of all detailed problems within the process, possible solutions, expected results, applied lean tools, as well as the overall impact on the KPI's, the author will use tables. The last step of the model is the simulation of the system by using the FlexSim HC software package. The aim of these steps within the model is to simulate the current system as well as to simulate the future system in order to assess the quality of the new system.

By integrating all the above-mentioned steps, in this doctoral dissertation the author has developed a model for the implementation of lean methods and tools within the clinical laboratory process:

– ***STEP 1: Identification of the stakeholders and their expectations from clinical laboratories;***

- ***STEP 2: Sorting the expectations of the stakeholders by using the Hoshin Kanri matrix;***
- ***STEP 3: Mapping the process by using VSM lean tools to identify the waste within the process;***
- ***STEP 4: Creating a matrix of goals & gaps / lean tools;***
- ***STEP 5: Mapping the future state of the process by using the VSM lean tool;***
- ***STEP 6: Simulation of the system.***

Implementation of the lean principles and tools in the clinical laboratory, through the developed model, will improve clinical laboratory processes and results, maximize process flow without adding more resources and reduce waiting time for laboratory results. These results can be presented by KPI's (key performance indicators) as:

- reducing lead time,
- reducing process time,
- reducing employee departure from the workplace,
- improvement of patient satisfaction,
- reducing % of all activities,
- the number of patients served,
- inventory turnover,
- reducing % of errors.

# 6. Implementation of the model

## 6.1 INTRODUCTION

In this doctoral dissertation, the author will present the possibility of the implementation of the lean concept in clinical laboratories. For the purposes of the dissertation, the researches are conducted in the Center for laboratory analysis of the Clinical Center of Vojvodina, which includes seven departments:

- Department for reception and distribution of materials
- Department of clinical biochemistry
- Department for emergency laboratory diagnostics
- Department for specialized laboratory diagnostics
- Department of hematology, hemostasis and thrombosis prevention
- Department of nuclear medicine and
- Department for endocrinology (www.kcv.rs)

Department of clinical biochemistry and Department for reception and distribution of materials were included in the research. Based on the available data, these two departments perform the largest number of analysis throughout the year. In 2017, the Department for clinical biochemistry carried out more than 1.000.000 analyses (in 2017 - with and without calibration, controls etc.) coming from different departments at the clinic together with an ambulance, while the Department for reception and distribution of materials served approximately 100.000 - 110.000 patients in 2017. Since there are carried out more than 3,000,000 analyses in all Laboratories at the Institute annually, with an increasing tendency, it is concluded that the departments for clinical biochemistry and the reception and distribution of materials are the most heavily burdened departments.

The research approach was conducted in a few phases:

- In the starting phase of the research, the questionnaire (Appendix A) of the opinion of the patients was used in order to explore the subjective feelings and expected subjective times. The idea was to compare the subjective predicted times with the real measured times, by using statistical methods which are explained in the continuation of the dissertation. Also, the questionnaire was used to explore customer satisfaction (patients) with the services they receive in laboratories. Mentioned questionnaire in this phase was an initial step in the determination whether the subjectively expected time is the same/or is similar to real-time, and on that basis, the simulation results are predicted, which is presented in more details in the conceptual model (see Figure 6.1).

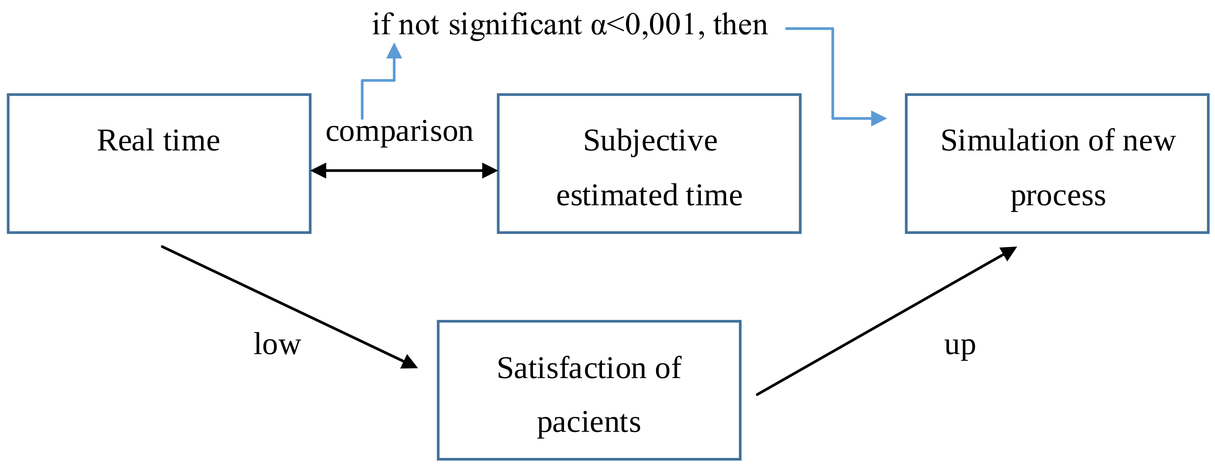



Figure 6.1. A conceptual model of the research

The analysis of the data gathered by questionnaires verified that there is a statistically significant correlation between the real-time and the subjective expected time ($\alpha < 0.001$), and there has been concluded that the measured times are positively correlated with the subjective times (more details about this issues are presented in the statistical analysis of the data). On the basis of that fact, the author used the unit time for further analysis. Also, based on the results of the survey and measures of the times the author explored the level of the satisfaction of the patients, which was used as the premise that the improvement of the process by applying lean tools with the help of simulation could raise the level of satisfaction of users of clinical services.

The second and the third questionnaire (Appendix B and C) in the research phase was used in order to collect the attitudes of the employees in the departments of clinical biochemistry and the reception and distribution of materials, and also, we examined the attitudes of managers of different departments. The aim of this questionnaire was to explore the overall “picture” of the process, finding "critical" places within the process that needs to be improved, as well as to observe the attitudes of employees about their workplace as well as the satisfaction of the employees in working with patients.

- In addition to the questionnaire for collecting patient attitudes and employee attitudes, the next step in the research part was the detailed recording of the current departmental work process, which was presented with the help of a lean tool for process mapping, the VSM (Value Stream Mapping). A detailed overview of mapped processes is presented below with a detailed description and characteristics of all process elements.

- After collecting patient, employee and doctors attitudes by using questionnaires, as well as system analysis and displaying the current state of the system with the help of the mapping tool, the application of the VSM tool, the author used the FlexSimHC software package (student license) for displaying advancement proposals (simulation). The prediction of the new system was done by using the tools of the lean concept which could regulate the layout and processes in the system, which will be displayed in the simulation.
    - ***Limitations:*** Since I, as a Ph.D. candidate, do not have permission from the laboratories and a general manager of the clinic to change the equipment within the laboratories, after the interview, survey and measuring flows of patients, timing, etc. I used the simulation for the assessment of the quality of the new system.
- The last phase of the research is an overview of the applied lean tools, the achieved improvements and benefits obtained by using the lean concept, the examination of the factors that influence the positive change as well as the consideration of the factors that can hinder the delivery of high quality results achieved by the implementation of lean principles and tools in clinical laboratories.

## 6.2 STEP 1 - (Identification of the stakeholders - statistical analysis of the data)

The first step in the model for the implementation of the lean concept in clinical laboratories is definitely the definition of stakeholder as well as their expectations from laboratories. Research conducted at the Clinical Center of Vojvodina defined the following stakeholders: patients – beneficiaries of services, doctors – heads of departments, employees and government. As already stated, in the initial phase of the research, a questionnaire for the examination of patients' opinions was used to explore the subjective feelings and expected subjective time and to compare it with real-time measurements using statistical methods. A survey of employees was also carried out aiming to collect attitudes of employees at the Clinical biochemistry departments and the department for reception and distribution of materials. In addition of investigating the attitudes of patients and employees, a questionnaire was also conducted with the aim of gathering the views of the heads of various departments, where the functionality of those departments is directly dependent on the clinical laboratory. For statistical data processing, the author used descriptive statistics, Mann-Whitney U for comparison of two groups, Kruskal Wallis test for comparison of several groups, and correlation and hierarchical regression analysis. Below we presented the data obtained by the statistical analysis of patients and employees.

### 6.2.1 Description of the sample

Table 6.1 shows the descriptive statistics of the sample.

Table 6.1. Demographic characteristics of the respondents (Source: Author)

| | | Patients | | Personnel | |
|---|---|---|---|---|---|
| | | Sex | Age | Sex | Age |
| N | Valid | 312 | 312 | 20 | 20 |
| | Missing | 0 | 0 | 0 | 0 |
| Mean | | 1,2115 | 52,6218 | 1,2500 | 36,90 |
| Std. Deviation | | ,40906 | 16,60602 | ,44426 | 10,79912 |
| Minimum | | 1,00 | 16,00 | 1,00 | 20 |
| Maximum | | 2,00 | 86,00 | 2,00 | 60 |

According to table 6.2, there were 312 respondents and 20 staff person from the laboratory who filled questionnaires. There were two questions that obtained two demographic characteristics, sex, and age.

Table 6.2. Demographic characteristics of the respondents -Sex (Source: Author)

| **Sex** | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Female | 246 | 78,8 | 78,8 | 78,8 |
| | Male | 66 | 21,2 | 21,2 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in Table 6.2, most of the respondents in the sample of patients were women, 78.8%, while male respondents made 21.2% of the sample and according to the data in Table 6.3, most of the personnel in the sample were women, 75%, while men made 25% of the sample.

Table 6.3. Demographic characteristics of the personnel -Sex (Source: Author)

| **Sex** | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Female | 15 | 75,0 | 75,0 | 75,0 |
| | Male | 5 | 25,0 | 25,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

Regarding the age of respondents, from the data in Table 6.4, it is obvious that all 6 groups of age range are represented in the sample, where people with more than 55 years make almost the half of the sample (49%). The largest part of the sample consists of people in the group with more than 66 years of life (25.3%), than in the group from 56 up to 65 years (23.7%), and from 46 up to 55 years (17.6%). The smallest share of the sample makes respondents in the group from 16 up to 25 years (only 7% of the sample).

Table 6.4. Demographic characteristics of the respondents -Age (Source: Author)

| **Age** | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | 16-25 | 22 | 7,1 | 7,1 | 7,1 |
| | 26-35 | 42 | 13,5 | 13,5 | 20,5 |
| | 36-45 | 40 | 12,8 | 12,8 | 33,3 |
| | 46-55 | 55 | 17,6 | 17,6 | 51,0 |
| | 56-65 | 74 | 23,7 | 23,7 | 74,7 |
| | 66+ | 79 | 25,3 | 25,3 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Regarding the age of personnel, from the data in Table 6.5, it is obvious that 4 groups of age range are represented in the sample, where people with less than 40 years make 75% of the sample. The largest part of the sample consists of people in the group from 31 to 40 years of life (55%) than in the group from 20 to 30 years (20%). In the groups from 41 to 50 years there were 2 respondents, and in the group, from 51 to 60 years there were 3 respondents.

Table 6.5. Demographic characteristics of the personnel -Age (Source: Author)

| **Age** | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | 20-30 | 4 | 20,0 | 20,0 | 20,0 |
| | 31-40 | 11 | 55,0 | 55,0 | 75,0 |
| | 41-50 | 2 | 10,0 | 10,0 | 85,0 |
| | 51-60 | 3 | 15,0 | 15,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

### 6.2.2 Descriptive statistics of the research variables – patients

According to the data in table 6.6, patients mostly felt well (good) before the blood draw (47.8% of respondents), while 20.2% of them expressed that they felt very good. Only 3 patients pointed that they felt very bad before they had a blood draw. Around 12% of respondents stated that they felt bad or unpleasant before the process, while 9.3% of them were not sure about their feelings.

Table 6.6. Feeling of respondents before blood test – A3 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very bad | 3 | 1,0 | 1,0 | 1,0 |
| | Bad | 9 | 2,9 | 2,9 | 3,8 |
| | Unpleasant | 29 | 9,3 | 9,3 | 13,1 |
| | Not sure | 29 | 9,3 | 9,3 | 22,4 |
| | Pleasant | 30 | 9,6 | 9,6 | 32,1 |
| | Good | 149 | 47,8 | 47,8 | 79,8 |
| | Very good | 63 | 20,2 | 20,2 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in table 6.7, most of the patients stated that they have waited a long time until they entered the laboratory for a blood draw. Almost 50% of them expressed that they had to wait a long or very long time to enter (47.5%). 28.8% of respondents stated that they did not find the waiting time long or short, and only 23.4% of them rated the waiting time and short or very short.

Table 6.7. How long you wait for a blood draw – respondents' impression – A4.1 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very long time | 46 | 14,7 | 14,7 | 14,7 |
| | Quite a long time | 46 | 14,7 | 14,7 | 29,5 |
| | Long time | 57 | 18,3 | 18,3 | 47,8 |
| | Not a long time or a short time | 90 | 28,8 | 28,8 | 76,6 |
| | Short time | 43 | 13,8 | 13,8 | 90,4 |
| | Quite a short time | 7 | 2,2 | 2,2 | 92,6 |
| | Very short time | 23 | 7,4 | 7,4 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Generally, the respondents stated that they see the waiting time as acceptable, 56.7%. The other part of the sample, 43.3% of them rated the waiting time as unacceptable (Table 6.8).

Table 6.8. In your opinion, waiting for blood extraction is – respondents' impression – A5

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Unacceptable | 135 | 43,3 | 43,3 | 43,3 |
| | Acceptable | 177 | 56,7 | 56,7 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Source: Author

Regarding the level of provided information from laboratory personnel, all respondents, 100% of them, pointed out that the laboratory technicians kindly provided all the information requested by patients (Table 6.9).

Table 6.9. Information services for respondents – A6 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Laboratory technician kindly provided all the information requested | 312 | 100,0 | 100,0 | 100,0 |

Regarding the level of the pain that respondents felt during a blood draw, only 2% of them stated that they felt pain. 19.6% of them expressed their feeling as a tolerable level of pain and 51.6% as painless. 27% of the respondents stated that the blood draw was totally painless (Table 6.10).

Table 6.10. The level of the pain during a blood draw – A7 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very painful | 3 | 1,0 | 1,0 | 1,0 |
| | Painful | 3 | 1,0 | 1,0 | 1,9 |
| | Tolerably | 61 | 19,6 | 19,6 | 21,5 |
| | Painless | 161 | 51,6 | 51,6 | 73,1 |
| | Very painless | 84 | 26,9 | 26,9 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Regarding the time duration of the blood draw, expressed as an opinion of the respondents, the most of them (45.5%) stated that it lasts short. 35% expressed that it lasts a very short time, while only 1% of the respondents thought that the process of the blood draw lasted too long (Table 6.11).

Table 6.11. How long was the process of a blood draw – A8.1 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Long time | 3 | 1,0 | 1,0 | 1,0 |
| | Moderate | 58 | 18,6 | 18,6 | 19,6 |
| | Short time | 142 | 45,5 | 45,5 | 65,1 |
| | Very short | 109 | 34,9 | 34,9 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Two questions were related to the behavior of the laboratory technician before and after a blood draw. According to the data in table 6.12, 91% of the respondents stated that the laboratory technician kindly talked with the patients during all the process. This is very important since the blood draw process can last more time than expected – because of the crowd, and can be painful for some people.

Table 6.12. The behavior of laboratory technician during a blood draw – A9 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | He did not talk with me | 6 | 1,9 | 1,9 | 1,9 |
| | I talked very little with me | 23 | 7,4 | 7,4 | 9,3 |
| | Kindly talked to me all the time | 283 | 90,7 | 90,7 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in table 6.13, 63.5% of the respondents stated that the laboratory technician kindly asked them about how they felt after the blood draw and let them up. 15.4% of the respondents stated that the technician asked them how they felt and kept them in the chair, while 21.2% stated that the technician did not ask them anything.

Table 6.13. The behavior of laboratory technician after a blood draw – A10 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | The technician asked me how I felt and let me get up | 198 | 63,5 | 63,5 | 63,5 |
| | The technician asked me how I felt and kept me in the chair | 48 | 15,4 | 15,4 | 78,8 |
| | The technician did not ask me anything | 66 | 21,2 | 21,2 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in table 6.14, 73.7% of the respondents pointed that the laboratory personnel was very kind after a blood draw process.

Table 6.14. After the blood draw laboratory personnel was – A11 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Kind | 230 | 73,7 | 73,7 | 73,7 |
| | There were no comments | 82 | 26,3 | 26,3 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

In general, the respondents found that employees in the laboratory for a blood draw were professional and very professional (85.9%). Only 3.5% of the respondents stated that the personnel was unprofessional (Table 6.14).

Table 6.14. Evaluation of work of employees in the laboratory by users/patients – A12

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very unprofessional | 5 | 1,6 | 1,6 | 1,6 |
| | Unprofessional | 6 | 1,9 | 1,9 | 3,5 |
| | Acceptable | 33 | 10,6 | 10,6 | 14,1 |
| | Professional | 137 | 43,9 | 43,9 | 58,0 |
| | Very professional | 131 | 42,0 | 42,0 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Source: Author

According to the data in table 6.15, almost 40% of the respondents were satisfied with the work of the staff at the desk. 21.2% of them could not decide whether they felt satisfied or unsatisfied, and 17% of them were very satisfied. 17,9% of the sample stated that they felt unsatisfied to some extent.

Table 6.15. Evaluation of work of employees at the desk – A13.1 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very unsatisfied | 14 | 4,5 | 4,5 | 4,5 |
| | Unsatisfied | 12 | 3,8 | 3,8 | 8,3 |
| | A little unsatisfied | 30 | 9,6 | 9,6 | 17,9 |
| | Not satisfied not unsatisfied | 66 | 21,2 | 21,2 | 39,1 |
| | A little satisfied | 13 | 4,2 | 4,2 | 44,3 |
| | Satisfied | 124 | 39,7 | 39,7 | 83,0 |
| | Very satisfied | 53 | 17,0 | 17,0 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

One very important question was related to the level of the crowd in the laboratory. The respondents found that the crowds in the waiting room were very excessive (88.5%). Only 11.5% of the respondents stated that the crowd was acceptable (Table 6.16).

Table 6.16. Crowds in the waiting room are – A14 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Excessive | 276 | 88,5 | 88,5 | 88,5 |
| | Acceptable | 36 | 11,5 | 11,5 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Based on the previous question, the author explored the patients'' feelings about the crowd in the waiting room. The respondents found that the crowds in the waiting room caused them to be little nervous (25%), nervous and very nervous (25%). The other half of the sample stated that the crowd in the waiting room did not cause them nervousness (Table 6.17).

Table 6.17. Feelings of the patients because of the crowds in the waiting room are – A15

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very nervous | 34 | 10,9 | 10,9 | 10,9 |
| | Nervous | 44 | 14,1 | 14,1 | 25,0 |
| | Little nervous | 78 | 25,0 | 25,0 | 50,0 |
| | Nothing | 34 | 10,9 | 10,9 | 60,9 |
| | Little relaxed | 111 | 35,6 | 35,6 | 96,5 |
| | Relaxed | 9 | 2,9 | 2,9 | 99,4 |
| | Very relaxed | 2 | ,6 | ,6 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Source: Author

According to the data in Table 6.18, most of the respondents (62.8%) stated that the necessary information was available and visible at the front desk. About 30% of the respondents did not pay attention to this issue, while 7.7% of them stated that the information was not visible.

Table 6.18. Availability of the necessary information – A16 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Not available - visible | 24 | 7,7 | 7,7 | 7,7 |
| | I did not pay attention | 92 | 29,5 | 29,5 | 37,2 |
| | Available – visible | 196 | 62,8 | 62,8 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in Table 6.19, the most of the respondents (51.8%) stated that the calling of patients for a blood draw was loud enough; they heard their names when laboratory nurse called them. About 34% of the respondents rated this as loud, while 4.5% of them stated that the calling was very loud. In contrast, 10,9% of the respondents stated that the calling for a blood draw was silent and that they had a problem to hear their names.

Table 6.19. Calling for patients is – A17 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very silent | 4 | 1,3 | 1,3 | 1,3 |
| | Silent | 30 | 9,6 | 9,6 | 10,9 |
| | Loud enough | 159 | 51,0 | 51,0 | 61,9 |
| | Loud | 105 | 33,7 | 33,7 | 95,5 |
| | Very loud | 14 | 4,5 | 4,5 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

One very important question was the opinion of the respondents about the waiting time for the results of the blood draw. According to the data in Table 6.20, most of the respondents (63.8%) stated that the waiting time for the results of the blood tests more than 24h is too long or very long. About 32.7% of the respondents rated this as moderately long time, while only 2 respondents stated that the waiting time is short.

Table 6.20. Waiting for blood test results over 24h is – A18 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very long time | 83 | 26,6 | 26,6 | 26,6 |
| | Long time | 116 | 37,2 | 37,2 | 63,8 |
| | Moderately long | 102 | 32,7 | 32,7 | 96,5 |
| | Average time | 9 | 2,9 | 2,9 | 99,4 |
| | Short | 1 | ,3 | ,3 | 99,7 |
| | Moderately short | 1 | ,3 | ,3 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in Table 6.21, most of the respondents (98.7%) stated that the laboratory space is well marked, which is important for the organization of the whole process.

Table 6.21. The doors of the spaces for a blood draw are – A19 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Poorly marked | 4 | 1,3 | 1,3 | 1,3 |
| | Well marked | 308 | 98,7 | 98,7 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Most of the respondents (70.8%) stated that the hygiene in the laboratory space is acceptable, while about 30% of them did not pay attention to this. Only one respondent stated that the hygiene of the laboratory is not acceptable (Table 6.22).

Table 6.22. The level of the hygiene in rooms for a blood draw – A20 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Unacceptable | 1 | ,3 | ,3 | ,3 |
| | Did not paid attention | 90 | 28,8 | 28,8 | 29,2 |
| | Acceptable | 221 | 70,8 | 70,8 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

Most of the respondents (71.5%) stated that the safety of the equipment in the laboratory is acceptable, while about 28% of them did not pay attention to this. Only 2 respondents said that the safety of the equipment in the laboratory is not acceptable (Table 6.23).

Table 6.23. The level of the safety of the equipment in the laboratory – A21 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Unacceptable | 2 | ,6 | ,6 | ,6 |
| | Did not paid attention | 87 | 27,9 | 27,9 | 28,5 |
| | Acceptable | 223 | 71,5 | 71,5 | 100,0 |
| | Total | 312 | 100,0 | 100,0 | |

According to the data in Table 6.24, the mean value of the duration of the blood draw (rated by respondents) is 73,13 seconds (SD=45,79) while the measured times (objectively) is 60.56 seconds (SD=33,41).

Table 6.24. Means and SD of several questions – A8 - A8.0 - A22 (Source: Author)

| | The process of blood extraction (seconds) - subjective times (questioning the respondent) – A8 | The process of blood extraction (seconds) - real-time measured – A8.0 | The level of satisfaction with the work of the laboratory – A22 |
|---|---|---|---|
| Mean | 73,1357 | 60,5643 | 5,6058 |
| Std. Deviation | 45,79941 | 33,41417 | 1,21950 |
| Minimum | 5,00 | 12,00 | 1 |
| Maximum | 240,00 | 173,00 | 7 |

Also, the respondents rated the overall satisfaction with the work of the laboratory. The mean value of the satisfaction with the laboratory (rated by respondents) is 5,60 (SD=1,22) in the range from 1 (very unsatisfied) to 7 (very satisfied).

### 6.2.3 Descriptive statistics of the research variables – personnel

The following tables present the descriptive statistics for the second part of the sample, where the laboratory staff was questioned. According to the table 6.25, the most of the laboratory staff work in a position of laboratory technician (50%), at a counter desk (25%), and at the position of reception and distribution (20%). Among 20 persons on staff, we also questioned the chief of the laboratory.

Table 6.25. Working position of the respondents – personnel – B2.1 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Laboratory technician | 10 | 50,0 | 50,0 | 50,0 |
| | Reception and distribution | 4 | 20,0 | 20,0 | 70,0 |
| | Counter desk | 5 | 25,0 | 25,0 | 95,0 |
| | Chief of laboratory | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to table 6.26, most of the respondents felt well or very well before they come to the job (70% of the respondents). Only two of them stated that they felt unpleasant, while 3 of them did not pay attention to their feelings before they entered their job.

Table 6.25 Feelings of personnel before they come to the job – B3 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Unpleasant | 2 | 10,0 | 10,0 | 10,0 |
| | Not sure | 3 | 15,0 | 15,0 | 25,0 |
| | Pleasant | 1 | 5,0 | 5,0 | 30,0 |
| | Well | 8 | 40,0 | 40,0 | 70,0 |
| | Very well | 6 | 30,0 | 30,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

The very important question was related to the lack of the material for work during a working shift. The most of the respondents stated that this happens almost never or rarely (85%) while 3 respondents stated that they experience the lack of working material often and almost always (Table 6.26).

Table 6.26. The lack of material for work during working hours – B4 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Never happens | 1 | 5,0 | 5,0 | 5,0 |
| | Almost never | 5 | 25,0 | 25,0 | 30,0 |
| | Rarely | 11 | 55,0 | 55,0 | 85,0 |
| | Often | 1 | 5,0 | 5,0 | 90,0 |
| | Almost always | 1 | 5,0 | 5,0 | 95,0 |
| | Always | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to the data in Table 6.27, most of the respondents need to leave their working position in order to perform other obligations (80% of the respondents). The most of them have to do that from 5 to 20 times a day (50% of the respondents).

Table 6.27. How often do personnel have to leave their working position to perform other obligations – B5 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | ,00 | 4 | 20,0 | 20,0 | 20,0 |
| | 3,00 | 1 | 5,0 | 5,0 | 25,0 |
| | 5,00 | 4 | 20,0 | 20,0 | 45,0 |
| | 10,00 | 2 | 10,0 | 10,0 | 55,0 |
| | 20,00 | 4 | 20,0 | 20,0 | 75,0 |
| | 30,00 | 1 | 5,0 | 5,0 | 80,0 |
| | 40,00 | 1 | 5,0 | 5,0 | 85,0 |
| | 50,00 | 3 | 15,0 | 15,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

Related to the previous question, the author explored whether the employees need to work on other jobs or perform jobs instead of their colleagues. 50% of the respondents stated that they never or almost never need to do the above mentioned. 35% of the staff stated that they need to work on other jobs or perform jobs instead of their colleagues for ¼ of their working time, while 15% of the respondents stated that they need to do that more than ½ of their working time or even always (Table 6.28).

Table 6.28. Does it happen that you have to work in other jobs or jobs instead of your colleagues? – B6 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Never | 4 | 20,0 | 20,0 | 20,0 |
| | Almost never | 6 | 30,0 | 30,0 | 50,0 |
| | 1/4 of working time | 7 | 35,0 | 35,0 | 85,0 |
| | 1/2 of working time | 1 | 5,0 | 5,0 | 90,0 |
| | Almost always | 1 | 5,0 | 5,0 | 95,0 |
| | Always | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to the data in Table 6.29, most of the respondents (85% of them) make mistakes sometimes during the work process.

Table 6.29. If there are mistakes during working hours, do some actions need to be repeated? – B7 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Sometimes | 17 | 85,0 | 85,0 | 85,0 |
| | Almost never | 3 | 15,0 | 15,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

Regarding the level of the equipment of the working space, 75% of employees stated that they see their workspace as correctly equipped or well equipped. 25% of the staff stated that their workspace is badly equipped, which is very important if we bear in mind that the laboratory is in question (Table 6.30).

Table 6.30. The level of the equipment of the workplace – B8 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very bad equipped | 1 | 5,0 | 5,0 | 5,0 |
| | Bad equipped | 4 | 20,0 | 20,0 | 25,0 |
| | Correctly equipped | 12 | 60,0 | 60,0 | 85,0 |
| | Well equipped | 2 | 10,0 | 10,0 | 95,0 |
| | Very well equipped | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

One very important question was related to the crowds in the laboratory. All the respondents found that the crowds in the waiting room were very excessive (100%), which is similar with the opinions of the patients who rated crowds also too excessive in 88.5% of cases (Table. 6.31).

Table 6.31. The crowds in the waiting room are – B9 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Excessive | 20 | 100,0 | 100,0 | 100,0 |

According to the data in table 6.32, most of the staff think that the patients wait too long for a blood draw (90%). This is a similar response as in the case of the sample of patients, who pointed that they have waited a long time until they entered into a laboratory for a blood draw.

Table 6.32. Waiting for a blood draw is – B10 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very long time | 9 | 45,0 | 45,0 | 45,0 |
| | Pretty long | 7 | 35,0 | 35,0 | 80,0 |
| | Long | 2 | 10,0 | 10,0 | 90,0 |
| | Not long or short | 2 | 10,0 | 10,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

All the respondents in the sample of the staff stated that they feel nervous because of the crowds in the waiting room. Some of them rated this level as little nervous (20%), and some as very nervous (35%) (Table 6.33).

Table 6.33. Feelings of the patients because of the crowds in the waiting room are – B11

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very nervous | 7 | 35,0 | 35,0 | 35,0 |
| | Nervous | 9 | 45,0 | 45,0 | 80,0 |
| | A little nervous | 4 | 20,0 | 20,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

Personnel of the laboratory was also questioned about the behavior of the patients towards them. 65% of the laboratory staff thinks that this behavior is correct, 15% stated that the patients are polite or very polite, while 15% stated that the patients are impolite to them (Table 6.34).

Table 6.34. The behavior of the patients towards health workers – B12 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very impolite | 1 | 5,0 | 5,0 | 5,0 |
| | Pretty impolite | 3 | 15,0 | 15,0 | 20,0 |
| | Correct | 13 | 65,0 | 65,0 | 85,0 |
| | Polite | 2 | 10,0 | 10,0 | 95,0 |
| | Very polite | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to the data in Table 6.35, the most of the respondents in the category of laboratory personnel (65% of them) stated that they feel stressful (very stressful, little stressful or stressful) while they work with patients. 20% of them stated that they do not feel stress or any other condition, while 15% of them stated that they feel relaxed.

Table 6.35. The level of stress while working with patients – B13 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very stressful | 2 | 10,0 | 10,0 | 10,0 |
| | Stressful | 5 | 25,0 | 25,0 | 35,0 |
| | A little stressful | 6 | 30,0 | 30,0 | 65,0 |
| | Neither stressful nor relaxed | 4 | 20,0 | 20,0 | 85,0 |
| | A little relaxed | 1 | 5,0 | 5,0 | 90,0 |
| | Relaxed | 1 | 5,0 | 5,0 | 95,0 |
| | Very relaxed | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

One very important question related to the staff is the number of services they provide each day. The term service has different mean in this context, so we included here a number of patients, and blood samples. According to the data in table 6.36, we can see that 7 employees (35%) provide between 50 and 60 services per day, 1 employee provides 70 services per day, 1 employee provides 80 services per day, 3 employees provide 100 services per day, 1 employee provides 120 services per day, 2 employees provide 300 services per day, while 5 of them provide more than 350 services per day (Table 6.36).

Table 6.36. How many services do you provide per day? – B15 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | 50,00 | 4 | 20,0 | 20,0 | 20,0 |
| | 55,00 | 1 | 5,0 | 5,0 | 25,0 |
| | 60,00 | 2 | 10,0 | 10,0 | 35,0 |
| | 70,00 | 1 | 5,0 | 5,0 | 40,0 |

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | 80,00 | 1 | 5,0 | 5,0 | 45,0 |
| | 100,00 | 3 | 15,0 | 15,0 | 60,0 |
| | 120,00 | 1 | 5,0 | 5,0 | 65,0 |
| | 300,00 | 2 | 10,0 | 10,0 | 75,0 |
| | 350,00 | 3 | 15,0 | 15,0 | 90,0 |
| | 500,00 | 1 | 5,0 | 5,0 | 95,0 |
| | 600,00 | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

The most of the respondents in the sample of laboratory staff (40%) feel very stressful while working with their colleagues, 30% feel stress, while 30% feel little stress (Table 6.37).

Table 6.37. Work with your colleagues is? – B16 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Very stressful | 8 | 40,0 | 40,0 | 40,0 |
| | Stressful | 6 | 30,0 | 30,0 | 70,0 |
| | A little stressful | 6 | 30,0 | 30,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

The level of the stress that staff feels while working with their colleagues cause a certain level of nervous. 15% of the staff feels little nervous, while 65% of them do not feel nervous (Table 6.38).

Table 6.38. Feelings of personnel during work with colleagues – B17 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | A little nervous | 3 | 15,0 | 15,0 | 15,0 |
| | Neither nervous nor am I relaxed | 4 | 20,0 | 20,0 | 35,0 |
| | A little relaxed | 2 | 10,0 | 10,0 | 45,0 |
| | Relaxed | 8 | 40,0 | 40,0 | 85,0 |
| | Very relaxed | 3 | 15,0 | 15,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to the data in Table 6.39, most of the personnel (6%) do not feel tiredness, while 20% do not feel tired or relaxed. Only 3 employees felt tired after working day.

Table 6.39. Feelings of personnel after working day – B18 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Tired | 3 | 15,0 | 15,0 | 15,0 |
| | Neither tired nor rested | 4 | 20,0 | 20,0 | 35,0 |
| | Rested | 1 | 5,0 | 5,0 | 40,0 |
| | Pretty rested | 8 | 40,0 | 40,0 | 80,0 |
| | Very rested | 4 | 20,0 | 20,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

According to the data in Table 6.40, 30% of the respondents think that their workspace should be improved, 45% of them think that their workspace is already well organized, and 25% of them stated that their workspace should not be changed or improved.

Table 6.40. Your workplace should be – B19 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Improved | 6 | 30,0 | 30,0 | 30,0 |
| | Workplace is already well organized | 9 | 45,0 | 45,0 | 75,0 |
| | Should not be improved | 4 | 20,0 | 20,0 | 95,0 |
| | Should not be improved at all | 1 | 5,0 | 5,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

The most of the respondents (95%) think that the laboratory is well organized and they would not change anything (Table 6.41).

Table 6.41. Opinions of the personnel about the laboratory – B20 (Source: Author)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Should be improved a lot | 1 | 5,0 | 5,0 | 5,0 |
| | Laboratory is well organized | 19 | 95,0 | 95,0 | 100,0 |
| | Total | 20 | 100,0 | 100,0 | |

### 6.2.4 The analysis of the factors important for the work of the laboratory for a blood draw

In the continuation of the research, special attention will be paid to the several variables which predominantly present the effectiveness of the laboratory for a blood draw.

#### 6.2.4.1 Differences between man and women regarding the work of the laboratory for a blood draw

In order to explore the differences between men and women about several questions regarding the work and processes in the laboratory for a blood draw, the author used the Mann-Whitney U test for comparing two groups (Table 6.42).

Table 6.42. Mann-Whitney U Test (Source: Author)

| Sex | | N | Mean Rank | Mann-Whitney U | Wilcoxon W | Z | Asymp. Sig. |
|---|---|---|---|---|---|---|---|
| Waiting for the blood draw (minutes) | Female | 246 | 159,14 | 7469,000 | 9680,000 | -1,002 | 0,316 |
| | Male | 66 | 146,67 | | | | |
| | Total | 312 | | | | | |
| Duration of the blood draw – measured times | Female | 110 | 72,85 | 1391,000 | 1856,000 | -1,316 | 0,188 |
| | Male | 30 | 61,87 | | | | |
| | Total | 140 | | | | | |
| Evaluation of the work of the laboratory staff | Female | 246 | 154,71 | 7676,500 | 38057,500 | -0,740 | 0,459 |
| | Male | 66 | 163,19 | | | | |
| | Total | 312 | | | | | |
| Waiting to hand over a | Female | 246 | 161,98 | 6769,000 | 8980,000 | -2,371 | 0,018 |

| Sex | | N | Mean Rank | Mann-Whitney U | Wilcoxon W | Z | Asymp. Sig. |
|---|---|---|---|---|---|---|---|
| health card at the counter | Male | 66 | 136,06 | | | | |
| | Total | 312 | | | | | |
| Evaluation of the work of the staff at the counter | Female | 246 | 154,87 | 7718,000 | 38099,000 | -0,640 | 0,522 |
| | Male | 66 | 162,56 | | | | |
| | Total | 312 | | | | | |
| Feelings of the patients because of the crowds in the waiting room | Female | 246 | 151,03 | 6773,000 | 37154,000 | -2,139 | 0,032 |
| | Male | 66 | 176,88 | | | | |
| | Total | 312 | | | | | |
| Waiting for the results of the blood test more than 24h | Female | 246 | 156,56 | 8103,500 | 10314,500 | -0,024 | 0,981 |
| | Male | 66 | 156,28 | | | | |
| | Total | 312 | | | | | |
| Level of the hygiene in the room for blood draw | Female | 246 | 151,99 | 7008,000 | 37389,000 | -2,157 | 0,031 |
| | Male | 66 | 173,32 | | | | |
| | Total | 312 | | | | | |
| Level of the safety of the instruments in the rooms for blood draw | Female | 246 | 157,44 | 7887,500 | 10098,500 | -0,451 | 0,652 |
| | Male | 66 | 153,01 | | | | |
| | Total | 312 | | | | | |
| Level of the satisfaction of the patients with the work of the laboratory | Female | 246 | 155,98 | 7990,000 | 38371,000 | -0,207 | 0,836 |
| | Male | 66 | 158,44 | | | | |
| | Total | 312 | | | | | |

According to the data in table 6.42, it can be concluded that:

– Women waited to hand over a health card at the counter statistically significantly longer than men (U = 6769; p = 0,018).
– Women felt worse because of the crowds in the waiting room than men (U = 6773; p = 0,032).
– Women saw the level of the hygiene in the room for a blood draw lower than men (U = 7008; p = 0,031).

For the rest of the variables, we have not found statistically significant differences between men and women.

#### 6.2.4.2 Difference between age groups regarding the work of the laboratory for a blood draw

In order to explore the differences between men and women about several questions regarding the work and processes in the laboratory for a blood draw, the author used the Kruskal Wallis test for comparing 6 age groups. The results are presented in the table below (Table 6.43).

Table 6.43. Kruskal Wallis Test (Source: Author)

| Age | | N | Mean Rank | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| Waiting for the blood draw (minutes) | 15-25 | 22 | 132.75 | 13.18794 | 5 | 0.022 |
| | 26-35 | 42 | 115.48 | | | |
| | 36-45 | 40 | 162.43 | | | |
| | 46-55 | 55 | 171.81 | | | |
| | 56-65 | 74 | 164.95 | | | |
| | 66+ | 79 | 163.35 | | | |
| | Total | 312 | | | | |
| Duration of the blood draw – measured times | 15-25 | 15 | 65.10 | 1.785436 | 5 | 0.878 |
| | 26-35 | 13 | 63.04 | | | |
| | 36-45 | 18 | 66.69 | | | |
| | 46-55 | 26 | 76.42 | | | |
| | 56-65 | 33 | 69.14 | | | |
| | 66+ | 35 | 74.43 | | | |
| | Total | 140 | | | | |
| Evaluation of the work of the laboratory staff | 15-25 | 22 | 175.02 | 2.925898 | 5 | 0.711 |
| | 26-35 | 42 | 163.23 | | | |
| | 36-45 | 40 | 161.45 | | | |
| | 46-55 | 55 | 160.48 | | | |
| | 56-65 | 74 | 151.47 | | | |
| | 66+ | 79 | 147.20 | | | |
| | Total | 312 | | | | |
| Evaluation of the work of the staff at the counter | 15-25 | 22 | 139.41 | 5.102 | 5 | 0.404 |
| | 26-35 | 42 | 174.51 | | | |
| | 36-45 | 40 | 152.30 | | | |
| | 46-55 | 55 | 164.89 | | | |
| | 56-65 | 74 | 160.72 | | | |
| | 66+ | 79 | 144.01 | | | |
| | Total | 312 | | | | |
| Waiting to hand over a health card at the counter | 15-25 | 22 | 169.89 | 2.992827 | 5 | 0.701 |
| | 26-35 | 42 | 167.51 | | | |
| | 36-45 | 40 | 142.85 | | | |
| | 46-55 | 55 | 150.46 | | | |
| | 56-65 | 74 | 157.77 | | | |
| | 66+ | 79 | 156.84 | | | |
| | Total | 312 | | | | |
| Feelings of the patients because of the crowds in the waiting room | 15-25 | 22 | 120.91 | 9.352863 | 5 | 0.096 |
| | 26-35 | 42 | 149.26 | | | |
| | 36-45 | 40 | 133.85 | | | |
| | 46-55 | 55 | 161.99 | | | |
| | 56-65 | 74 | 166.53 | | | |
| | 66+ | 79 | 168.51 | | | |
| | Total | 312 | | | | |
| Waiting for the results of the blood test more than 24h | 15-25 | 22 | 159.82 | 9.652294 | 5 | 0.086 |
| | 26-35 | 42 | 159.30 | | | |
| | 36-45 | 40 | 164.34 | | | |
| | 46-55 | 55 | 153.15 | | | |
| | 56-65 | 74 | 132.95 | | | |
| | 66+ | 79 | 174.51 | | | |
| | Total | 312 | | | | |
| Level of the hygiene in the room for a blood draw | 15-25 | 22 | 152.18 | 4.446434 | 5 | 0.487 |
| | 26-35 | 42 | 149.83 | | | |
| | 36-45 | 40 | 149.99 | | | |
| | 46-55 | 55 | 147.95 | | | |
| | 56-65 | 74 | 156.91 | | | |
| | 66+ | 79 | 170.11 | | | |
| | Total | 312 | | | | |
| Level of the safety of the instruments in the rooms for a blood draw | 15-25 | 22 | 144.32 | 4.561957 | 5 | 0.472 |
| | 26-35 | 42 | 160.04 | | | |
| | 36-45 | 40 | 146.43 | | | |
| | 46-55 | 55 | 171.60 | | | |

| Age | | N | Mean Rank | Chi-Square | df | Asymp. Sig. |
|---|---|---|---|---|---|---|
| | 56-65 | 74 | 158.16 | | | |
| | 66+ | 79 | 151.04 | | | |
| | Total | 312 | | | | |
| Level of the satisfaction of the patients with the work of the laboratory | 15-25 | 22 | 179.93 | 3.907851 | 5 | 0.563 |
| | 26-35 | 42 | 155.54 | | | |
| | 36-45 | 40 | 137.63 | | | |
| | 46-55 | 55 | 162.77 | | | |
| | 56-65 | 74 | 157.15 | | | |
| | 66+ | 79 | 155.07 | | | |
| | Total | 312 | | | | |

According to the data in table 6.43, it can be concluded that:

- There were statistically significant differences between age groups regarding the waiting for the blood draw (measured in minutes) (Chi-Square = 13,188; p = 0,022) with a mean rank of waiting time of 132.75 for the group of patients from 15-25 years of life, 115.48 for the group of 26-35 years, 162.43 for 36-45, 171.81 for the group of 46-55 years of life, 164.95 for 56-65, and 163.35 for the group of patients who belongs to the age of 66+.

For the rest of the variables, we have not found statistically significant differences between proposed age groups.

### 6.2.5 Waiting time for a blood draw

For the purposes of the analysis of the waiting time, which is one of the most important parts of the laboratory working process, we performed a correlation and regression analysis (Table 6.44).

Table 6.44. Means and Spearman's rho Correlations (Source: Author)

| | | Mean | SD | Waiting time for a blood draw – measured in minutes | The level of satisfaction with the waiting time for a blood draw |
|---|---|---|---|---|---|
| Waiting time for a blood draw – measured in minutes | rho | 71,07 | 48,63 | 1,000 | -,764** |
| | Sig. (2-tailed) | | | . | ,000 |
| The level of satisfaction with the waiting time for a blood draw | rho | 3,48 | 1,65 | -,764** | 1,000 |
| | Sig. (2-tailed) | | | ,000 | . |
| ***. Correlation is significant at the 0.01 level (2-tailed).* | | | | | |

According to the results in Table 6.44, the mean value of the waiting time for a blood draw is around 70 minutes (M=71,07; SD=47,63; MAX=200; MIN=0; N=312), while the level of the satisfaction with the waiting time for a blood draw is 3,5 (M=3,48; SD=1,65; MAX=7;

MIN=1; N=312). There has been detected a strong negative statistically significant correlation between the waiting time for a blood draw and the satisfaction of the patients with this waiting time (rho= -0,764; p<0,001; N=312).

In order to explore this relationship in a greater extent, the author performed regression model with only one dependent, the level of satisfaction with the waiting time for a blood draw, and one independent variable, the measure waiting time for a blood draw. According to the data in table 6.45, the value of R, the multiple correlation coefficients, is considered to be one measure of the quality of the prediction of the dependent variable. A value of 0.740 indicates a good level of prediction. R square value represents the proportion of variance in the dependent variable that can be explained by the independent variables, the proportion of variation accounted for by the regression model. The coefficient of the determination, R square, is 0,547 which means that the model explains 54,7% of the variability of the dependent variable. Also, the author explored the level of autocorrelation. The Durbin-Watson statistic is 1,613 which is between 1.5 and 2.5 and therefore the data is not auto-correlated. VIF and tolerance coefficients also pointed out that there was no multicollinearity in the model.

Table 6.45. Model Summary (Source: Author)

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | ,740 | ,547 | ,546 | 1,11443 | 1,613 |

The next part of the regression model was to explore whether the model is statistically significant. The F-ratio in the ANOVA table tests shows whether the overall regression model is a good fit for the data. The table 6.46 shows that the independent variable statistically significantly predicts the dependent variable (F(1, 310) = 373,343, p < 0.001).

Table 6.46. ANOVA test (Source: Author)

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 464,915 | 1 | 464,915 | 374,343 | ,000 |
| | Residual | 385,005 | 310 | 1,242 | | |
| | Total | 849,920 | 311 | | | |

According to the data in table 6.47, in the model, the coefficient of the "waiting time for blood draw" was negative and had *p*-value higher than 0,01. This means that waiting room for a blood draw has a negative relationship with the dependent variable, the level of satisfaction with the waiting time for a blood draw. The waiting time for a blood draw measured in minutes (t(312)=19,348; p<0,01) is a significant predictor of the satisfaction of the patients with the waiting time.

Table 6.47. Regression coefficient (Source: Author)

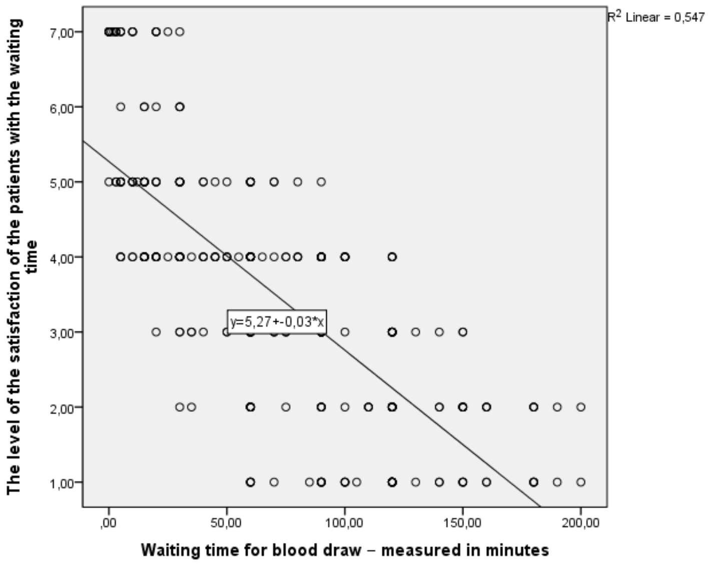
| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 5,271 | ,112 | | 47,126 | ,000 |
| | Waiting time for a blood draw – measured in minutes | -,025 | ,001 | -,740 | -19,348 | ,000 |

The regression model (Graph 6.1) can be presented as:

$$y=\beta_0 + \beta_1 x$$

*y=5,27 – 0,03*Waiting time for a blood draw – measured in minutes*

Graph 6.1. Regression line (Source: Author)




### 6.2.6 The duration of the blood draw process

Table 6.48. Means and Spearman's rho Correlations (Source: Author)

| | | Mean | SD | The duration of the blood draw process – subjective times | The duration of the blood draw process – objective times |
|---|---|---|---|---|---|
| The duration of the blood draw process – subjective times | rho | 73,1357 | 45,79941 | 1,000 | ,837** |
| | Sig. (2-tailed) | | | . | ,000 |
| The duration of the blood draw process – objective times | rho | 60,5643 | 33,41417 | ,837** | 1,000 |
| | Sig. (2-tailed) | | | ,000 | . |
| ***. Correlation is significant at the 0.01 level (2-tailed).* | | | | | |

According to the results in Table 6.48, the mean value of the duration of the blood draw process – subjective times (presented as opinion of the patients who were questioned) is around 73 minutes (M=73,14; SD=45,80; MAX=240; MIN=5; N=140), while the mean value of the duration of the blood draw process – objective times (presented as the measured times by researcher) is 60,56 minutes (M=60,56; SD=33,41; MAX=173; MIN=12; N=140). There has been detected a strong positive statistically significant correlation between the mean value of the duration of the blood draw process – objective times and subjective time (rho= 0,837; p<0,001; N=140). Based on the high positive statistically significant correlation between the duration of the blood draw process objective times and subjective times it is possible to implement a simulation of the process, which is explained and presented in Figure 5.1.

### 6.2.7 The satisfaction of the patients with the overall work of the laboratory for a blood draw

For the purposes of the analysis of the waiting time, which is one of the most important parts of the laboratory working process, we performed correlation and hierarchical regression analysis. At first, we performed the Spearman’s correlation (rho) test. According to the data in table 6.49, there have been detected positive statistically significant correlations between the mean value of the satisfaction of the patients with the work of the laboratory for the blood draw and:

- (5) the evaluation of the work of the laboratory staff (rho= 0,408; p<0,01; N=312);
- (7) the evaluation of the work of the desk staff (rho= 0,216; p<0,01; N=312);
- (9) the availability of the information at the counter (rho= 0,282; p<0,01; N=312);
- (11) the level of the hygiene in the room for a blood draw (rho= 0,124; p<0,05; N=312);
- (12) the level of the safety of the instruments in the rooms for a blood draw (rho= 0,219; p<0,01; N=312).

Also, there was detected a negative statistically significant correlation between the mean value of the satisfaction of the patients with the work of the laboratory for the blood draw and

- (3) the waiting for the blood draw (minutes) (rho= – 0,275; p<0,01; N=312).

Table 6.49. Means and Spearman's rho Correlations (Source: author)

| | | Mean | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | rho | 1,2115 | ,40906 | 1,000 | ,106 | -,057 | -,112 | ,042 | -,134* | ,036 | ,131* | -,015 | -,001 | ,122* | -,026 | ,012 |
| Age | rho | 52,6218 | 16,60602 | ,106 | 1,000 | ,124* | ,089 | -,082 | -,023 | -,059 | ,034 | ,116* | ,006 | ,109 | ,008 | ,002 |
| Waiting for the blood draw (minutes) | rho | 71,0737 | 48,63438 | -,057 | ,124* | 1,000 | -,003 | -,254** | ,039 | -,113* | -,172** | -,119* | -,110 | -,194** | -,156** | -,275** |
| Duration of the blood draw – measured times | rho | 60,5643 | 33,41417 | -,112 | ,089 | -,003 | 1,000 | ,017 | ,224** | -,059 | -,111 | -,024 | -,142 | -,041 | ,196* | ,090 |
| Evaluation of the work of the laboratory staff | rho | 4,2244 | ,84924 | ,042 | -,082 | -,254** | ,017 | 1,000 | -,151** | ,217** | ,099 | ,218** | -,017 | ,206** | ,119* | ,408** |
| Waiting to hand over a health card at the counter | rho | 3,1058 | 9,04357 | -,134* | -,023 | ,039 | ,224** | -,151** | 1,000 | ,005 | -,062 | -,019 | -,038 | -,027 | ,057 | ,083 |
| Evaluation of the work of the staff at the counter/desk | rho | 4,6827 | 1,51263 | ,036 | -,059 | -,113* | -,059 | ,217** | ,005 | 1,000 | ,107 | ,121* | -,099 | ,138* | ,153** | ,216** |
| The level of the crowd in the waiting room | rho | 1,1250 | ,38511 | ,131* | ,034 | -,172** | -,111 | ,099 | -,062 | ,107 | 1,000 | ,059 | -,052 | ,076 | ,072 | ,095 |
| Availability of the information at the counter | rho | 2,5513 | ,63443 | -,015 | ,116* | -,119* | -,024 | ,218** | -,019 | ,121* | ,059 | 1,000 | -,077 | ,109 | ,079 | ,282** |
| Waiting for the results of the blood test more than 24h | rho | 2,1410 | ,87809 | -,001 | ,006 | -,110 | -,142 | -,017 | -,038 | -,099 | -,052 | -,077 | 1,000 | -,061 | -,040 | -,032 |
| The level of the hygiene in the room for blood draw | rho | 2,7083 | ,46917 | ,122* | ,109 | -,194** | -,041 | ,206** | -,027 | ,138* | ,076 | ,109 | -,061 | 1,000 | ,278** | ,124* |
| The level of the safety of the instruments in the rooms for blood draw | rho | 2,7115 | ,47456 | -,026 | ,008 | -,156** | ,196* | ,119* | ,057 | ,153** | ,072 | ,079 | -,040 | ,278** | 1,000 | ,219** |
| Level of the satisfaction of the patients with the work of the laboratory | rho | 5,6058 | 1,21950 | ,012 | ,002 | -,275** | ,090 | ,408** | ,083 | ,216** | ,095 | ,282** | -,032 | ,124* | ,219** | 1,000 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

In order to explore the relations between the predictors and the dependent variable, the hierarchical regression was performed. At first, we entered only demographic variables of patients as independents in the regression model. In the second step, we entered variables that explore the work of the laboratory, as predictors.

Table 6.50. Model Summary (Source: Author)

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change | |
| 1 | .055 | .003 | -.012 | 1.28074 | .003 | .207 | 2 | 137 | .813 | |
| 2 | .635 | .404 | .347 | 1.02883 | .401 | 8.530 | 10 | 127 | .000 | 1.627 |

According to the data in Table 6.50, the value of R, the multiple correlation coefficients, is considered to be one measure of the quality of the prediction of the dependent variable. A value of 0.055 in the first model indicates a bad level of prediction. R square value represents the proportion of variance in the dependent variable that can be explained by the independent variables, the proportion of variation accounted for by the regression model. The coefficient of the determination, R square, is 0,003 which means that the model explains a very small share of the variability of the dependent variable. When the predictors in the second step were entered into the regression model, the value of R increased to 0,635 which now shows a good level of prediction. The coefficient of the determination, R square, now is 0,404 which means that the model explains 40,4% share of the variability of the dependent variable. This change of the R square for 40,1% is statistically significant, based on the results of the F test ($F(10,127) = 8,530$, $p<0,05$). Also, the author explored the level of autocorrelation. The Durbin-Watson statistic is 1,627 which is between 1.5 and 2.5 and therefore the data is not auto-correlated. VIF and tolerance coefficients also pointed out that there was no multicollinearity in the model.

The next part of the regression model was to explore whether the model is statistically significant. The F-ratio in the ANOVA table tests for the first model shows whether the overall regression model is a good fit for the data.

Table 6.51. ANOVA test (Source: Author)

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | .679 | 2 | .340 | .207 | .813 |
| | Residual | 224.721 | 137 | 1.640 | | |
| | Total | 225.400 | 139 | | | |
| 2 | Regression | 90.971 | 12 | 7.581 | 7.162 | .000 |
| | Residual | 134.429 | 127 | 1.058 | | |
| | Total | 225.400 | 139 | | | |

The table 6.51 shows that the independent variables do not statistically significantly predicts the dependent variable ($F(2, 137) = 0{,}207$, $p > 0.05$). After the second step in the hierarchical regression was made, when we entered other independent variables which are connected to the process of a blood draw, the model becomes statistically significant. The F-ratio in the ANOVA table tests for the second model shows that the overall regression model is a good fit for the data. The table 6.52 shows that the independent variables t statistically significantly predict the dependent variable ($F(2, 127) = 7{,}163$, $p < 0.001$).

Table 6.52. Regression coefficient (Source: Author)

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 5.913 | .484 | | 12.216 | .000 |
| | Sex | -.170 | .264 | -.055 | -.644 | .521 |
| | Age | .000 | .006 | -.002 | -.019 | .985 |
| 2 | (Constant) | .671 | 1.001 | | .670 | .504 |
| | Sex | -.191 | .226 | -.062 | -.849 | .398 |
| | Age | .002 | .005 | .020 | .284 | .777 |
| | Waiting for the blood draw (minutes) | -.005 | .002 | -.184 | -2.404 | .018 |
| | Duration of the blood draw – measured times | .004 | .003 | .093 | 1.291 | .199 |
| | Evaluation of the work of the laboratory staff | .404 | .114 | .276 | 3.561 | .001 |
| | Waiting to hand over a health card at the counter | .016 | .009 | .119 | 1.694 | .093 |
| | Evaluation of the work of the staff at the counter | .081 | .058 | .101 | 1.387 | .168 |
| | The level of the crowd in the waiting room | .413 | .207 | .149 | 1.991 | .049 |
| | Availability of the information at the counter | .622 | .143 | .311 | 4.335 | .000 |
| | Waiting for the results of the blood test more than 24h | -.045 | .109 | -.030 | -.413 | .681 |
| | The level of the hygiene in the room for a blood draw | .131 | .191 | .052 | .684 | .495 |
| | The level of the safety of the instruments in the rooms for a blood draw | .318 | .187 | .125 | 1.697 | .092 |

a. Dependent Variable: The satisfaction of the patients with the overall work of the laboratory for a blood draw

Table 6.52 presents the coefficients of the regression model for the satisfaction of the patients with the overall work of the laboratory for a blood draw as the dependent variable. The first regression model showed that both of controls, sex, and age of the respondents did not have significant relations with the satisfaction of the patients with the overall work of the laboratory for a blood draw.

The second regression model, step two in the hierarchical regression, showed that some of the predictors had statistically significant relations with the level of the satisfaction of the patients with the overall work of the laboratory for a blood draw. Controls, sex, and age of the respondents, also did not show statistically significant relations with the dependent. Waiting time for the blood draw (measured in minutes) has a statistically significant relationship with the dependent. According to the negative beta coefficient, the shorter waiting time for blood draw has a statistically significant relationship with the level of satisfaction with the work of the laboratory. Evaluation of the work of the laboratory staff has statistically significant relations with the level of the satisfaction of the respondents with the work of the laboratory for a blood draw. The more that the respondents are satisfied with the work of the laboratory staff, the more they will be satisfied with the overall work of the whole laboratory.

This means that for the increase in the level of the satisfaction with the work of the staff, there is an increase in the level the satisfaction of the patients with the overall work of the laboratory for 0,404. Another predictor that has a statistically significant relationship with the dependent variable is the level of the crowd in the waiting room of the laboratory. According to the positive beta coefficient, if the crowd in the waiting room of the laboratory for a blood draw is acceptable, by the opinion of the patients, they will be more satisfied with the work of the laboratory. According to the data in Table 6.52, the availability of the information at the counter had also a statistically significant relationship with the dependent. If the information are totally available (visible) in the waiting room and at the desk, the more satisfied the patients will be with the overall work of the laboratory. Other predictors did not show statistically significant relations with the dependent variable.

According to the results of the regression model presented in the previous tables, we present the regression equation:

$$y=\beta_0 + \beta_1 x1 + \beta_n x_n$$

*The level of the satisfaction of the patients with the overall work of the laboratory for a blood draw =0,671 – 0,005* Waiting for the blood draw (minutes) + 0,404* Evaluation of the work of the laboratory staff + 0,413* The level of the crowd in the waiting room + 0,622* the availability of the information at the counter*

### 6.2.8 Discussion on the results of the research

The research of the work of the laboratory for a blood draw was performed in order to get an insight in the real functioning of the processes in the laboratory in eyes of the users/clients (in this case, patients), but also from the aspect of the staff who work in the laboratory. This part of the research, besides the value-stream mapping (VSM) of the laboratory, is very important because it gives an empirical base for further exploration and confirmation of the proposed hypothesis H2 which is:

*H2: Implementation of Lean principles and tools in the clinical laboratory will:*

- *improve clinical laboratory processes and results,*
- *maximize process flow without adding more resources,*
- *reduce waiting time for laboratory results.*

The analyzed data from the laboratory showed that most of the respondents (patients and employees) have similar opinions on several issues:

- *the crowds in the waiting room*, where 88,5% of the patients and 100% of the employees stated that the crowds are too excessive, and because of that,
- about 50% of the patients felt *nervous or under pressure*, while 100% of employees stated that all of the patients are nervous, while some are more and some are less nervous,
- *waiting time for a blood draw process*, 48% of the patients and 90% of the employees stated that the waiting time for a blood draw is long, and thereby, people are wasting a lot of time for waiting,
- also, *waiting time for a blood draw* is found to be one of the predictors that have *negative statistically significant relations* with the level of the satisfaction of the patients with the work of the laboratory (B=-0.005; t=-2.404; p=0.018), which means that longer waiting time is related to the lower satisfaction of the patients,
- *waiting time for getting the results of the blood tests*, which is almost always more than 24h, where 96% of the patients stated that this is a too long time for waiting, so it is also one of the most important issues in the work of the laboratory.

In the case of the other variables, such as the level of the hygiene of the spaces for a blood draw and the level of the safety of the equipment in the spaces for blood draw are seen as acceptable by approximately 70% of the patients.

Regarding the level of the equipment of the working space from the aspect of the staff in the laboratory, 75% of employees stated that they see their workspace as correctly equipped or well equipped. 25% of the staff stated that their workspace is badly equipped, which is very important if we bear in mind that the laboratory is in question. Also, there has been detected a strong positive statistically significant correlation between the mean value of the duration of the blood draw process – objective times and subjective time (rho= 0,837; p<0,001; N=140). Based on the high positive statistically significant correlation between the duration of the blood draw process objective times and subjective times it is possible to implement a simulation of the process, which is explained and presented in Figure 5.1.

Based on the results of the research conducted in the clinical laboratory for a blood draw, it is obvious that there are few very important issues that harm the working process of the laboratory, thus confirming the H3 hypothesis. Summarized, they can be presented as:

- *excessive crowds in the waiting room of the laboratory;*
- *long waiting time for the blood draw process;*
- *long waiting time for getting the results of the blood tests,*
- *work of the laboratory staff*
- *the availability of the information at the counter*.

These variables showed that, in general, the process of the blood draw, from its beginning until the end, has some disturbing factors, which need to be resolved in order to increase the overall process of the laboratory. Also, besides these responses, the sample consisted only of the patients who agreed to fill the questionnaire, while 188 patients, out of 500 (the number of interviewed patients) did not want to participate stating that they are totally dissatisfied with the whole process and the work of the laboratory. In addition to the conducted surveys, the author examined the attitudes of the directors of various departments (9 departments agreed to participate in the surveys) that cooperate with the Department of Clinical Biochemistry and whose total work processes are influenced by the results from analyzes from the Department of Clinical Biochemistry. Through the questionnaire, the author concluded that one of the key problems in almost all departments is the waiting for analysis results, ranging from 5% to 15%. Having in mind the results of the statistical analysis made in this chapter as well as other collected data, the author will use the VSM lean tool to show the current "as is" process in order to show gaps and suggest possible solutions and improvements. When it comes to the government, it is important to note that the Clinical Center of Vojvodina belongs to the state/provincial institutions that are financed largely by the provincial budget, and hence the creation of a process that will function according to the principle "do more with less" is certainly the imperative on which the government insists. In other words, the creation of such processes based on savings in excessive spending of dedicated assets, while increasing the number of service users, is the goal of each government. A detailed analysis of stakeholder attitudes can be used to define long-term and short-term goals as well as KPIs that need to be improved in order to meet the expectations of the stakeholders. KPIs can be displayed as:

- reducing lead time,
- reducing process time,
- improvement patient satisfaction,
- reducing employee departure from the work place,
- reducing the number of all activities,
- inventory turn over,
- reducing the number of errors and
- increase number of patient served,

and the mentioned KPI will serve as the input data for the creation of the Hoshin Kanri X matrix, which will directly impact on both short-term and long-term goals. The above step represents the second phase of the model presented in the continuation of the dissertation.

## 6.3 STEP 2 - (HOSHIN KANRI MATRIX - Sorting the expectations of the stakeholders)

After summing up the collected stakeholder views, the authors approached to the second phase of the development of the model, where, based on the collected data (in the first phase of the model), the expectations of the stakeholders are sorted, i.e. the goals are defined as well as the short-term goals + KPIs necessary for improving the work of clinical laboratories using the lean concept. The display of KPI's couplings with short-term and long-term goals is given in detail in the Hoshin Kanri X matrix (Figure 6.2). In the study, the Hoshin Kanri X matrix is showing the long-term clinical laboratory plans, the annual actions to be completed with the precisely defined activities to be applied and the KPI’s that need to be improved. For an easier understanding of the Figure, one of the long/term goals of the Clinical Center is definitely an improvement in terms of doing business according to the lean principles as one of the 4 annual plans. A multi-year plan can be created with the realization of a one-year plan where training of employees in the first cycle – 25% of staff will be trained. Training will be achieved by using the lean tool’s which are more precisely defined in the fourth phase of the model, and the realization will be monitored through the certification of 25% of employees (training for 5% of employees every 2 months). Training of employees will primarily affect the improvement of KPIs such as reducing employee departure from workplace and reducing the number of errors, while the secondary impact of employee training will be on the improvement of patient satisfaction and on the increase of the number of patients served.

ANNUAL IMPROVEMENT PRIORITIES

BUSINESS LEVEL IMPROVEMENT PRIORITIES (ANNUAL)

TARGETS TO IMPROVE (KIP/goals)

3-5 YEARS OBJECTIVES

| Development of appropriate IT system | Increase the number of analyzes by 10% | Procurement of new equipment and improvement of employees' work | Reducing crowds in waiting rooms and waiting for blood extraction | Active employee training - 1 cycle of 4 yearly training - 25% of employees | Integration of the reception and distribution department with the biochemistry laboratory | | lead time / reduced by 10% | process time / reduced by 5% | patient satisfaction / improvement by 10% | reducing employee departure from work place by 25% | reducing number of all activities by 5% | inventory turn over | reducing number of errors | increase number of patient served by 5% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ● | | | ● | | | Scheduling patients by daily groups on every 30 minutes by scheduling system | ● | ● | ● | | | ● | | |
| | | | ● | | | Reduce waiting time for blood extraction by 35% | | | ● | | | | | |
| | | | ● | | | Reduce crowds in waiting rooms | | | ● | | | | | |
| ● | | | | | | Installation of monitors in waiting rooms, boards, etc.) | | | ● | | | | | |
| ● | ● | ● | | | ● | Eliminate unnecessary steps within the process by 10% implementation of VSM tool | ● | ● | | | ● | | ● | ● |
| | | | | ● | | Every 2 months, train 5% of employees with the acquisition of the certificate | | | ● | ● | | | ● | ● |
| | | ● | | | | Procurement of new equipment for work - new sample racks, new tubes with bar codes, etc. | | ● | | ● | | | ● | |
| ● | ● | ● | | | ● | Connecting machines for analysis into an information system | | ● | | | ● | | ● | |
| | ● | ● | | ● | | Introduction of standard work procedures and quality systems - implementation of quality system | | | | ● | ● | ● | ● | |
| | | | | | ● | Shortening waiting for analysis results (results in the same day) - new IT system | ● | ● | ● | | | | | |
| | | | ● | | | Change the system for calling patients in waiting rooms - by using new boards | | | ● | | | | | |
| | ● | | | | ● | Shorten waiting time for samples true integration of departments | ● | ● | | | | | | ● |
| ● | | | | | ● | System integration of all departments of the Clinical Center of Vojvodina | | | | | | | | |
| | | | | ● | | Lean way of business of clinical laboratories and rational management of the means of work | | | | | | | | |
| | ● | | ● | | | Maintain a leading position in the number of patients served | | | | | | | | |
| ● | | ● | | | | Working with state-of-the-art equipment and best working conditions | | | | | | | | |

RESOURCE

● PRIMARY RESPONSIBILITY

○ SECONDARY RESPONSIBILITY

Figure 6.2. Hosin Kanri - X matrix

## 6.4 STEP 3 - (VSM of the current process)

After the collected attitudes of the clinical laboratory stakeholders in the first phase, as well as the definition of long-term and short-term goals, as well as KPI's that need to be improved, using the Hoshin Kanri X matrix in the second phase, the author approached to the third stage of the development of the model. The third phase of the model includes the complete mapping of the clinical laboratory workflow using the VSM lean tool with a detailed description and labeling of all sites that do not contribute to the process value (gaps/waste), or where the kaizen for the elimination of gaps/waste can be applied. As already mentioned, for the purpose of the research the author explored two departments within the Center for Laboratory Analysis, of the Clinical Center of Vojvodina, both the Department of clinical biochemistry and the Department for material admission and distribution. The Department for reception and distribution of materials is located in the Polyclinic Building (No. 12) while the Department for clinical biochemistry is located in the Center for Laboratory Medicine (No. 13) (Figure 6.2). The measured distance between the two departments located in different buildings is approx. 150-200 meters. A detailed overview of the entire process in two departments was demonstrated by using the lean mapping tool VSM in Figure 6.3, while each step of the process is described in details below.

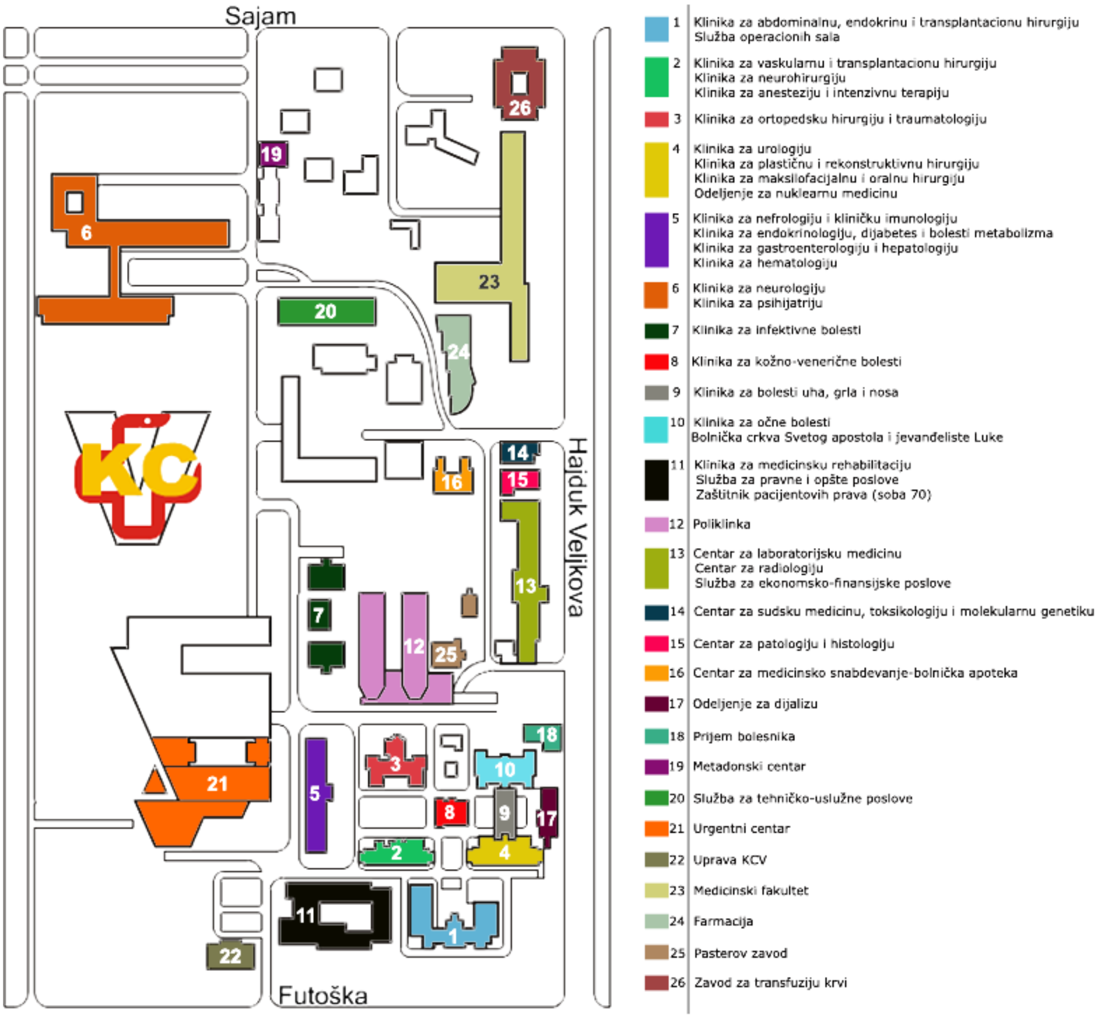



Figure 6.2. The overview of the map of the Clinical Center of Vojvodina (https://www.kcv.rs)

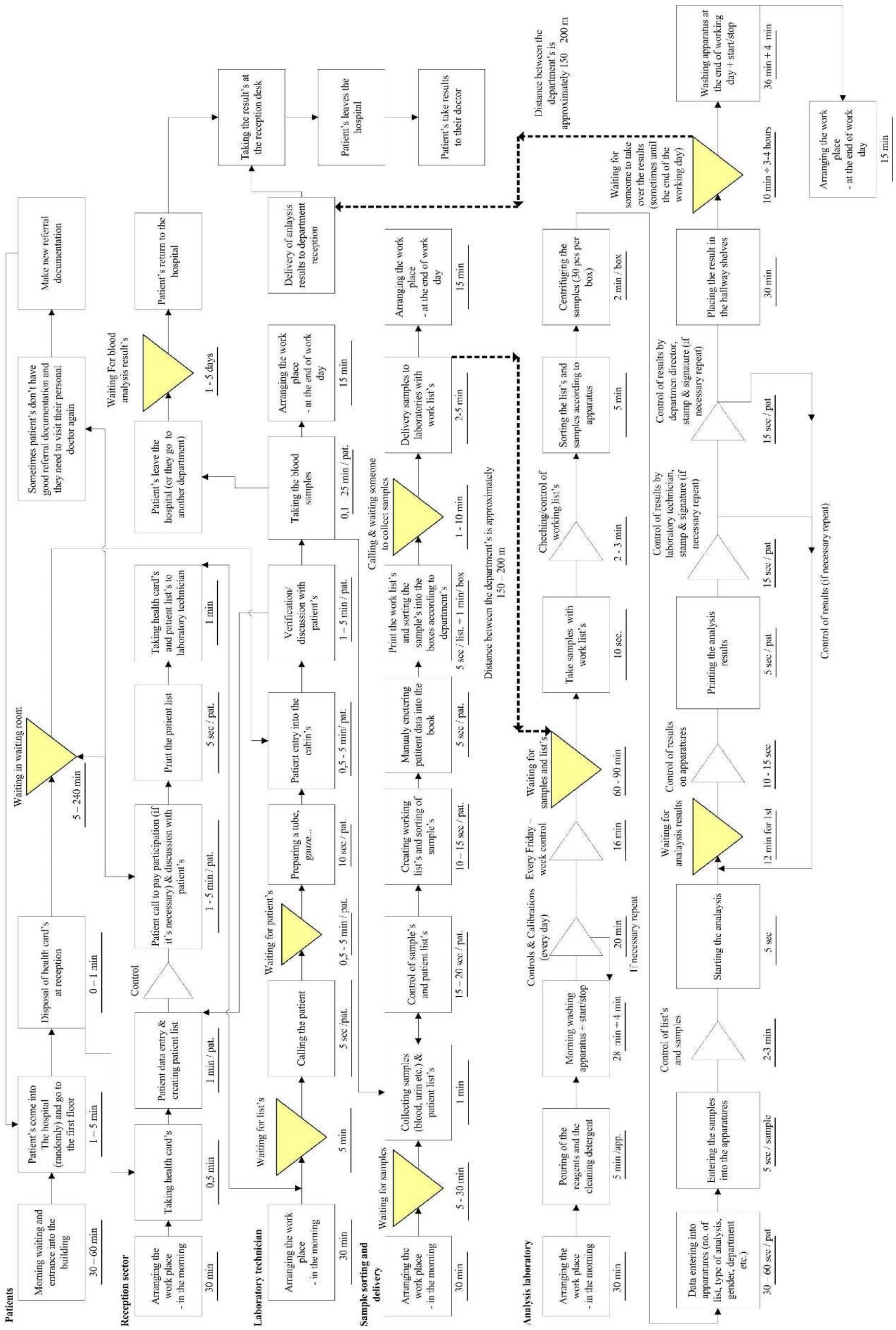



Figure 6.3. VSM of the current process (present state)

## 6.4.1 Department for reception and distribution of materials

The department of reception and distribution of material is located on the first floor of the Polyclinic and currently employs 20 employees. They have a reception area in their facilities - a reception desk for receiving health cards and patient instructions, eight rooms (boxes) for taking samples (blood, stool sample, urine), room for sample sorting, rooms for relaxing, restrooms, etc. As noted earlier, during 2017, the Department for the reception and distribution of materials carried out serving of approximately 100.000 - 110.000 per patients/year, which daily averages about 370 - 410 patients/day. A detailed overview of the workflow shown by the simulation is presented in Figure 6.4.

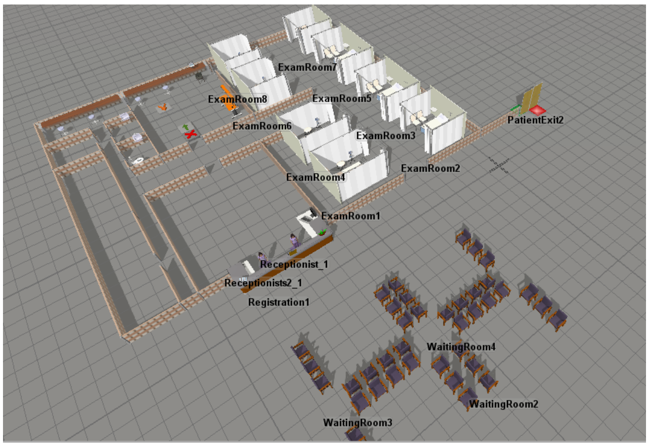



Figure 6.4. The overview of the layout of the department for the reception and distribution of materials

During the research, it was noted that patients were making waiting rows even up to half an hour earlier in front of the clinic in order to get to the department as soon as possible (figure 6.5). One of the reasons for creating crowds in the laboratory is the practice of receiving of health cards only in the period from 7am to 9am in the morning (2 hours), which leads to the situation in which all patients need to come earlier, usually at the same time, if they want to schedule a blood draw and/or to bring samples.


Figure 6.5. Waiting rows in the morning

After the opening of the door by the staff at the clinic, patients are trying to reach the reception desk at the first floor as soon as possible in order to hand over the health cards and thus have the opportunity to complete the process according to the FIFO principle (first in first out) with blood draw and waiting in the waiting room. After they hand of the booklets, the patients are waiting in the waiting rooms to be called by the laboratory technician through the announcement and to enter into the box for blood extraction. Often it happens that patients are subsequently called back to the receiving counter because they do not have proper documentation issued by their doctors, so there is a "discussion" with the employees, referrals to other departments if they missed the right department, return to their competent doctors to deliver a regular instruction or they are called to come to the receiving counter to pay the participation, if necessary. After the patient is called by a laboratory technician, he/she enters into the room for taking samples where, after blood extraction or after they submit the samples (urine, etc), the laboratory technician returns him/her the health card and gives a confirmation paper with the indicated date when he/she should come to take results of the test (waiting for analysis results from 1 to 5 days). After leaving the clinic, patients after a few days, depending on the date indicated on the confirmation, return to the clinic to the receiving counter in order to take the results.

The initial stage in the process of work at the department for reception and distribution of materials in the preparation of workspaces by employees. After preparation of workspaces and the start of the work, reception accepts health cards and instructions from patients at the counter service where employees insert the data and create worksheets in which they define the type of analyses that are going to be done, participation is charged, etc. Some of the most common problems observed during the work are discussions with patients due to inadequately delivered health paperwork (without certified instructions from selected doctors), nervous approach of patients, nervous approach of employees (noticeable at a later stage of work), and incorrect data entry. It is not rare that due to excessive crowds, in the initial phase, besides the technical service that works at the counter, laboratory assistants also come to help their colleagues, to process as much data as possible in order to shorten the time. The reason why there is a lot of crowds in the morning is that there is no a system of scheduling blood extraction, so it is not possible to know the exact order of patients, how many patients will come every day, etc., and therefore, the entire department works on the assumptions of how many patients have to serve every day.

After handing over health cards, patients sit or stand in the waiting room (from 1 minute and up to 240 minutes), and after calling, which is performed by laboratory technicians through the speakerphone, they enter into the sampling rooms. The patients' calling is based on the list of patients delivered to laboratory technician in the way "Name, Last name, with an emphasis on the number of the room", where the specific data is repeated several times (eg. *Majed Alkher, room number 4; Majed Alkher, room number 4* ). After entering the room, samples are taken (blood, stool, urine, etc.). It has been observed that laboratory technicians sometimes perform the action of the patients calling at the same time (two different names at the same time), and therefore the action must be repeated. It is also noteworthy that due to the large crowds in the waiting room, it is sometimes impossible to understand what name laboratory technician called. This procedure often leads to waiting for patients to come to the room for extracting blood and repeating the step. Among the other problems observed in this phase of work, there are: waiting for older patients due to mobility issues or age-related hearing loss, the arrival of wrong patients due to lack of understanding of the voice from the speakerphone, the leave of patients (most often they drink coffee or burn cigarettes).

After receiving a patient in the sampling room, a laboratory technician makes an interview with a patient in order to confirm the patient's identification, data collection (whether the patient is taking some medicines, whether the patient had some operations, etc.) and returns him/her a health card with a date when to come to get the results of the analysis. In addition to the above actions, the laboratory technician, on the basis of the submitted worksheet, selects the tubes for the necessary analyses, registers the tubes with the number assigned to the patient, and with the name and surname, marks the subsequently delivered samples. During the analysis of the work, it was noticed that the laboratory technician sometimes noticed the lack of some necessary analyses (most often through interviews with patients) that need to be done and which were not registered at the desk service. Because of that, it happens that the laboratory technician must leave his job and make a correction of the work order. After a detailed check of all data and preparatory actions, the laboratory technician performs a blood draw operation. The process of blood extraction consists of the following stages:

- preparing the tubes and needles for extracting blood,
- employee takes sterile gloves,
- tightens the tie around the patient's hand,
- disinfects the place of blood extraction with alcohol and gauze

- finds a suitable place for extracting blood (veins)
- venipuncture (needle sticking and tube changes)
- releasing a tie around the patient's hand
- a needle removal and
- treating the wound with a gauze and a patch, and by showing the proper sticking of the wound.

Depending on the patient, blood extraction can last quite shortly or in some cases very long (and up to half an hour). The reason why in some cases the extraction of blood lasts for a long time is related to the inability to find a suitable vein for extracting blood, the patient's fear (sometimes even the vein for the extraction of blood (jargon) is "healthy", due to the fear of patients it happens that the flow of blood is not good), faint, nausea (vomiting), etc. If a laboratory technician is unable to find a vein, another laboratory technician is called, etc. All of the aforementioned causes lead to the fact that it is very often necessary to repeat the process of blood extraction and sometimes it is impossible to take the next patient due to the weakness of the current patient after the blood draw. In some cases, it happens that patients stay very short (if they bring a stool or urine sample), and sometimes patients, depending on the type of analysis, have to repeat the procedure of blood extraction after two hours in the same day. In addition to all the steps mentioned in the laboratory technician's work, frequent occurrences of leaving the workplace were noticed: lack of materials for work (test tubes, pre-cleaning and removing after venipuncture were used up), invitation of other employees for help, missing worksheets, and they must either get it or wait for someone to deliver it, etc.. Also, it has been noticed that often all boxes for blood draw are not working at the same time.

A laboratory technician, after a certain time, approaches the collection of samples from boxes and workbooks. After collecting samples, in the sample sorting room, they are sorting the lists and samples depending on the analyses and departments to be delivered, as well as entering the data of patients with precisely defined analyses that are listed in the lists in the computer. After entering all the necessary data into the computer, the data of patients are entered manually into the health books. After that, a printing of lists is done, which together with samples are packed in transport boxes, and delivered to the laboratories for further analysis. In the concrete case, in the doctoral dissertation, the sample was monitored in the Department of biochemistry.

The most common problems that are noticed in this phase are:

- poorly labeled (illegible) samples by laboratory technicians,
- error while typing the data and a necessary repeat of the procedure,
- lack of lists to be followed by samples,
- leaving the workplace in order to fulfill other obligations,
- waiting for transport boxes from other departments,
- calling other departments to take samples to analyze and wait for employees from other departments to come by,
- spillage of samples (usually urine),
- inability to work due to unpleasant smells (inadequately delivered sample of the stool by patients),
- interpersonal relations among employees, etc.

### 6.4.2 Department of clinical biochemistry

Department of clinical biochemistry is based on the first floor of the Center for laboratory analysis and employs 18 employees. As noted earlier, in 2017, the Department for clinical biochemistry carried out 724.434 analysis (in 2017, on all apparatus without calibration - WOC) and 611.365 analysis (in 2017, on all apparatus with calibrations, controls and repeats - WCCR) from samples that are submitted with 29 departments belonging to the Clinic and ambulance and , which is about an average of about 2.700 analysis/day (WOC) and 2.300 analysis/day (WCCR) in 2017. The department uses the following sample analysis apparatus in its system:

- apparatus for sample analysis - ADVIA 1800,
- apparatus for sample analysis - BS-2000-M,
- centrifugal apparatus for samples,
- apparatus for electrophoresis,
- ion analyzer, and
- immunoglobulin light chain analysis apparatus.

The layout of the laboratory for clinical biochemistry is presented in Figure 6.6.

Figure. 6.6 Layout of the Department for clinical biochemistry

The first step in the work of the department for biochemical analysis consists of the preparation of workplaces and apparatus for sample analysis. The ADVIA 1800 and BS-2000-M devices used for sample analysis (ALP, ALT, Urea, Bilirubins, GGT, LDH and many more) have the following preparatory/final actions:

- pouring reagents and washing detergents,
- morning wash – lasts 28 minutes,
- once a week (usually on Fridays), the control of lamps is done - duration of 16 minutes,
- start/stop device - duration of 4 minutes,
- afternoon washing - duration of 36 minutes,
- start / stop device - duration 4 minutes
- controls and calibrations - duration of 20 minutes (if everything is good if the procedure is not repeated).

After preparing workplaces and apparatus, it was noticed that employees were waiting for samples to be taken from the Department for the reception and distribution of materials, as well as from other departments of the clinic and ambulance. Waiting time for samples from the reception and distribution department takes about 60 to 90 minutes each day. In the 2017 year, there were 260 working days. If the minimum waiting time of 60 minutes per day is taken into account, it can be concluded that during the year, the waiting for analyzing samples cause loses of minimum 260 hours, which in eight-hour working hours results in approximately 32 working days per year.

After receiving materials from other departments, it is accessed to the following actions:

- downloading samples, lists, and plans,
- centrifuge samples,
- list preview,
- division of lists according to the apparatus in which the samples are to be processed,
- marking of the lists (manually) and enter each list into the computer,
- stacking of samples by lists and numbers in the apparatus,
- start of the device and the first results come out in 12 minutes,

Sometimes (rarely) other samples do not arrive on time for analysis, and it happens that the apparatus after the last analysis, if there is no next sample, start with automatic cleaning and consume cleaning reagents - the cleaning operation takes 12 minutes and the cleaning operation is repeated as many times as the delay of the samples occurs. During the analysis, it is possible to monitor the results after the apparatus shows that a certain sample analysis is done.

After completed analysis, the laboratory technician prints the results and they are:

- reviewed, checked, signed and stamped by a laboratory technician,
- reviewed, checked, signed and stamped by a department manager,
  - if it is determined that the results differ significantly from the reference values, a re-analysis of the specific sample is performed,
- placement of results on shelves for departments - depending on the dynamics of arrival from different departments, the results are taken by the end of the working day),
- bringing results to desks of departments,
- publishing results to patients.

By analyzing the work system in the department for reception and distribution of materials and department for clinical biochemistry as well as the statistical analysis of the data gathered by questionnaires regarding the attitudes of patients and employees, there were identified certain places that provide the possibility of improving the process with the use of lean tools (a detailed review of the lean tool that will be used to improve the corresponding gap is shown below) which can be summarized as:

- excessive crowds,
- too long waiting for patients to extract blood,

- long time for waiting for blood results,
- insufficient information for patients,
- a large number of repeat operations,
- material disappearance during work,
- unnecessary leaves of employees from their jobs,
- lack of multidisciplinarity,
- inadequate labeling of samples,
- inadequate equipment for work,
- lack of an adequate information system,
- lack of scheduling system
- long waiting for samples from other departments,
- oversized control lists
- machine waiting due to lack of samples (loss of working material during operation),
- excessive waiting for results on the shelves.

## 6.5 STEP 4 - (Matrix of the gaps/lean methods)

Based on the current state of the system that is demonstrated by using the VSM lean tool (phase 3 of the model) as well as on the basis of all the observed "problems" - the gap's within the process, the next step, phase 4, applied in the developed model for the implementation of the lean concept in clinical laboratories is to demonstrate lean methods and tools through which these disparities will be solved. Table 6.52 gives an overview of the gaps, that are, the places for improvement of the work of clinical laboratories, as well as the presentation of methods and tools for improving the problems mentioned above.

Table 6.52. The matrix of the gaps/lean methods and tools

| | | Lean methods and tools | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 5S | VSM | TPM | Jidoka | Heijunka | JIT | Kan Ban | Poka Yoke | Visual Management | Kaizen | SMED | TQM | Standardization | Pull system | Nagara | Andon | Layout |
| Gaps/waste | Patient crowd | | Δ | | | | | | | | Δ | | | | Δ | | | |
| | Waiting for samples | | Δ | | | | Δ | | | | Δ | | | Δ | | | | Δ |
| | Waiting for results | | Δ | | | | Δ | | | | Δ | | | | | | | |
| | Waiting for a blood drive | | Δ | | | | | | | | Δ | | | Δ | Δ | | | |
| | Over moving | | Δ | | | | | | | | Δ | | | | | | | |
| | Unnecessary repetition of operations | | Δ | Δ | | Δ | | | | | Δ | | | | | | | |
| | Inventories | | | | Δ | | | Δ | | | Δ | | | Δ | Δ | | | |
| | Inadequate equipment for | | Δ | Δ | | | | | Δ | | Δ | Δ | | | | | | |

| | Lean methods and tools | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gaps /was | | 5S | VSM | TPM | Jidoka | Heijunka | JIT | Kan Ban | Poka Yoke | Visual Management | Kaizen | SMED | TQM | Standardization | Pull system | Nagara | Andon | Layout |
| | work | | | | | | | | | | | | | | | | | |
| | Inadequate labeling of samples | Δ | | | | | | | Δ | | Δ | | | Δ | | | | |
| | Informing patients | | Δ | | | | | | | Δ | Δ | | | | | | | |
| | An inadequate information system | | Δ | | | | | | | | Δ | | | | | | | |
| | NVAT - Non-Value Added Time | Δ | Δ | | | Δ | Δ | | | | Δ | | Δ | Δ | | | | |
| | Multidisciplinarity | | | | | | | | | | Δ | | | Δ | | Δ | | |
| | Analysis errors | | | Δ | | | | | | | Δ | | | Δ | | | Δ | |
| | Unorganized workplace | Δ | | | | | | | | Δ | Δ | | | Δ | | | | |

By summarizing of the data from table 6.52 it is possible to present an interconnection between define wastes in the current process that needs to be eliminated by implementation of a certain number of the lean tools and improvements in the proposed KPI's (table 6.53).

Table. 6.53. Review of the wastes, used lean tools and affect's on used KPI's

| Wastes | Lean tools | Influences on KPI's |
|---|---|---|
| | | |
| Patient crowd | VSM, Kaizen, Pull system | - improvement of the patients' satisfaction |
| Waiting for samples | Kaizen, VSM, JIT, Standardization Layout | - lead time; reducing employee departure from work place; reducing number of all activities |
| Waiting for results | Kaizen, VSM, JIT | - lead time; reducing number of all activities |
| Waiting for a blood drive | Kaizen, VSM, Standardization Pull system | - improvement of patients' satisfaction; lead time; increase numbers of patient served |
| Over moving | Kaizen, VSM | - lead time; reducing number of all activities |
| Unnecessary repetition of operations | Kaizen, VSM, TPM, Heijunka, Kan Ban | - lead time; process time; reducing number of errors |
| Inventories | Kaizen, Jidoka, Kan Ban Standardization, Pull system | - inventory turn over |
| Inadequate equipment for work | Kaizen, VSM, TPM Poka Yoke, SMED | - lead time; process time; reducing employee departure from work place; reducing number of errors; increase number of patients served |
| Inadequate labeling of samples | Kaizen, Poka Yoke, 5S, Standardization | - process time; reducing employee departure from work place; reducing number of all activities; reducing number of errors |
| Informing patients | Kaizen, VSM Visual management | - improvement patient satisfaction; reducing number of errors |
| An inadequate information system | Kaizen, VSM | - improvement patient satisfaction; reducing number of all activities; increase number of patients served |
| NVAT - Non-Value Added Time | Kaizen, 5S, VSM, Heijunka, JIT, TQM Standardization | - lead time; process time; reducing number of all activities |
| Multidisciplinary | Kaizen, Standardization Nagara | - process time; reducing employee departure from work place; reducing number of all activities; reducing number of errors |
| Analysis errors | Kaizen, TPM Standardization | - lead time; process time; reducing number of errors |
| Unorganized workplace | Kaizen, 5S Visual management Standardization | - reducing employee departure from work place; reducing number of errors |

## 6.6 STEP 5 - (VSM - Future state of clinical laboratories process)

Based on all the data collected from the previous 4 steps of the model, where the stakeholders' views were acquired, their requirements were sorted, the current state of the system is presented by using the VSM lean tool as well as the presentation of the lean tools and methods needed to improve some of the gaps, in the continuation of the dissertation, the author proposed a future state of improvement of the work of the departments for the reception and distribution of materials and departments for clinical biochemistry, which was improved in accordance with eight key questions for drawing a future state value stream which is shown in Figure 4.8 with a detailed explanation. Eight key issues to draw on the future state of the process (see Rother and Schook, 2009) can be presented as:

1. "*What is the takt time*? - the current need of the clinical laboratory service users that is the subject of the study is around 400 patients/day to be served from 7 am to 11 am. Since that the available time for serving patients is 4 hours/day or 240 minutes/day and the fact that the current system has 8 rooms for sample collection it is concluded that the available takt time per patient is:

   240 [minutes/day] x 8 [rooms]/ 400 [patients/day] = 4,8 [minutes/patient]

   On the basis of calculation, it is possible to conclude that the takt time for serving patients is 5 minutes/patients. It is very important to note that due to the excessive crowds as well as limitations in research (inability to record patients - due to legal regulations) it was not possible to determine the exact time.
2. *Will you build to a finished-goods supermarket from which the customer pulls, or directly to shipping?* - since the research is being carried out in clinical institutions or in service activities, the process of work will be set to work on the principle of placing services directly for service users not though finished-goods supermarket.
3. *Where can you use a continuous flow process?* – during the recording of the process there has been observed that, since this is a service process involving patients with different health conditions and a large number of patients, a process will be created that ensures continuous flows to the extent that is most possible with respect to all specific process characteristics.
4. *Where will you need to use a supermarket pull system to control production?* - "pull system" for the planning of the process, is planned to be established in blood collection rooms where it is possible to establish a pull system by calling the patient

system while monitoring the consumed resources to be delivered to laboratory technicians.

5. *At what single point in the production chain will you schedule production?* - in order to ensure "pace of delivery", the planning of "production" will be introduced at the very beginning of the process by the patient scheduling system.
6. *How will you level the production mix?* - as the research was carried out in the blood analysis laboratory, it was noted that the existing process already works on the principle of mixing production due to a large number of different analyzes, which are made on two same machines (machines are performing several different analysis in the same time), and in that sense, when creating a map of a new state, there is no need for a mix of production.
7. *What increment of work will you consistently release?* - the size of the "series" or patient will be defined through system simulation to determine the most optimal amount of patients serving at a given time interval.
8. *What process improvements will be necessary?* - a detailed view of the sites needed to be improved in the process is shown in Figure 6.14 which are marked with "kaizen stars" with a detailed description of why these places need to be improved as well as with a detailed description with the mode of improvement and the benefits obtained below.

One of the first proposals for improving is the introduction of the appointment scheduling system (Kaizen star K.01). In this way, it would be possible that the selected patient's doctor set the appointment through the network and select all the necessary analyses for the patient. This way will eliminate errors that occur due to unsuitable paper, so the patient is sometimes forced to visit his doctor again (Kaizen star K.03). After scheduling the appointment, the doctor could inform the patient about the scheduled appointment and all other details. This will help to eliminate the waiting of the patients in the morning hours when entering the building, as well as excessive crowds at the counter and waiting rooms in (Kaizen star K.02). In addition to eliminating crowds in the waiting rooms, the benefit of scheduling would also be reflected in the ability to accurately plan the procurement of materials needed for the work of the department. Employees could be able to prepare accurate quantities of materials for the next day to avoid unnecessary leaves of workplaces due to the disappearance of materials for work. The implementation of the lean tool Kan Ban will be used to make a connection between the data obtained from the scheduling and the stock level of the materials for work, which could be timely signalized when new material procurement is required.

Upon the patient's arrival at the counter service, typing the ID from the health card would confirm the identity of the patient, and the patient would get a specific ID number for the process of a blood draw. Health card will be returned to the patient, and he will get all the instruction - when the analysis results could be taken. The scheduled analysis related to the specified ID patient number would be further processed. The processing would be done electronically and the need for unnecessary printing of patient lists would be omitted (Kaizen star K.04). After the assignment of the ID number, the patient would wait in the waiting room until the number that calls him to give the samples, in the indicated room which is shown on the board (Figure 6.7). According to the regression model (Graph 6.1) where is *y=5,27 – 0,03*Waiting time for a blood draw – measured in minutes*, in order to secure at least patient satisfaction - *"neutral"*, waiting in the waiting rooms should not last longer than 40 minutes. While waiting for call for the blood draw (Kaizen star K.05), in waiting rooms it is necessary to apply lean tool - visual management or monitor-TVs, where patients will be informed about the way the laboratory works, patient's obligations, ways of proper delivery of samples, cultural behavior, information on ways of extracting blood (how to behave if the patient has dry skin, if the patient is susceptible to fainting, poorly visible veins, etc.). By this way, patient waiting would be easier and the patients will be educated, too (Figure 6.8).


Figure 6.7. Proposal for an electronic board in the waiting room (http://www.qtechqueueingsystem.com)


Figure 6.8. Notification monitors (source: https://www.pinterest.com)

After the ID number was determined, the laboratory technician would see the analyses to be done on the monitors in the sampling rooms. The preparation of tubes would be done via barcodes on the tubes, which would be read by the barcode reader, and the subsequently delivered samples (urine, stool) would get barcodes that would then be read and identified with the ID of the patient. The process of blood extraction, as such, is difficult to improve, but one of the lean tools that can be applied is definitely 5S for job scheduling, standardization of the process and heijunka, where will be provided an education of laboratory technicians and, if necessary, other employees in the department about the best ways of taking samples, behavior with patients, behavior in stressful situations, etc. Currently, there are 8 rooms where samples are taken. As the number of patients grows, one of the suggestions is definitely an increase in the number of sampling rooms that will ensure the ability to serve more patients during the day.

One of the problems encountered in collecting samples is sample stands, urine bottles and bottles for stool samples. In the sample stand, all samples from one patient cannot be uniquely placed (for example, several different tubes, a sample of the stool, a sample of urine). The suggestion for improvement is, of course, consisted of the creation of a new stand, where there will be, apart from the place for test tubes, places for blood and urine samples that can be in the line (Figure 6.9 and Figure 6.10) - (Kaizen star K.06).

Figure 6.9. Sample stand

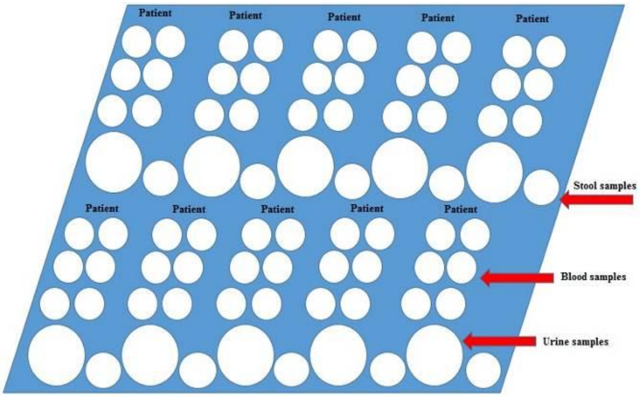



Figure 6.10. Sample stand – proposal for improvement

In the case of urine bottles, as well as the bottle for a stool sample, there are no indications about the quantity of the sample that is needed (Figure 6.11 a.b. and 6.12 a.b.), so it often happens that the samples are inadequately delivered (excessive amounts, contamination of the bottles, delivery of samples in jars or bottles, etc.).


Figure 6.11. Urinal samples (as they are) - and with suggestions for improvement

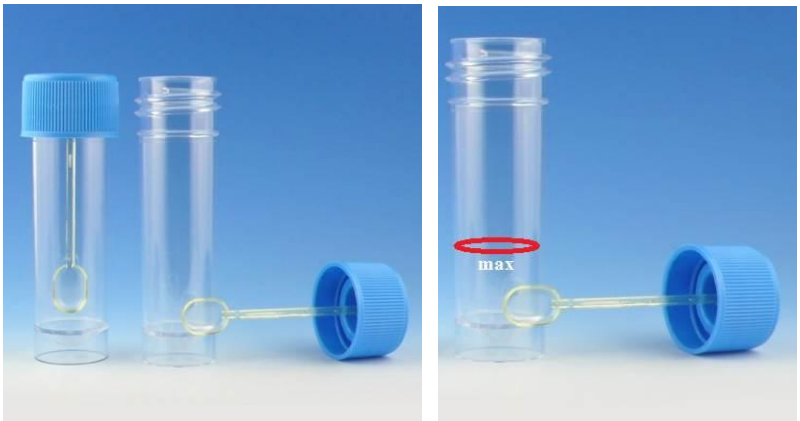



Figure 6.12. Stool samples (as they are) - and with suggestions for improvement

In order to exclude the manual writing of the tubes, which can result in an error in reading the data from the test tube (impure), the author proposes the usage of the tubes that contain barcodes, which could accelerate the process of reading the data and making the worksheets electronically. Figure 6.13 (a and b) shows the test tubes that are now in use as well as tubes containing barcodes (Kaizen star K.08). Also, in the new process, the redistribution of the work process would involve one person who would provide continuous sampling which would eliminate the waiting for samples (Kaizen star K.07)

Figure 6.13.a. Tubes without (source: author) and figure 6.13.b. with barcode (source: https://www.pinterest.com)

After collecting samples by an employee, they are delivered to the laboratory technicians for sorting through departments and creating worksheets. A review of the samples would be simpler with the use of barcodes that would be linked to lists, which will be electronically delivered by the desk service and with the use of new stands, which would speed up the process of sorting and creating worksheets. Duplicate writing of workbooks could be avoided by printing worksheets that would be entered into the registry instead of being manually written (Kaizen star K.08). After creating worksheets and sample sorting, a layout was changed, so both, receiving and distribution department and the biochemical analysis department were set up as one department (located next to each other) (Kaizen star K.09). After sorting samples and making worksheets, laboratory technicians could immediately take samples for their department and sort them according to the devices where they are going to be processed (Kaizen star K.10). Also, samples will be centrifugate, data and sample will be entered into the apparatus, and the analysis of the samples will start. At the same time, during the morning preparation of apparatus, that lasts for about half an hour, it is possible for laboratory technicians to assist the reception and distribution department and vice versa if the need arises.

Organizing process in this way will completely ensure elimination of the waiting time for the samples for 60-90 minutes per day, saving time from minimum 30 working days per year (for example in 2017), and waiting for the apparatus functionality of 12 minutes due to lack of samples. Since the daily level of analysis in the biochemical laboratory is 2.700 analysis/day, the merger of the departments would provide more analyses of approximately

80.000 analysis per year and will result in time-saving, too. In addition to the increase of the efficiency of the laboratory, it would eliminate the movement of samples in the amount of 39,000 - 52,000 meters / year, as well as the movement of employees who must cross the path to take samples from the reception and distribution department and submit it to the department for clinical biochemistry from 78,000 - 104,000 meters / year. It is also important to note that due to the loss of the time in the amount of at least one month, the savings on the salaries of employees would save minimum EUR 10,000.00 annually, that could be invested in improving the process itself or in hiring new people.

Considering the results of the examination of the department's directors who say that the number of delays in the results of the analyses ranges from 5% to 15%, a proposal for improvement is given in the new VSM, which would directly influence the timely delivery of data and is reflected in the following: after obtaining the results of the analyses, the proposal for improvement is to review and verify the results in electronic form by verifying and stamp in electronic format by a laboratory technician. After checking by a laboratory technician, the results of the analyses, together with the electronic signature and stamp would be electronically checked by the department manager (Kaizen star K.11). The results obtained will be electronically delivered to the departments from which the analyzes are requested (Kaizen star K.13) instead of putting the results in the shelves in the hallway (Kaizen star K.12), which would completely shorten the waiting time for the results required by the doctors in other departments, especially if we take into account that the timely delivery of the data (this segment of improvement, in the sense of timely delivery of the data according to the opinions of the director of the department, it is very important; the results should be obtained before 01:00 PM, prior to the visit of the patients). This approach would eliminate the waiting for the results of analyzes on the shelves (Kaizen star K.12), which are taken by employees in a few minutes, up to a few hours (until the end of working hours), which results in eliminating unnecessary time from 2 to even 43 days per year. Also, the results of the analyzes that came from the reception and distribution department would be forwarded to the receiving department where the patient could request the printout of those results or the electronic versions of them on the e-card so that their selected doctors will have direct access to the data (Kaizen star K.14). Delivery of the results electronically into the patient's card, as well as to the different departments from which the samples come, will achieve the JIT (just in time) delivery of data to doctors, which, from a medical point of view, can be a very important factor in the timely identification of possible patient illnesses and the creation of therapies for treatment. As the results in the new system are electronically delivered to different departments, it is possible to find potential errors in the results of analyzes much earlier, thus creating the possibility of accelerating signaling on a potential error in analyzes.

Delivering the results electronically will also eliminate returning of the patients again into the hospital to get results (Kaizen star K.15), excessive printing and therefore the waste of working materials such as paper for printing, toner, consuming and maintaining printers, etc., will be eliminated, too. A detailed view of the VSM of the current state of the system with the display of all kaizen stars where these improvements need to be carried out is shown in Figure 6.14.

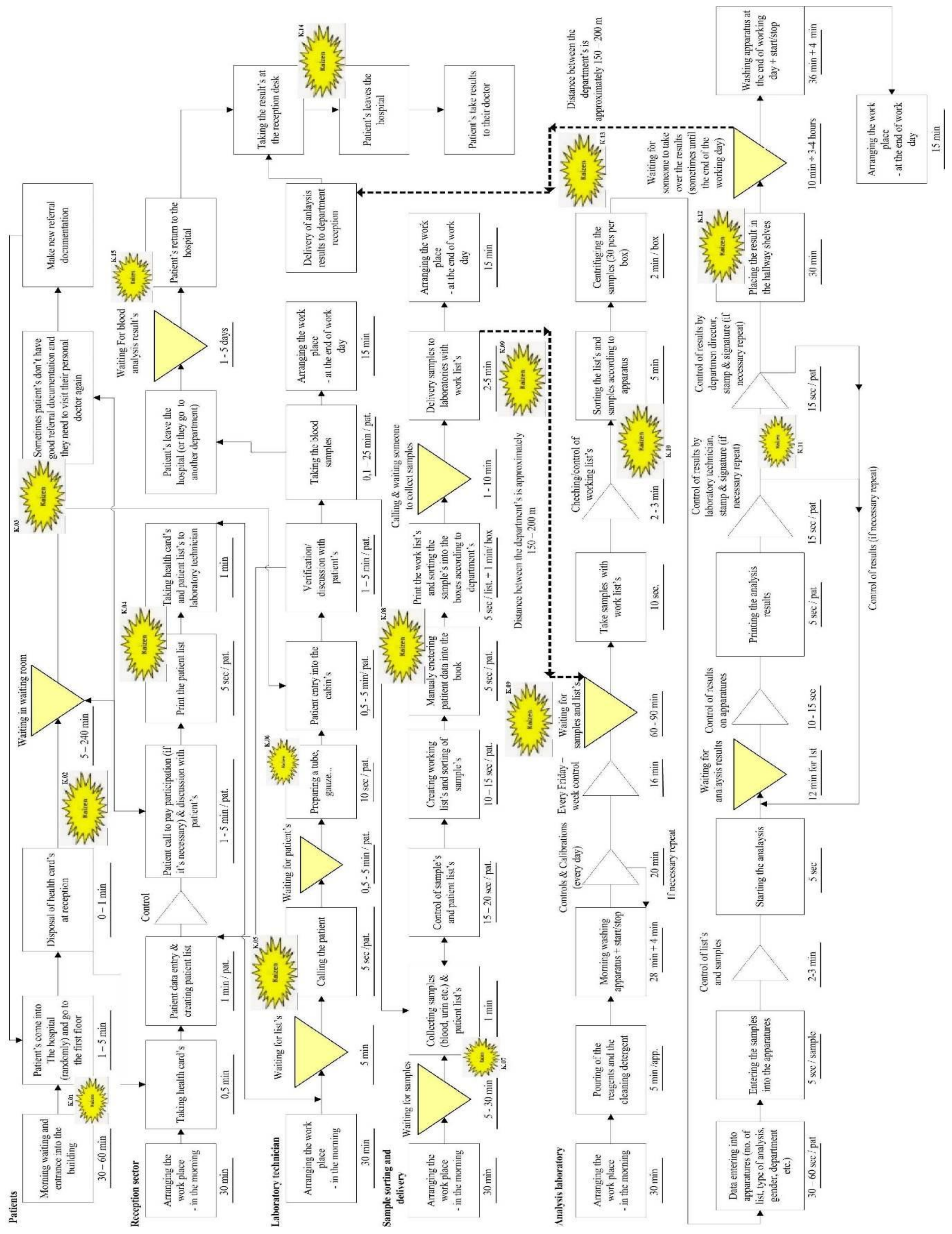



Figure 6.14. VSM of the current process with necessary improvements (kaizen stars)

In order to give a more precise explanation of why it is necessary to implement each Kaizen star in the VSM of the current state, the table below presents a preview of the problems - solutions and expected results for each Kaizen star with display how those improvements will affect the selected KPI's (Table 6.54), and figure of the VSM of the new process after improvement is shown in Figure 6.15.

Table 6.54. Tabular display of the problem - solution - expected results & Kaizen star with impact on KPI’s

| **Kaizen star No.** | **Problem** | **Solution** | **Expected results** | **Lean tools** | **Influence on KPI’s** |
|---|---|---|---|---|---|
| | | | | | |
| Kaizen star 1 | - absence of system for scheduling patients | - a new system for scheaduling patients | - possibile appointment through the network | Kaizen, VSM | - improvement of patients’ satisfaction |
| Kaizen star 2 | - waiting of the patients in the morning hours<br>- excessive crowds at the counter and waiting rooms | - enabling the scheduling and creation of patient groups that would arrive at a precisely defined time | - elimination of waiting in the morning hours and also elimination of the excessive crowds at the counter and waiting rooms | VSM, Kaizen, Pull system | - improvement of patients’ satisfaction<br>- inventory turn over<br>- lead time<br>- process time<br>-increase no. of patient served |
| Kaizen star 3 | - errors that occur due to unsuitable document | - selected doctor through the electronic system defines which analysis should be done for the patient | - elimination of errors that occur due to unsuitable document<br>- selection of all necessary analyses for the patient by his doctor | Kaizen, VSM, TPM, Heijunka, 5S, Standardization | - reducing number of errors |
| Kaizen star 4 | - unnecessary spending of resurces (paper, toners etc.) | - since the entire scheduling process would go to electronic system there will be eleiminated unnecessary printing of different work lists, duplication of patient records, etc. | - assigment of the ID to patient that follow patient samplet true process<br>- ellimination of unnecessary printing of patient list’s | Kaizen, Jidoka, Kan Ban, Standardization, Pull system | - inventory turn over |
| Kaizen star 5 | - lack of information for patients in waiting room | - in the corridors it is necessary to set up different types of monitors to provide adequate information to patients(visual management) | - education of patients<br>- information of patients | Kaizen, VSM<br>Visual management | - improvement of patients’ satisfaction |
| Kaizen star 6 | - inadequately sample delivery and handling | - new sample stands made on poka yoke principle<br>- new urin and stool bottles | - elimination of inadequately samples delivery | Kaizen, VSM, TPM, Poka Yoke, SMED, 5S, Standardization | - reducing number of errors<br>-reducing employee departure from work |
| Kaizen star 7 | - samples stand too long in sample rooms | - redistribution of work process | - faster delivery of samples to sample sorting and delivery room | Kaizen, VSM, JIT, Standardization<br>Layout | - lead time<br>- process time<br>-reducing employee departure from work |

| Kaizen star No. | Problem | Solution | Expected results | Lean tools | Influence on KPI's |
|---|---|---|---|---|---|
| | | | | | |
| Kaizen star 8 | - errors due to manual writing on the tubes | - a new tubes with bar code | -ellimination of manual writing<br>-elimination of errors due manual writing and errors in reading data from tubes | Kaizen, VSM, TPM, Heijunka, Kan Ban', Nagara, Standardization | - reducin number of errors<br>-reducing employee departure from work |
| Kaizen star 9 | - very long waiting for samples between departments for biochemistry and receiving and distribution department | -integration of the departments | - elimination for sample waiting (at least 60-90 minutes per day) | Kaizen, VSM, JIT, Standardization Layout | - lead time<br>- process time<br>- reducing number of all activities<br>- increase no. of patient served |
| Kaizen star 10 | - too long spending time for preparing the samples | - after the merger of the department, the preparation of the samples would be significantly accelerated because the workers from both departments would work in conjunction | - after sorting samples and making worksheets, laboratory technicians can immediately take samples and sort them according to devices | VSM, Kaizen, Layout, JIT | - lead time<br>- process time<br>- increase no. of patient served |
| Kaizen star 11 | - manual checking, stamping of the analysis results | - a new electronic system that will enable electronic control and document check | - the results can be checked, signed and stamp electronically by a laboratory technician and department manager | Kaizen, VSM, Standardization | - lead time<br>- process time<br>- reducing the number of all activities<br>- reducing number of errors |
| Kaizen star 12 | - results wait in the shelves in the hallway sometimes up to few hours per day | - a new electronic system would ensure that the results of the analysis are no longer deposited in the hallway shelves | - elimination of that step in the process | Kaizen, VSM, JIT | - lead time<br>- process time<br>- reducing number of all activities |
| Kaizen star 13 | - too long waiting for results | - a new electronic system would allow the direct transmission of results after control to different departments | - elimination of unnecessary time for 2-43 days/year | Kaizen, VSM, JIT | - lead time<br>- process time<br>- reducing number of all activities<br>-improvement of patients' satisfaction |
| Kaizen star 14 | - unnecessary spending of resources (papers, toners etc.) | - since the entire scheduling process would go to the electronic system there will be eliminated unnecessary printing of different work lists, duplication of patient records, etc. | - electronically results in delivery on patients e-card | Kaizen, Jidoka, Kan Ban, Standardization, Pull system | - lead time<br>- process time<br>-improvement of patients' satisfaction |
| Kaizen star 15 | - unnecessary patient return in the hospital for analysis results | - a new electronic system would allow the results of analyzes to be delivered to selected doctors from patients, or directly to the patient's carton. | - electronically delivery of results and elimination of unnecessary patient return in hospital | VSM, Kaizen, Pull system, Standardization, | - improvement of patients' satisfaction |

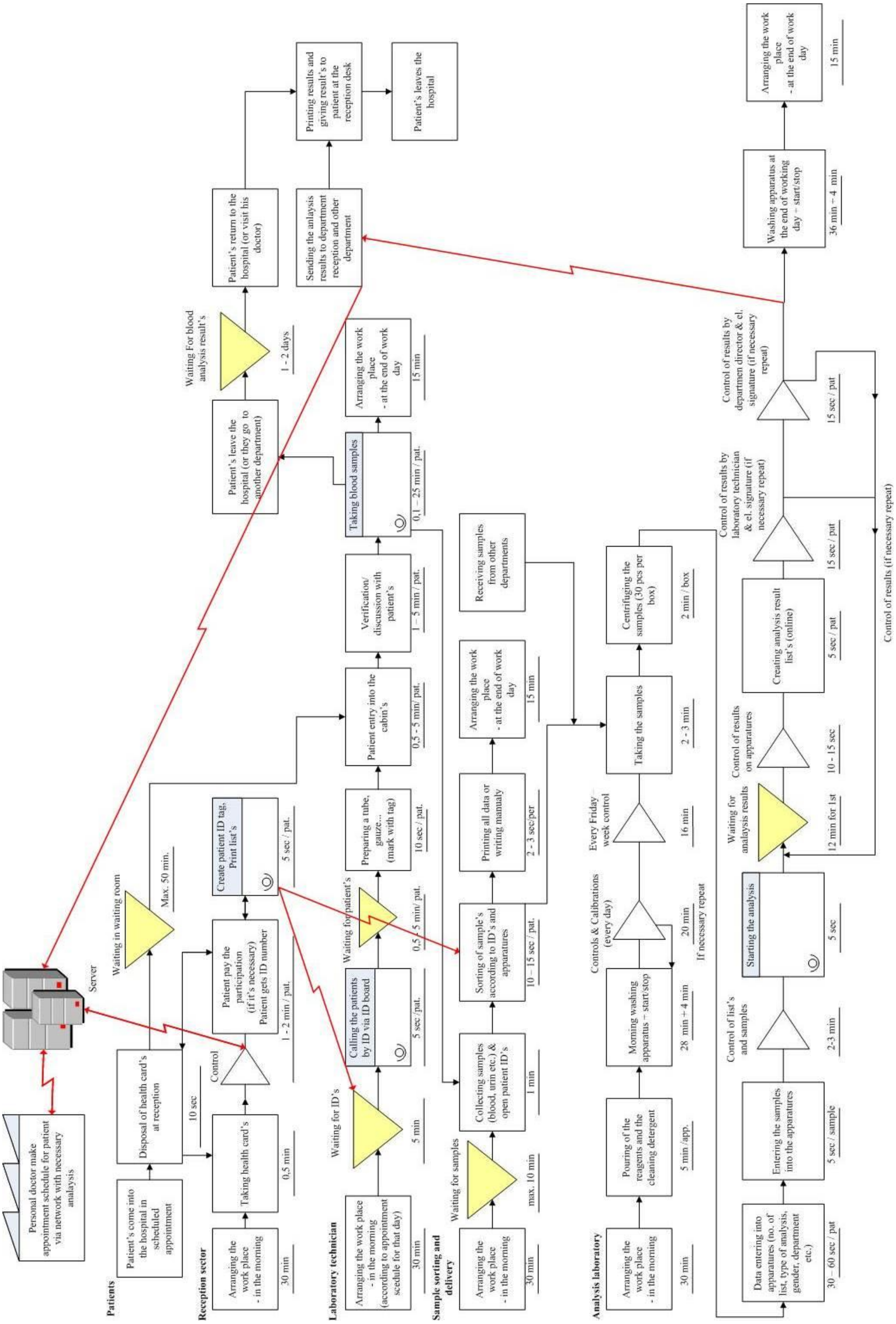



Figure 6.15. VSM of the new process (future state)

# 7. Simulation

## 7.1 INTRODUCTION

As already mentioned, the simulation of the system represents the last step of the developed model. After collecting patients', employees' and doctors' attitudes by using questionnaires, defining KPI's, as well as detail system analysis and displaying the current state and future state of the system with the help of the mapping tool, the application of the VSM tool, the author used the FlexSimHC software package (student license) for displaying advancement proposals (simulation).

The prediction of the new system was done by using tools of the lean concept which could regulate the layout and processes in the system, which will be displayed in the simulation. It is important to note the limitations that the author had during the simulation of the system. In the doctoral dissertation, the author used a student version of a software package that has appropriate limitations in terms of the number of allowed objects during the simulation and the limited number of operations offered. In order to confirm the results of the system improvement, there has been made a simulation (figure 7.1) of patient movement in the new system based on the future state VSM, which was set up according to the lean principles.

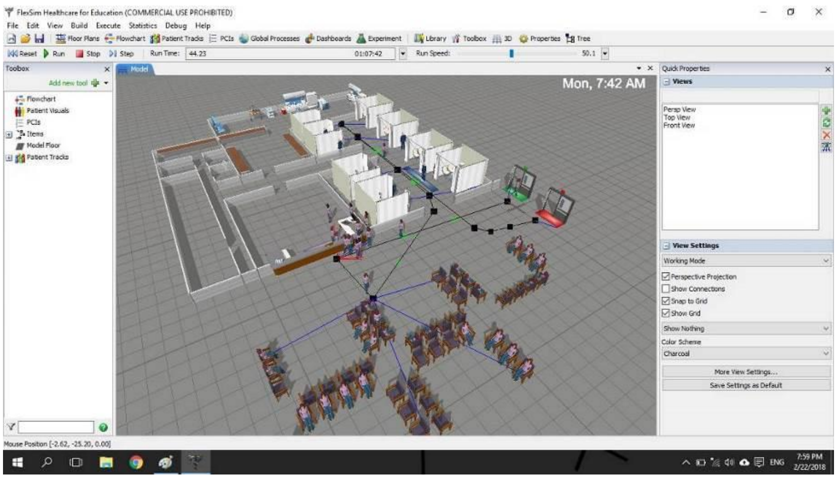



Figure 7.1. Simulation of patient movement in the new system

Figure 7.1 shows a new layout of the process according to VSM of the new process (figure 6.15) where the department for reception and distribution of materials and the clinical biochemistry department are integrated. Such spatial structure ensures the elimination of the movement of samples between the departments (in the amount of 150-200 meters between buildings) as well as the movement of employees. Based on the available data, it is concluded that between 350 and 400 patients are served per day in the department for reception and distribution of materials, the collection of health cards is performed according to the scheduling system, and the sampling period lasts until all the patients are serviced.

It is important to emphasize that the system is modeled according to the current status of the layout of the department for receiving and distribution of materials to which the department of biochemistry was added. The reason for the reduced layout display is the limitation of the number of modules allowed by the Flex Sim HC software package with a student license. Of course, the number of modules does not diminish the simulation results that are explained in more details in the continuation of the doctoral dissertation.

The simulation of the system has been performed in several repetitions. Initially, it was performed the simulation of the system (system 1), which was designed based on the current VSM state, shown in Figure 6.14. The aim of this simulation was to show current times in the system and which was used us as a comparative view in relation to the times that have been enhanced in the new system. After simulation of system 1, it has been made a simulation 3 variations of the system that was designed according to the future state VSM shown in Figure 6.15. which includes systems 2, system 3 and system 4. In the new system's, the receipt of patient cards would not be performed in the morning from 7 to 9 hours, but it would have been distributed according to scheduled appointments, that is, the system will be set up so that patients came in line with scheduled appointments, which would ensure the service of approximately 400 patients per day. The simulation of these systems was made on the basis of the future state VSM, but each of these systems had different input parameters and consequently different output parameters of the simulation. The aim of this approach was to select the most favorable system, which, on the basis of the defined input parameters, gives the most favorable output parameters. A more detailed view of the input parameters is defined below. Simulation of the system was performed, as stated, on four samples:

- **SYSTEM 1:** the simulation of the system represents the current state of the system (see figure 6.14) that does not have a scheduling system with the current number of employees (7 employees at the desk – three employees in direct contact with patients while the other four employees are processing data, and 8 rooms and technicians for sampling),
    - time for data/patients health card processing is 1 minute/patient,
    - the time that patient spend in sampling rooms is 4 minutes/patient,
    - time of collecting health cards is in the period from 7 am to 9 am in the morning,
    - a number of patients is 400 per day.

- **SYSTEM 2:** the simulation of the system represents the future state of the system (see figure 6.15). The system work according to the scheduling system with 7 counter employees (all in direct contact with patients), and 8 rooms and technicians for sampling,
    - scheduling patients every half hour,
    - time for patient data processing is 1 minute/patient,
    - the time that patient spend in sampling rooms is 4 minutes/patient,
    - a number of patients is 400 per day.

- **SYSTEM 3:** the simulation of the system represents the future state of the system (see figure 6.15). The system works according to the scheduling system with 5 counter workers (all in direct contact with patients) and increasing room for sampling and laboratory technicians from the current 8 to 10 (2 workers moved from counter to sampling)
    - scheduling patients every half hour,
    - time for patient data processing is 1 minute/patient,
    - the time that patient spend in sampling rooms is 4 minutes/patient,
    - a number of patients is 400 per day.

- **SYSTEM 4:** the simulation of the system represents the future state of the system (see figure 6.15). The system works according to the scheduling system with 5 counter workers (all in direct contact with patients) and increasing room for sampling and laboratory technicians from the current 8 to 12 (2 added technicions)
    - scheduling patients every half hour,
    - time for patient data processing is 1 minute/patient,
    - the time that patient spend in sampling rooms is 4 minutes/patient,
    - a number of patients is 400 per day.

The time for receiving patients and processing the health cards was set on 1 minute/patient, and the average time that patient spend in eight sampling rooms (blood draw) was set on 4 minutes/patient (the average patient service times, as well as the average retention of patients in the rooms for taking samples, were obtained on the basis of patient recording and recording of employees at the counter service). Although the average speed of a healthy man is approx. 60-80 meter/min, for the purpose of the simulation speed of 50 meters/minute was used since it was observed during the study that a large number of patients are elderly people who move slower. The new layout presents a system based on the principle of scheduling as well as on the principle of FIFO (first in first out), assuming that all the patients scheduled are complying with the dates of arrival.

## 7.2 SIMULATION OF THE SYSTEM 1

In System 1 (see figure 7.1 above), which is based on the current state of the system, it is possible to notice very large crowds in the receiving department, by simulation. One of the reasons is certainly the time for collecting health cards that last for two hours and the lack of a scheduling system for patients. Given that 350-400 patients are served on a daily basis, due to the admission of health cards for a period of two hours, all patients must come in the specified period if they want to be served. Current hospital capacities are not designed to accommodate so many patients in such a short period of time and also there is not enough seating space in the waiting room. As emphasized earlier, it was noticed that all the rooms are not operating at the same time and that samples are not taken in all rooms. The simulation is set so that the average time in all rooms is 4 minutes per patient and that all the rooms work constantly, but even then it was not possible to speed up the process that would lead to the reduction in the crowd in the waiting room. One of the parameters of the new system that was obtained in the simulation confirming the results of the study is the average time spent by the patients in the simulation at the counter min. 1 [min]; max. 9.54 [min] and avg. 2.31 [min]. When it comes to waiting times, the simulated times are min. 1 [min]; max. 165.5 [min] and avg. 91.3 [min]. As all other shortcomings in the current system have already been described in detail, a more detailed description of all other simulation parameters will be preseted in detail for newly simulated systems.

## 7.3 SIMULATION OF THE SYSTEM 2

System 2 (see figure 7.1 above) is also based on the current system in terms of resources (number of employees and number of sampling rooms) but with the implementation of the scheduling system. This approach ensures the elimination of excessive crowds, especially in the early morning hours. The simulation provided a division of patients in groups of 50 patients for every half an hour, but even such kind of approach did not provide significant reductions in crowds, especially at a later stage of the simulation. In this simulation system, different combinations were performed, with the number of patients per group, but satisfactory data could not be obtained to ensure the high quality of service for 400 patients per day. It is important to note that the number of employees in system 2 did not change, nor did the number of blood collection rooms, etc. The average time of patients at the counter obtained from the simulation are min. 1 [min]; max. 7.41 [min] and avg. 1.34 [min]. When it comes to waiting times, the simulated times are min. 0.5 [min]; max. 24.44 [min] and avg. 18.03 [min] but crowds in the waiting room are not avoided. Technicians in the simulation do not have continuity of work all the time and it happens that sometimes they wait for the possibility of equalizing the number of patients by groups that provide a continuous process regardless of the combination of a number of patients.

## 7.4 SIMULATION OF THE SYSTEM 3

Simulation in systems 1 and 2 showed that too many staff at the counter provide services for a larger number of patients who then create crowds due to the waiting in the waiting room and that the number of laboratory technicians and number of rooms does not meet the needs for serving patients in the appropriate time period. Based on the above deficiencies in the previous two systems, System 3 (Figure 7.2) is set up so that the number of workrooms is expanded from 8 to 10 rooms, while the number of employees at the counter is reduced by two employees, from the current 7 to 5 employees. The idea of reducing the number of employees is not in layoffs, but in the idea that two workers from the counter could be re-qualified into laboratory technicians.

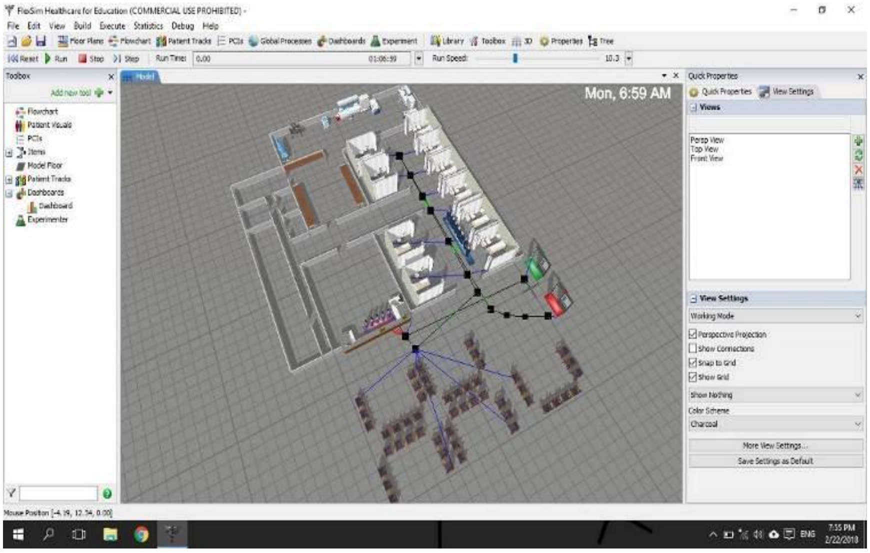



Figure 7.2. System 3 – simulation

Since the time spent in the sampling rooms is the longest working phase, by introducing only two sampling rooms and two more employees in the process of the blood draw, the process is accelerating for almost 20 patients per hour, representing almost 60 patients in 3 hours, an increase of 15% on an observed sample of 400 patients per day. So, the simulated time for serving 400 patients per day is 3 hours and 20 minutes. The new system has also been upgraded with a patient scheduling system. A system was first set up in the way that the scheduling system encompasses 50 patients every half-hour, but during the simulation, it was found that in some instances the work process ended due to patient deficiencies. Based on this, the system was simulated in several combinations until the optimal number of patients per group was found, as shown in Table 7.1.

Table 7.1. Displaying the number of scheduled patients per group

Patientarrival

**Custom Arrivals**

Rows 7 Labels 0

| | Start Time | End Time | Number of Arrivals | PCI |
|---|---|---|---|---|
| 1 | 01:06:59 | 01:07:00 | 40 | 1.00 |
| 2 | 01:07:10 | 01:07:31 | 50 | 2.00 |
| 3 | 01:07:40 | 01:08:01 | 60 | 1.00 |
| 4 | 01:08:10 | 01:08:31 | 65 | 2.00 |
| 5 | 01:08:40 | 01:09:01 | 65 | 1.00 |
| 6 | 01:09:10 | 01:09:31 | 60 | 2.00 |
| 7 | 01:09:40 | 01:10:01 | 60 | 1.00 |

In the initial phase of the work, the first group of scheduled patients should not be greater than 40 patients in order to avoid crowds in the waiting room at the very beginning. All the patients in the group can be serviced in 10 minutes at the counter, and the first patients can complete the entire process for 6-7 minutes. In order to be as precise as possible in the simulation, the following groups are set up to allow the arrival of patients up to 25 minutes before the appointment. The next group of scheduled patients includes 50 patients, then 60, etc. This arrangement of patients per group permits a continuous process with very short wait times while ensuring that there are no interruptions in the work process. Unlike system 1, the receipt of health cards is shifted for 1 hour, reception of health cards lasts between 7:00 and 10:00 AM, while the maximum time required for serving all patients, as already stated, is 3 hours and 20 minutes.

The average patient time at the counter obtained from the simulation is min. 1 [min]; max. 7.47 [min] and avg. 2.75 [min]. Although the average patient waiting time at the counters is a bit longer than in the system 2, it is important to note that, when it comes to waiting in waiting rooms, the simulated waiting times for patients in the waiting rooms are min. 0.5 [min]; max. 9.57 [min] and avg. 4.39 [min] and crowds in the waiting room are avoided. As already stated, the maximum waiting time for patients at the counter is 10 minutes, while the longest stay of patients in the waiting room is 20-25 minutes, which is significantly below the time obtained by statistical data processing in the amount of 40 minutes, which ensures the patient's satisfaction status is neutral. Technicians in simulation due to the uniform inflow of patients have continuity of work all the time and it is avoided that they sometimes wait for patients. Also, the possibility of equalizing the number of patients by groups that provide a continuous process is ensured.

## 7.5 SIMULATION OF THE SYSTEM 4

Since the number of sampling rooms is a part of the process that determines the waiting period in the waiting rooms, it is checked whether the increase in the number of rooms significantly influences the improvement of the process. The number of rooms in system 4 (Figure 7.3) was increased by two more places in relation to system 3, from 10 to 12 rooms. In such an established system, significant improvement in service time is obtained (48 patients/hour more than in system 1 and 2, respectively 24 patients/hour more than in system 3), which accelerates the whole process for 35 minutes. Although this system gives the best results when it comes to the speed of serving patients, it is important to emphasize the disadvantages that such system pulls behind. At the initial stage, it is necessary to significantly increase the capacities and equipment, and it is necessary to employ two more new employees, which at the initial stage represents a significant cost. The issue that could not be ensured by increasing the number of sampling rooms is the creation of groups of patients that would provide that the number of patients per group will not increase the crowds in the waiting room or the interruption of the process. The average time of patients at the counter obtained from the simulation are min. 1 [min]; max. 7.50 [min] and avg. 1.40 [min]. When it comes to waiting times, the simulated times are min. 0.5 [min]; max. 10.48 [min] and avg. 6.06 [min] indicating that the average waiting time for patients is longer than the system 3, although the capacity within the system 4 has been significantly increased.

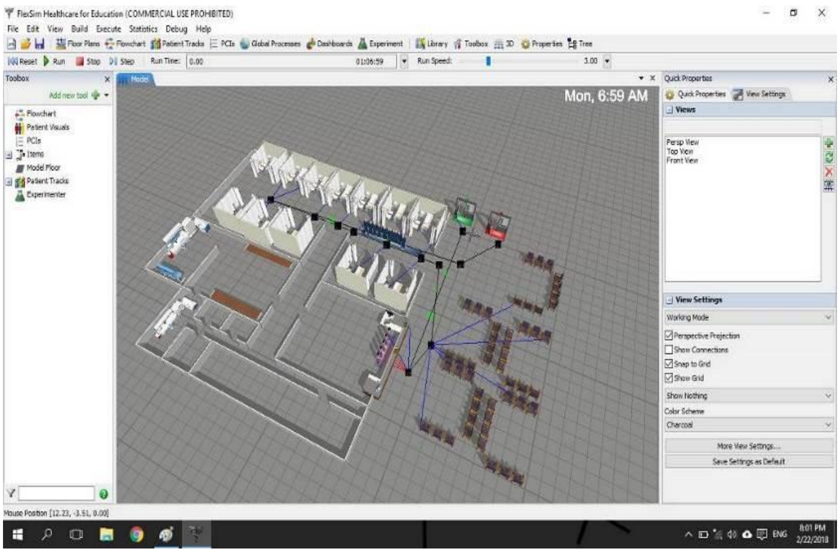



Figure 7.3. System 4 – simulation

## 7.6 CONCLUSION

Based on all of the above facts, it was concluded that System 3 is the most optimal solution that, with very little investment in resources, using existing resources (employees), ensures the best use of resources, it equips patient waiting, ensures continuous flow of the process, provides approximately uniform patient groups according to scheduling terms, etc. The presentation of the data obtained in the simulation of all four systems is shown in Table 7.2 while the simulation of all systems (video simulation) is shown in the attachment of the doctoral dissertation. In addition to the data obtained in the simulation, the table gives an overview and influence of the implementation of the lean tools in the clinical laboratory processes on the defined KPI's. KPI enhancements relate only to the comparison of system 1 (as is) with system 3 (to be) whose simulation results show the best solution.

Table 7.2. Results of the simulation on four systems

| | **System 1** | **System 2** | **System 3** | **System 4** |
|---|---|---|---|---|
| System for scheduling patients | Does not exist | Exists | Exists | Exists |
| The time that patients spend at the counter (simulation) | min. 1 min<br>max. 9,54 min<br>avg. 2.31 | min. 1 min<br>max. 7,41 min<br>avg. 1.34 | min. 1 min<br>max. 7,47 min<br>avg. 2,75 | min. 1 min<br>max. 7,50 min<br>avg. 1,40 |
| Waiting time in the waiting room (simulation) | min. 1 min<br>max. 165,5 min<br>avg. 91,3 min | min. 0,5 min<br>max. 24,44 min<br>avg. 18,03 min | min. 0,5 min<br>max. 9,57 min<br>avg. 4,39 min | min. 0,5 min<br>max. 10,48 min<br>avg. 6,06 min |
| Crowds in the waiting rooms | yes | yes | justify | occasionally |
| Total duration of the process for 400 patients | 3h 55min | 3h 55min | 3h 20min | 2h 45min |
| Do technicians work in the sampling rooms all the time | no | yes | yes | yes |
| The possibility of equalizing the number of patients by groups that provide a continuous process | / | no | yes | no |
| Number of employees at the counter | 7 | 7 | 5 | 5 |
| Number of employees in sampling rooms | 8 | 8 | 10 | 12 |
| Total number of employees | 15 | 15 | 15 | 17 |

**Improvement of the KPI's**

| | **AS IS (system 1)** | **TO BE (system 3)** | **Improvement** |
|---|---|---|---|
| lead time (from beginning to the end) | more than 24 hours | 2 hours | decreased by cca. 90% |
| process time for 400 patients | 3h 55 min | 3h 20min | decreased by 8,51% |
| reducing % of all activities | 53 different activities | 42 different activities | decreased by 20,75% |
| number of analysis [per year] | 724.434 | approx. 804.000 | improvement for 9,90% |
| inventory turnover | without control | with control | improved |
| employee departure from work place | yes | no | improved |
| reducing % of errors | 5-10% | / | assume to be reduced |
| improvement of patient satisfaction | low | / | assume to go up |

# 8. Discussion of the research

The objective of this research is reflected in the fact that the model for the selection of lean methods and tools that are applicable to healthcare institutions should contribute to the achieving, maintaining and enhancing the competitiveness of those institutions, with the realization of the conditions for business success and consumers' satisfaction. The need for such approach lies in the fact that the implementation of the lean concept in healthcare enables the elimination of all unnecessary processes and thus provides the increase of the efficiency and effectiveness for the implementation process and the system. As stated earlier in this thesis, health systems are composed of subsystems integrated as a whole, for example, one medical institution – hospital consists of different objects (depending on the application), laboratories, operating rooms, room for viewing, storage rooms, rooms for waste removal, etc. In each of these locations, there are processes that can be improved by applying lean concepts. When speaking of "subsystems" of a medical institution that is primarily related to clinical laboratories, nursing, primary care, perioperative service, emergency department, anatomic pathology, etc. The authors Plyutiuc et al. (2013) in his work conducted a systematic literature review of the lean in the healthcare sector with the aim of pointing out the poor relations of research and the area that is rich for further research. As previously mentioned, the literature review shows that the lean concept in healthcare facilities represents a trend that is increasing but the implementation of the lean concept in so-called "subsystems" is not so rich.

One of the very important "subsystems" of health systems are clinical laboratories. Clinical laboratories mainly serve as the backbone for the other processes in the health sector. Those processes could not be implemented without these clinical laboratories. In other words, clinical laboratories are indispensable units that make specific health processes a whole. For example, some doctors cannot bring the appropriate conclusions about the patient's condition until he receives the results of blood, smears on the results of various bacteria, etc., from clinical laboratories. In order to perform certain surgical procedures, preliminary results of the various laboratory tests are usually required in order to avoid possible errors or incorrect treatment of the patient. That fact tells us about the importance of clinical laboratories within the healthcare process, and the importance of improving clinical laboratories to a higher level in order to remove the possibility of any fault. Errors occurred in clinical laboratories often may have disastrous consequences for the patient in terms of poor and improper treatment, for a doctor or his reputation, as for a reputation of the whole organization. Considering the importance of clinical laboratories, the discussion of the obtained results in this doctoral dissertation obtained through the implementation of lean principles and tools in the processes of the clinical laboratory is given below.

By reviewing the improvements obtained by implementing the lean concept within the clinical laboratory process, it is possible to notice the influence of the lean concept on the defined KPI's. Improvements of defined KPIs were made by organizing the Kaizen events (improvements) that are presented as Kaizen stars on the VSM map of the current process as precisely defined places where the implementation of certain lean tools and methods is required in order to improve the process. The influence of different kaizen improvements with the application of various lean methods and tools has had an impact on different defined KPIs. Kaizen star 1 - KS.1 represents a place where the absence of a system for scheduling patients is identified as a problem. The proposed solution was to introduce a new system for scheduling patients, by using Kaizen and VSM lean tools to provide patient scheduling over the network, which would directly affect the KPI defined as an improvement of patients' satisfaction. Kaizen Star 2 - KS.2 signifies the problem that is waiting for the patients in the morning hours and excessive crowds at the counter and waiting rooms. As a solution, it was presented enabling a scheduling system and creation of patient groups that would arrive at a precisely defined time, which will result in the elimination of waiting in the morning hours and also in the elimination of excessive crowds at the counter and waiting rooms. KS.2 enhancement was performed by using VSM and kaizen with the use of a pull principle and the effects would be directly reflected on the improvement of KPIs such as improvement of patients' satisfaction, inventory turnover, lead time, process time and increase number of patient served. KS.4 and KS.14 are places where unnecessary spending of resources arises due to excessive use of different documents, but since the future system will work electronically, these steps would be eliminated with the application of different lean tools with simultaneous impact on the KPI defined as an inventory turnover, lead time, process time and improvement of patients' satisfaction. The new electronic system would provide elimination of errors that occur due to unsuitable document and selection of all necessary analyses for the patient by his doctor, which would directly affect the reducing number of errors. This improvement is defined as KS.3. In addition to the aforementioned improvements in KS.3, due to the implementation of the new electronic system, the problem related to manual checking and stamping of the analysis results (KS.11), results wait in the shelves in the hallway sometimes up to few hours per day (KS.12), too long waiting for results (KS.13) and unnecessary patient return in hospital for analysis results (KS.15) will be eliminated. By enhancing these segments through different lean tools, it will be ensured that the results can be checked, signed and stamp electronically by a laboratory technician and department manager (doctor), completely eliminating the steps within the process of waiting for results on the shelves, elimination of unnecessary time for 2 -43 days / year and electronic delivery of results and elimination of unnecessary patient return in hospital. These improvements directly influence the improvement of KPIs such as lead time, process time, reducing the number of all activities, reducing the number of errors and improving patient satisfaction. Related to the lack of information for patients in the waiting room, by using different lean tools and especially visual management lean tool in KS.5, it was ensured that in the corridors it is necessary to set up different types of monitors to provide adequate information for patients that will provide education and information of patients with improvement of patients' satisfaction. Within KS.6 and KS.8, the problem is defined in terms of inadequately sample delivery and handling, and also errors due to manual writing on the tubes whose improvement will directly affect the reduction of the number of errors and reducing employee departure from work. The KS.6 enhancement will be ensured by the use of a new sample stands made on a poka-yoke principle of new urine and stool bottles which will provide elimination of inadequately samples delivery while the improvement in KS.8 is provided by applying new tubes with a bar code which provides the elimination of manual writing and elimination of errors due to manual writing and errors in reading data from tubes. One of the more significant problems is shown in KS. 9, as very long waiting time for samples between departments for biochemistry and receiving and distribution department. Integration of two departments will provide elimination for sample waiting (minimum 60-90 minutes per day), which will result in improved KPIs such as lead time, process time, reducing the number of all activities and increase the number of patients served. KS.9 enhancement will result in a KS.10 improvement that is associated with the problem of too long time for the preparation of the samples. After the merger of departments, the preparation of the samples would be significantly accelerated because workers from both departments would work in conjunction and after sorting samples and making worksheets, laboratory technicians can immediately take samples and sort them according to devices. This improvement will directly affect the lead time, process time and increase the number of patients served. Problems related to samples stand too long in sample rooms (KS.7) is possible to solve by the redistribution of work process through faster delivery of samples to sample sorting and the delivery room which will certainly influence the lead time, process time and reducing employee departure from work.

All summarized improvements of all defined KPIs that were achieved by implementing lean tools and methods in clinical laboratory processes are presented in more detail below. When it comes to lead time, it has been noted that the entire process has been improved, from the beginning of patient arrival in clinical laboratories to the obtaining of the results of analyzes by 90%. It is important to emphasize that, due to the complexity of the process, lead time and value added time lines, that should have been shown in Figure 6.15, are omitted. Lead time in current system is more then 24 hours while the lead time in the new system is around 2 hours, which, as already mentioned, represents an improvement of cca. 90%. When it comes to value added times, in upgraded system is around 10 minutes/patient. All other times inside the process are non value added times as well as the non value added but necessary steps inside the process. The overall improvement of lead time is the result of all improvements in all processes, such as the elimination of unnecessary movement of samples and employees, the introduction of an electronic patient scheduling system and the delivery of analysis results, etc. This type of improvement is supported by other authors who have been concerned with the influence of the lean tools on the lead time within clinical laboratories (see Chan et al., 2014; Coons, 2007; Sugianto et al, 2017).

Waiting time for patients in waiting rooms has been reduced to a maximum 20 minutes, which is in comparison with the current situation of average waiting time of about 70 minutes, an improvement of 71.25%, which represents a significant improvement (see

Melanson et al., 2009), while reducing the crowd in waiting rooms. The new system would largely avoid unnecessary movements of employees from their jobs (see also Yerian et al., 2012). By statistical processing of the obtained data, the patient's satisfaction with the time-to-wait in the waiting rooms is approximately neutral, 40 minutes of waiting, which indicates that the patient's satisfaction would certainly be increased by reducing the waiting time of patients. Another factor that has greatly influenced the reduction of lead time is certainly a decrease in the number of activities within the process, from 53 different activities to 42 activities, which represents a reduction of 20.75%. Such improvements confirm the views of researchers who claim that the lean concept within clinical laboratories after implementation and standardization of the process significantly reduces all activities (see Amirahmadi et al., 2007). When it comes to the number of analyzes carried out, the possibility for improving the number of analyzes conducted per year was noticed by 9.90% or 724.434 analyzes (observed for the period in 2017) to approximately 804,000 analyzes per year. Some authors investigated the number of patients served (Morón-Castañeda et al., 2015) after implementing the lean concept, and found an improvement of 38%. Since in this research we obtained only the results of the number of analyzes, it is possible to conclude that the increase of the number of performed analyzes could be directly related to the increase of the number of patients served. When it comes to inventory turnover at this stage, we could conclude that the current system does not have an adequate information system that adequately monitors and optimize the procurement of funds for the work, and in order to create the conditions for its optimization, we proposed the appropriate information system. Also, when it comes to the number of errors related to the results of the analysis, the survey of department heads concluded that the errors are in the amount of 5-10%. The introduction of the electronic system and the purchases of the new equipment (machines and means of operation with all of the aforementioned improvements described in the part 6.5), etc., will obtain conditions for reducing the number of errors both by the employees and by the machines (see Novis, 2008), with the possibility of faster detection of possible errors and signaling for correction of them.

Hypotheses **H1** (***Principles and tools of Lean concept can be implemented in the clinical laboratory***) and **H2** (***Implementation of Lean principles and tools in the clinical laboratory will: improve clinical laboratory processes and results, maximize process flow without adding more resources and reduce waiting time for laboratory results***)**:** based on the above-mentioned, it is possible to conclude that the implementation of lean principles and tools is possible within the process of clinical laboratories, and that implementation of various lean principles and tools improved clinical laboratory processes and results, maximize the process flow without adding more resources and reduce waiting time for laboratory results. These facts lead to the confirmation of defined hypotheses H1 and H2 in this doctoral dissertation.

**Hypothesis H3** (***It is possible to identify factors that affect a patient's satisfaction with the overall work of the laboratory for a blood draw, which can be improved by applying lean principles and tools***)**:** also, during statistical data processing, there were identified "factors" that need to be addressed during the implementation of lean methods and tools within clinical laboratories that directly affect patient satisfaction. Those are defined as excessive crowds in the waiting room of the laboratory, long waiting time for a blood draw process, long waiting time for obtaining the results of the blood tests and the availability of the information at the counter. On the basis of the obtained results, the third hypothesis in the doctoral dissertation (H3) was also confirmed, defined as: It is possible to identify factors that affect patient's satisfaction with the overall work of the laboratory for a blood draw, which can be improved by applying lean principles and tools.

There were several difficulties during the implementation of the lean concept in the clinical laboratory shown in the doctoral dissertation. Difficulties are primarily reflected in the differences between the implementation of lean concept within production and within service systems. The diversity itself is reflected in the significant interaction of consumers as the ultimate beneficiaries of service activities (e.g. patients) with service providers (e.g. doctors) where they have a significantly greater impact when creating a final service than consumers in production systems where consumers (product users) are not in direct "contact" with manufacturers (machine workers). Also, creating process flow maps through eight questions to create a future situation is significantly more difficult in service sector than in production and is reflected in more difficult definition of the tact time, and also in the fact that the service in clinical laboratories cannot be defined through the finished-goods supermarket from which the customer pulls services. A product as such can be created to meet the demands of more consumers at the same time, while service, especially in clinical laboratories for sampling and analysis, cannot be uninformed, but each service is related to each patient individually. Repeatability of services is significantly more difficult than the repeatability of production of products.

# 9. CONCLUSION

In an increasingly turbulent market environment, the imperative of every company, regardless it is a manufacturing or service one, is the improvement of its business processes while maintaining its customers, and at the same time, the increasing of the consumer satisfaction, and attracting new consumers. One of the most important representatives of the service sector companies is certainly healthcare institutions. Like any other sector, healthcare institutions have begun with the acceleration of their business processes in order to reduce resource consumption, improve and expand their services, improve the position of employees and improve the satisfaction of users of their services, etc. One of the approaches for improving business process of healthcare institutions that have more and more applications worldwide is definitely the Lean concept. The Lean concept “provides a- way to specify a value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less—less human effort, less equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want” (Womack and Jones, 2003). The focus of the doctoral dissertation was on the research of the application of the lean concept within clinical laboratories, conducted at the Clinical Center of Vojvodina at the departments for clinical biochemistry as well as the department for the reception and distribution of samples.

The research problem in this doctoral dissertation was presented as the development of the framework for the implementation and application of the lean concept in service systems - healthcare institutions, which allow modernization of institutional arrangements, both organizational and managerial. The “steps” in implementing the lean concept inside clinical laboratories ensure procedures and tools that directly affect the structure of clinical processes in order to increase their effectiveness and efficiency, competitiveness, etc. In other words, the expected results can be summarized as:

- Individual lean methods and tools increase the effectiveness and efficiency of the clinical laboratories.
- Shortening the flows of business processes.
- Reduction of the time of the process, an increase in the efficiency, reduction of the number of resources.
- Increasing the satisfaction of the users (patients, doctors, employees).

Those results in the doctoral dissertation can be shown through three research hypotheses that have been defined where H1 was: *Principles and tools of Lean concept can be implemented in the clinical laboratory.*

The first tool applied during the implementation of the lean concept in clinical laboratories was Hoshin Kanri. The goal of the Hoshin Kanri X matrix was showing the long-term clinical laboratory plans, the annual actions to be completed with the precisely defined activities to be applied and the KPI's that need to be improved. The second tool applied during the implementation was the VSM - lean tool for mapping the process. With the help of this tool and the previous interviews with the employee, trough the survey of the users of the services, employees, and the directors of various departments, the current state of the process with all the significant characteristics is provided. This process demonstrated the detection of "problematic" sites that need to be improved in order to shorten the process, eliminate unnecessary steps within the process, etc. The VSM tool was also used to create the display of the enhanced process state. Following the presentation of the new state of the process, conditions for the application of KanBan lean were provided, which could be applied after the implementation of the patient scheduling system. This also created conditions for the timely procurement of resources for work in optimal quantities, based on the number of patients scheduled. By eliminating waiting for analysis results in the corridor of the Department of Clinical Biochemistry, the application of the JIT lean tool was provided, too. The significance of this enhancement is reflected in the timely delivery of analytical results for doctors from other departments, the results which were necessary to obtain before visiting the patients in order to be able to monitor the health status of patients and to apply appropriate therapy. In order to inform patients of all necessary information and for the purpose of education, Visual Management lean was used as a monitor on which all necessary information was written for patients. The system of calling of patients based on the usage of the microphone could be excluded since it often leads to confusion among patients in terms of who is on the line and where patients need to go. Such an improved system of operations certainly provided the basis for applying standardization of the process, which enabled one more application of the lean tools – work standardization. With the application of the 5S tool, in addition to improving the jobs that are well marked, the improvements of the working equipment have also been provided. The sample bottles are appropriately labeled in order to give patients an indication of the required quantity of samples to be delivered and a proposal for a new sample collection stand provides uniquely all the samples for a particular patient.

The application of the new system has already begun during the research, but in small steps, through one-off improvements, which ensured the use of the Kaizen lean tool for improving the processes. Since the new process does not expand the resources in terms of the number of employees, the redistribution of the jobs shown in the simulation has been already done. The use of the Nagara tool has ensured that employees are trained to work in all workplaces within their departments. In order to avoid mistakes that could occur during the entry of the data into worksheets from the test tubes, which were written manually by the laboratory technicians, before taking blood or taking samples, the improvement was made in the form of the introduction of bar codes located on the tubes. This enabled the use of the Poka-Yoke lean tool.

The research of the work of the laboratory for a blood draw was performed, also in order to get an insight in the real functioning of the processes in the laboratory in eyes of the users/clients (in this case, patients), but also from the aspect of the staff who work in the laboratory. This part of the research, besides the value-stream mapping (VSM) of the laboratory, is very important because it gives an empirical base for further exploration and confirmation of the second hypothesis which is H2: *Implementation of Lean principles and tools in the clinical laboratory will: improve clinical laboratory processes and results, maximize process flow without adding more resources and reduce waiting time for laboratory results.*

By implementing lean methods and tools in improving the process of clinical laboratories, where the implementation is supported by HC Flex Sim software, improvements have been made, which confirmed the hypothesis H2, primarily reflected in:

- lead time - decreased by cca. 90%
- process time - decreased by 8,51%
- reducing the number of all activities by 20,75%
- increase number of patient served - the number of analysis (per year) is an improvement for 9,90%
- inventory turnover - improved
- patient satisfaction - improved
- reducing employee departure from work place - improved
- reducing the number of errors - reduced

Based on the results of the research conducted in the clinical laboratory for a blood draw, it is obvious that there are few very important issues that “harm” working process of the laboratory and this task is defined in the third hypothesis which is H3: *It is possible to identify factors that affect a patient's satisfaction with the overall work of the laboratory for a blood draw, which can be improved by applying lean principles and tools*.

According to the statistical results of the regression model which is obtained is $y=\beta_0 + \beta_1 x1 + \beta_n x_n$, actually: *The level of the satisfaction of the patients with the overall work of the laboratory for a blood draw =0,671 – 0,005* Waiting for the blood draw (minutes) + 0,404* Evaluation of the work of the laboratory staff + 0,413* The level of the crowd in the waiting room + 0,622* the availability of the information at the counter*

In other words, factors that affect a patient's satisfaction with the overall work of the laboratory for a blood draw can be presented as:

- *excessive crowds in the waiting room of the laboratory;*
- *long waiting time for a blood draw process;*
- *work of the laboratory staff,*
- *long waiting time for getting the results of the blood tests,*
- *the availability of the information at the counter.*

According to the regression model where is *y=5,27 – 0,03*Waiting time for a blood draw – measured in minutes*, in order to secure at least patient satisfaction - *"neutral"*, waiting in the waiting rooms should not last longer than 40 minutes (based on the results from statistical analysis - see Graph 4.1.). By setting up a new system as well as simulating the operation of the new system by using the HC Flex Sim software package, results were obtained where the average waiting times in the waiting room are 4.39 minutes and the maximum waiting time is 9.57 minutes, which represents process improvement for almost 94% compared to the current state of the system, where the average waiting time for the patients is almost 70 minutes. With the application of the HC Flex Sim software solution, there is no evident crowd in the new system, and this problem is solved by introducing the patient scheduling system.

When it comes to long waiting for analysis results, the results obtained would be electronically delivered to the receiving department where the patients could request printing of the results or an electronic version on its e-cards so that their doctors will have direct access to the analysis data same day. Delivery of the results electronically into the patient's card will achieve the JIT (just in time) delivery of data to doctors, which, from a medical point of view, can be a very important factor in the timely identification of possible patient illnesses and the creation of therapies for the treatment. Delivering the results electronically will eliminate excessive printing and therefore the waste of working materials such as paper for printing, toner, consuming and maintaining printers, etc., will be eliminated, too.

While waiting for call for the blood draw, in waiting rooms it is necessary to apply lean tool - visual management or monitor-TVs, where patients will be informed about all necessary information and also the way the laboratory works, patient's obligations, ways of proper delivery of samples, cultural behavior, information on ways of extracting blood (how to behave if the patient has dry skin, if the patient is susceptible to fainting, poorly visible veins, etc.). In this way, in addition to all the necessary data that they need to have, patients would have spent less time in the waiting room and they would be educated, too. Based on the above, it can be concluded that the hypotheses set in the doctoral dissertation have been fully confirmed. All of the above results were obtained by research conducted at the Clinical Center of Vojvodina at the departments for clinical biochemistry as well as the department for the reception and distribution of samples. The lean concept as an approach for improving business processes is an inexhaustible source for future research. The directions for further research include a detailed analysis of the implementation of lean principles, methods, and tools with the support of various software tools within all systems and "subsystems" of healthcare institutions.

# 10. LITERATURE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## FIGURES

## TABLES

# Appendices

**Appendix 1.** Questions for Patients.

**Appendix 2.** Questions for Staffs.

**Appendix 3.** Questions for Doctors.

## Appendix 1

Poštovani, molimo Vas da popunite ovaj anketni upitnik kako biste nam pomogli u podizanju kvaliteta rada na zadovoljstvo svih onih koji su uključeni u proces rada laboratorije.

**A1.** Pol (zaokružiti broj) 1. Ženski (F - female) 2. Muški (M - male)

**A2.** Starost:____________ godina (upisati godine)

**A3.** Pre davanja krvi osećam se (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma loše | loše | neugodno | nisam siguran | ugodno | dobro | veoma dobro |

**A4.** Čekanje na vađenje krvi traje prema Vašem mišljenju traje _____ min, a to je po Vama (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma dugo | prilično dugo | dugo | ni dugo ni kratko | kratko | prilično kratko | veoma kratko |

**A5.** Po Vašem mišljenju čekanje na vađenje krvi je: (zaokružiti broj)
1. neprihvatljivo
2. prihvatljivo

**A6.** Laboratorijski tehničar (osoba koja vadi krv) je na Vaša pitanja (zaokružiti broj)
1. uskratio tražene informacije
2. dao površne informacije
3. ljubazno dao sve tražene informacije

**A7.** Venepunkcija (vađenje krvi) je bila (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma bolna | bolna | podnošljivo | bezbolna | veoma bezbolna |

**A8.** Proces vađenja krvi traje prema vašem mišljenu ________ min a to je po vama: (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma dugo | dugo | umereno | kratko | veoma kratko |

**A9.** Laboratorijski tehničar je za celokupno vreme vađenja krvi (zaokružiti broj)
1. nije razgovaralo samnom
2. vrlo malo razgovaralo samnom
3. ljubazno razgovaralo samnom svo vreme

**A10.** Pre ustajanja sa stolice, nakon vađenja krvi: (zaokružiti broj)
1. tehničar me je pitao kako se osećam i dozvolio mi da ustanem
2. tehničar me je pitao kako se osećam i zadržao me na stolici
3. ništa me nije pitao

**A11.** Po završetku čula/o sam od osoblja (zaokružiti broj)
1. ljubaznu zahvalnost
2. nije bilo komentara

**A12.** Rad zaposlenih ocenjujem (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma neprofesionalnim | neprofesionalnim | prihvatljivim | profesionalnim | veoma profesionalnim |

**A13.** Da bi predao knjižicu na šalteru čekao/la sam ________ minuta što je po Vama (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma dugo | dugo | prihvatljivo | kratko | veoma kratko |

**A13.1** Kako ocenjujete rad zaposlenih na prijemnom šalteru (zaokružite broj)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma nezadovoljnim | malo nezadovoljnim | nezadovoljnim | niti sam zadovoljan niti sam nezadovoljan | zadovoljan | malo sam zadovoljan | veoma sam zadovoljan |

**A14.** Gužve u čekaonici ocenjujem kao (zaokružiti broj)

1. veoma velike
2. prihvatljive (nije velika gužva)
3. nema gužve

**A15.** Zbog gužvi u čekaonici osećam se:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma nervozno | nervozno | malo nervozno | neodlučno | opušteno | malo opušteno | veoma opušteno |

**A16.** Sve potrebne informacije na šalteru prema Vašem mišljenju (zaokružiti broj)

1. nisu dostupne/vidljive
2. prihvatljivo
3. dostupne/vidljive su

**A17.** Prozivanje pacijenata od strane zaposlenih smatram (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma tiho | tiho | prihvatljivo | glasno | veoma glasno |

**A18.** Čekanje na rezultate traje preko 24 časa, što je prema Vašem mišljenju (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma dugo | umereno dugo | dugo | prihvatljivo | kratko | umereno kratko | veoma kratko |

**A19.** Brojevi na sobama u kojima se vadi krv su prema Vašem mišljenju (zaokružiti broj)

1. loše označene
2. dobro označene

**A20.** Higijenu u kabinama za vađenje krvi smatram (zaokružiti broj)

1. neprihvatljivo
2. nisam obraćala/o pažnju
3. prihvatljivo

**A21.** Kakvo je Vaše mišljenje o bezbednosti (sterilnosti) opreme u laboratorijama (zaokružiti broj)

1. neprihvatljivo
2. nisam obraćala/o pažnju
3. prihvatljivo

**A22.** Zadovoljstvo celokupnim radom laboratorije prema Vašem mišljenju ocenjujete kao (zaokružiti broj)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma nezadovoljnim | malo nezadovoljnim | nezadovoljnim | niti sam zadovoljan niti sam nezadovoljan | zadovoljan | malo sam zadovoljan | veoma sam zadovoljan |

## Appendix 2

Poštovani, molimo Vas da popunite ovaj anketni upitnik kako biste nam pomogli u unapređenju kvaliteta rada na zadovoljstvo svih onih koji su uključeni u proces rada laboratorije.

**A1.** Pol **(zaokružiti broj)**: 1. Ženski (F - female) 2. Muški (M - male)

**A2.** Starost:____________ godina **(upisati godine)**

**A3.** Pre dolaska na posao osećam se **(zaokružiti broj)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma loše | loše | neugodno | nisam siguran | ugodno | dobro | veoma dobro |

**A4.** U toku rada dešava se da mi nestane materijala za rad (epruvete, gaza, liste, itd.): **(zaokružiti broj)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| nikada | skoro nikada | retko | nije moguća takva greška | često | skoro uvek | uvek |

**A5.** Koliko često morate da napustite svoje radno mesto u toku radnog dana kako bi izvršili neke druge obaveze **(upisati broj)** ________________________

**A6.** Da li se dešava da morate da radite na drugim radnim mestima ili poslove umesto svojih kolega **(zaokružite broj)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| nikada | gotovo nikada | ¼ radnog vremena | ½ radnog vremena | ¾ radnog vremena | skoro svo vreme | uvek |

**A7.** U toku radnog vremena dešavaju se greške pa je potrebno neke radnje ponoviti **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| događa se stalno | događa se povremeno | nije moguće da se greška dogodi | skoro nikada se ne događa | nikada se ne događa |

**A8.** Vaše radno mesto je prema Vašem mišljenu: **(zaokružiti broj)**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| veoma loše opremljeno | loše opremljeno | korektno opremljeno | dobro opremljeno | veoma dobro opremljeno |

**A9.** Gužve u čekaonici ocenjujete kao **(zaokružiti broj)**

1. veoma velike
2. prihvatljive (nije velika gužva)
3. nema gužve
4. **A10.** Čekanje pacijenata na vađenje krvi prema Vašem mišljenju traje **(zaokružiti broj)**
5. 

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma dugo | prilično dugo | dugo | ni dugo ni kratko | kratko | prilično kratko | veoma kratko |

6. 
7. **A11.** Prema Vašem mišljenju, zbog gužvi su pacijenti najčešće **(zaokružiti broj):**
8. 

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| veoma nervozni | nervozni | malo nervozni | ni nervozni ni opušteni | malo opušteni | opušteni | veoma opušteni | nemam dodira sa pacijentima |

9. 

10. **A12.** Ponašanje pacijenata prema zdravstvenim radnicima smatram **(zaokružiti broj)**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| veoma nekulturnim | prilično nekulturnim | nekulturnim | korektnim | kulturnim | prilično kulturnim | veoma kulturnim | nemam dodira sa pacijentima |

**A13.** Rad sa pacijentima prema Vašem mišljenju je **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| veoma stresno | stresno | malo stresno | niti stresno niti opušteno | malo opušteno | opušteno | veoma opušteno | nemam dodira sa pacijentima |

**A14.** Zbog rada sa pacijentima osećam se **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| veoma nervozno | nervozno | malo nervozno | niti sam nervozan niti sam opušten | malo opušteno | opušteno | veoma opušteno | nemam dodira sa pacijentima |

**A15.** Prema Vašem mišljenju dnevno uslužite približno _______ pacijenata (ili knjižica, uzoraka) ..........................................................................................**(upišite broj)**.....................................

**A16.** Rad sa kolegama prema Vašem mišljenju je **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma stresno | stresno | malo stresno | niti stresno niti opušteno | malo opušteno | opušteno | veoma opušteno |

**A17.** Zbog rada sa kolegama osećam se **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma nervozno | nervozno | malo nervozno | niti sam nervozan niti sam opušten | malo opušteno | opušteno | veoma opušteno |

**A18.** Nakon završetka radnog dana najčešće se osećam **(zaokružiti broj):**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| veoma umorno | prilično umorno | umorno | niti sam umoran niti sam odmoran | odmorno | prilično odmorno | veoma odmorno |

**A19.** Vaše radno mesto prema Vašem mišljenju treba da se **(zaokružiti broj)**

| 1 | 3 | 4 | 5 | 7 |
|---|---|---|---|---|
| veoma unapredi | unapredi | radno mesto je idealno uređeno | ne unapređuje | uopšte ne unapređuje |

**A20.** Rad laboratorije prema Vašem mišljenju treba da se **(zaokružiti broj)**

| 1 | 3 | 4 | 5 | 7 |
|---|---|---|---|---|
| veoma unapredi | unapredi | laboratorija je idealno uređena | ne unapređuje | uopšte ne unapređuje |

**A21.** Navedite ukratko nekoliko načina kako bi unapredili Vaše radno mesto ili laboratoriju:

1.--------------------------------   2. --------------------------------
3.--------------------------------   4. --------------------------------
5.--------------------------------

**Appendix 3**

Anketa je anonimna

Navedite naziv vašeg departmana

_________________________________________________

1. Vaš opšti utisak o usluzi koju dobijate od Laboratorije: izuzetno loše / loše / prosečno / dobro / odlično
2. Vaš opšti utisak o komunikaciji sa Laboratorijom: izuzetno loše / loše / prosečno / dobro / odlično
3. Procenite koliko prosečno mesečno analiza zahtevate od Laboratorije: __________.
4. Procenite koliko različitih analiza u toku jednog meseca zahtevate od Laboratorije: __________.
5. Rezultate dobijate u dogovorenom / očekivanom roku? DA / NE
6. Ako je odgovor na prethodno pitanje DA: Procenite procenat rezultata kod kojih se javlja kašnjenje:_____%
7. Da li bi Vam odgovaralo da rezultate dobijate brže? DA / NE
8. Da li možete zahtevati i dobiti (u izuzetnim situacijama) rezultate u kraćem roku? DA / NE
9. Da li se dešava da nekada rezultati budu sa greškom? DA / NE
10. Ako je odgovor na prethodno pitanje DA: Procenite procenat rezultata na kojima se javlja greška: _____ %
11. Da li bi se kvalitet Vašeg rada popravio, ako bi Laboratorija poboljšala svoj rad? DA / NE
12. Ako je odgovor na prethodno pitanje DA, navedite kakvo poboljšanje u radu Laboratorije biste želeli:

    ____________________
    ____________________
    ____________________
    ____________________
    ____________________

13. Da li bi se kvalitet Vašeg rada popravio, ako bi se promenio / unapredio rad Vašeg Departmana prilikom saradnje / komunikacije sa Laboratorijom? DA / NE
14. Ako je odgovor na prethodno pitanje DA, navedite kakvo unapređenje u radu Vašeg Departmana biste želeli:

    ____________________
    ____________________
    ____________________
    ____________________
    ____________________