Process optimization of hospital units using life-cycle assessment methods

Sarancha, Vitality

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Vitaliy Sarancha

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This dissertation was designed at School of Public Health "Andrija Štampar" University of Zagreb School of Medicine.

First Mentor: Prof. Ksenija Vitale, MPH, PhD

Second Mentor: Prof. Stjepan Orešković, PhD

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Dedicated to my lovely grandfather, teacher and great surgeon prof. Stanislav Sulyma (1928 – 2012). To him I am eternally grateful.

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List of symbols and abbreviations

BIS – Hospital Informational System (software)

CEO – Chief Executive Officer

CEZIH – Central Informational Software of Croatian National Healthcare System

DCA/QCA – Direct Content Analysis/Qualitative Content Analysis

DTP - Diagnostic and Therapeutic Procedures of the Croatian Health Insurance Institution

GDPR – General Data Protection Regulation according to Directive 95/46/EC

ISCED - International Standard Classification of Education

ISO – International Standardization Organization

LCA – Life Cycle Assessment

LCM – Life Cycle Management

LIS – Laboratory Informational System (software)

MCDM - Multi-criteria decision-making software

OED – Oxford English Dictionary

QMS - Quality Management System

REPA - Resource and Environmental Profile Analysis

1. Introduction:

1.1 Quality management: the historical background

The first traces of life cycle assessment and quality management appeared more than four thousand years BC, at the time when commodity barter had been replaced by the development of trade among Greek, Roman, Egyptian, Arab and Phoenician traders (1, 2). Artisans described to their suppliers in simple words from their experience what kinds of materials would be preferable and those that could usefully be eliminated or optimized. This was the common practice because an artificer had no tools with which to measure the composition, strength, chemical and physical characteristics of a given material (3). The Industrial Revolution contributed to the emergence of product specifications (4, 5). Manufacturers began issuing precise descriptions of materials and processing methods in order to ensure that supplies met certain quality criteria (3). Thus, producers were obliged to take samples from each batch, which were then subjected to tests determining their elasticity, tensile strength and so on. When the first factories were established, the requirements for a higher level of order, a greater focus on precision and the subsequent product quality control were introduced (6). Evolving through different stages, beginning during the 'division of labor' of the late 1700s and continuing until early 20th century, the scope of activities from the beginning of a production cycle and to a final phase led to the emergence of the first model-based managerial approaches (7). The revelation of the demandingness of complex tasks was reflected in the implementation of basic managerial principles such as planning, execution, monitoring, controlling, completion and improvement (8). Therefore, for a structurally oriented organization, systematic quality control became a necessity. Later, such generally acceptable quality patterns that won general consent as models or examples were enshrined in law and today are known as standards.

1.2 Standardization and Accreditation

The idea of standardizing is to change the characteristics of a product, process or production cycle so that they are consistent and agree with rules about what is proper and acceptable (9). A standard is a document that specifies such an established set of criteria. More than 21000 International Standards covering almost all aspects of human activity, including healthcare, have been published since February 1947, when delegates from 25 countries met at the Institute of Civil Engineers in London and founded the International Organization for Standardization

(ISO) (10). Today the organization has 162 country members and more than 238 technical committees taking care of the development of standards (11). Since the foundation of the European Union a web of new institutions, such as European Standardization Organizations (ESOs) of 33 European countries and CEN, the European Committee for Standardization, has been established (12). CEN (together with the European Committee for Electro-technical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI)) is officially recognized by the European Union and by the European Free Trade Association as being responsible for developing voluntary standards at European level (13). Regarding the various products, materials, services and processes, the CEN provides a platform for the development of European Norms (ENs) (14). An EN imposes the obligation to be implemented at a national level by being given the status of a national standard and by the withdrawal of any conflicting national standard previously in use. Therefore, a European Standard automatically becomes a national standard in each of the 33 CEN-CENELEC member countries (15). For example, Croatia, after entering the EU, had to harmonise local HRNs (Croatian Norms) with EN's. To facilitate and control the standardization process Conformity Assessment Bodies or Accreditation agencies (AA) were created. An Accreditation Agency is an independent public institution regulated by law whose role is to assess and accredit certification bodies (CBs). A Certification Body is a third party auditing firm that assesses an organization in terms of a specific international standard. Such accreditation, performed by a respected body, ensures competence, fostering confidence in and acceptance by end-users in the public and private sectors. Different countries have their own quality management traditions based on their history, mentality, socio-economic environment and local regulations (16, 17). This otherness is fundamental when well-developed countries such as USA, Germany and Great Britain are being considered, as distinct from the converging nations of Eastern and South Eastern Europe (18, 19). The US has developed a quality infrastructure and there are many organizations that provide accreditation services covering various aspects of health care and public health. Some of them are the Accreditation Association for Ambulatory Health Care, the Community Health Accreditation Partner, the Joint Commission and the Accreditation Commission for Health Care, the American Accreditation Council, and the Healthcare Quality Association on Accreditation (20-25). One of the main acknowledged bodies in healthcare is the National Association for Healthcare Quality (NAHQ). It certifies professionals in health care by according them the recognition of being a Certified Professional in Healthcare Quality (CPHQ). A CPHQ plays an important role in the clinical outcomes, reliability and financial stability of healthcare organizations The key elements of the knowledge of such a professional are information management, measurement and

analytics, quality measurement and improvements well as planning, implementation, evaluation, training, strategic and operational tasks concerning patient safety. In Great Britain, the national standards body is the BSI Group (26). One of the outstanding resulting documents that a group of representatives from BSI created to help organizations put in place occupational health and safety performance is the Occupational Health and Safety Assessment Series 18000 (OHSAS) with its following revision OHSAS 18002, which was accepted as a standard. In the updated edition the "health" component was given greater emphasis and current version became more closely aligned with the structures of ISO 9000 and ISO 14000. This has made it easier for organizations to adopt OHSAS alongside existing management systems (27, 28). Another institution is the United Kingdom Accreditation Forum or UKAF. Founded in 1998 by a group of leading healthcare accreditation organizations, nowadays UKAF is an umbrella structure for organizations providing healthcare accreditation and operates with an interest in developing assessment and accreditation programs in health care and public health (29). The National Institute for Health and Care Excellence (NICE) provides guidance and contains governance information, publications, and policies concerning health care. It collaborates with public health institutions; social care professionals and service users and designs concise sets of statements and guidelines to drive measurable quality improvements within a particular area of health care (30). Furthermore, there is a supervision structure in the UK called the Professional Standards Authority. This body is responsible for overseeing the UK's nine health and care professional regulatory bodies (31, 32). With referrals for topics having a principal area of focus in the UK's healthcare system it is important to mention the United Kingdom Accreditation Service (UKAS), National Health Service (NHS) and the Department of Health (33-35). In Germany as a result of agreement with the German Federal Government, the national standards body is the German Institute for Standardization (DIN) (36). Its experts administer about 29000 standards and it was one of the first well-structured certification institutions in Europe. DIN remains the competent authority regarding technical issues and widely known product/material specifications. The accreditation body for the Federal Republic of Germany is DakkS (37). This has a special Health/Forensics division, which among other tasks attests the third-party certification bodies taking care of Health Care, Forensic Medicine, Medical Laboratory Diagnostics and Medical Devices. Also playing an important role is the German Worker's Welfare Association (AWO) (38). Together with ISO they developed an effective tandem that allows the ensuring of quality in AWO rehabilitation facilities and health organizations. The model combines the requirements of ISO 9001 with those of AWO quality and risk assessment guidelines (39, 40).

Consequently, the quality of a particular facility is measured by the care provided, the organization structure and by the satisfaction of patients and residents. In addition, important requirements for patient safety are formulated by the German initiative called the German Coalition for Patient Safety (41). It provides the basis for process audits, conducted on the client's premises, with the aim of providing it with feedback regarding the degree of implementation of the quality dimension of „patient safety" inside, for example, a particular health care system unit.

1.3 Standards implementation in different countries

Approaches to Standards Implementation are different in the countries, which entered the European Union and in those, which are not. In Croatia the national accreditation bodies are Croatian Accreditation Agency, acting as the national accreditation service and Agency for Quality and Accreditation in Health (52). This latter one acts under the National Strategy for Development of Health 2012 – 2020, whose key points are to define the priorities of encouraging quality and accreditation procedures in public health and social care (53). Despite the general problems in health care, common to every country in transition, due to its strategic location, mild climate, a plenitude of medical and rehabilitation facilities, reasonable prices for recreational activities and an increasing flow of tourists Croatia has great potential with respect to quality standards implementation and development. Targeted assistance in the further development of the Quality Infrastructure in Croatia has been successfully provided by the Joint Research Centre of the European Commission with such amended action programs as the CARDS - Croatia project on the "Development of National Metrology, Standardization, Conformity Assessment and Accreditation System" (54). Other institutions that cope with quality paradigm introduction in Croatian health care and public health are the Andrija Stampar School of Public Health and European Society of Quality in Healthcare (55). In comparison to the quality management systems of the developed countries, Ukraine, as a non-EU member, has a relatively unbalanced quality infrastructure. It bears elements of the former USSR standardizing paradigm, which has to be re-evaluated, updated and adapted to the existing economic and social environment. There are state and industry branch systems of standardization in Ukraine (42). The State branch includes the Ukrainian Scientific Research Institute of Standardization Certification and Informatics, and the Ukrainian State Research and Production Center of Standardization, Metrology and Certification (43, 44). The most flexible are the Service Standards Departments and Industrial Standards Departments. State social standards in the health sector are regulated by the Law

of Ukraine „Fundamentals of Ukraine on Health Care" (45). Since Ukraine became the participant of the Euro Integration process, the reform on local standards adaptation to European and International norms has been significantly accelerated (46). The main principles are shown in the "National Strategy of reforming the healthcare system in Ukraine" which is accepted for implementation for the period 2015 – 2020 (47). More often, private clinics and research centers all over the country engage certification bodies to perform an external audit with the aim of meeting international quality requirements. Standardization in the Russian Federation is based on GOSTs. The word GOST (Russian: ГОСТ) is an acronym for "государственный стандарт" and means the National Standard. There is a set of technical norms maintained by the Euro-Asian Council for Standardization, Metrology and Certification (EASC) (48). One of the steps toward standardizing is the Order of the Ministry of Health "On the introduction of standardization in health care" (49). There are also many national programs and orders in Russia working on the implementation of particular standards in public health (50). The problem in Russia is a hyper-regulation in standardization. The numerous orders, instructions and procedures on the one hand and lack of specific implementation mechanisms on the other causes confusion and regress with regard to harmonization of national standards with their international counterparts. Thus, the Organization for Economic Co-operation and Development (OECD) Series on Principles of Good Laboratory Practice (GLP) is currently operating with GOST R53434-2009 "Principles of Good Laboratory Practice" together with the support of another 14 interstate standards which have been already successfully implemented (51). According to the 2009 Ministry of Health National Background Report "Health in Albania", the country performed very well in sustaining high rates of economic recovery after the financial collapse of 1997 (56). Quality assurance of health systems has been outlined as a priority in Primary Health Care Reform: A Pilot Project to Provide Evidence for Health Policy (57). The national agencies are empowered by the government to be responsible for accreditation of hospitals and licensing of medical personnel. Albania maintains initiatives and a continuous dialog with public institutions such as The Institute of Public Health, private laboratories and clinics as well as with international NGOs, WHO, UNICEF, WB, USAID, regarding the more active participation of the country in the international activities of quality system implementation (58).

1.4 Internationalization of Standards

With the aim of the internationalization of the standardizing efforts in a healthcare, the international quality bodies are operating successfully. One such example is the International Society

for Quality in Health Care (ISQua). It is a parent institution for bodies providing international healthcare accreditation. ISQua provides services in the guidance of health professionals, providers, researchers, agencies, policy makers and consumers to achieve excellence in healthcare delivery to the public and to continuously improve the quality of care (59). Among others, the quality bodies working on the international level are ASTM International, International Accreditation Forum (IAF), Council for Health Service Accreditation of Southern Africa, Quality Management Institute, etc (60, 61- 63).

1.5 Implementation of quality standards in health care

Quality standards cover a broad range of topics and are applicable to commissioners of health, specialists in primary care, public health staff, and social care providers as well as to local authorities and the users of services. Health products, ranging from medical devices and health informatics to traditional medicines and unconventional healing tools are all in the focus of a standards application (64). Standards are designed to encourage healthcare organizations to improve internal quality and performance, minimize risks, including measures to protect, and improve the safety of, patients, to promote a culture of continual improvement, support efficient exchange of information and data protection while benefiting the environment. Depending on the scope of responsibilities and areas of activity every organization is able independently to choose which standards and quality management principles to implement. Another useful standard is ISO 13485:2016 – Medical devices. It is designed to define the requirements for a Quality Management System with the aim to demonstrate a company's ability to provide medical devices and related services that meet client and regulatory requirements. Together with EN 15224:2012 - Certification of quality management systems of health care, with its emphasis on hospital process and risk management, both standards become strong indicators of the care quality level in an institution. The best way to find a relative ISO standard is to search through the work of a particular ISO technical committee (TC) on the ISO web page. Committees focuses on different subjects such as TC94, Personal safety - Protective clothing and equipment, ISO/TC 212, Clinical laboratory testing and in vitro diagnostic test systems, and ISO/TC 210, Quality management and corresponding general aspects for medical devices, TC157, Contraceptives/STI, TC168, Prosthetics and orthotics, TC170, Surgical instruments, TC173, Assistive products for persons with disability, TC194, Biological evaluation of medical devices, TC198, Sterilization of health care products and due to increasing interest in unconventional medicine –on some exotic tools such as ISO/TC 249, Traditional Chinese medicine. The globalised 21st

century brings new challenges for organizations exposed to the international market. With a drastic number of competitors, the increasing demands of consumers and legislators, requirements for quality of goods and services are constantly increasing while there is an ever-growing lack of resources (69). Whether for environmental protection, in the food industry or public health objective testing, calibrations and certifications play a notable role. Assessments ensure that tested products, methods, services or systems are reliable with regard to their quality and safety, and that they correspond to technical criteria and conform to the characteristics, guidelines, and laws. Observational findings indicate that nowadays OECD countries have a relatively well-developed infrastructure of quality management in almost all segments of human activity, including in social care and public health. According to the ISO Health Report, healthcare is one of the world's largest and fastest-growing sectors of society. In 2009 about 12,4% of the gross domestic product of the OECD was spent on health care. These countries are the basis for research and development (R&D) as well as for the improvement of the international standardization environment. On the other hand, studies have shown that South European Countries together with Ukraine and Russia are still a long way from a social paradigm shift and the understanding of quality principles. The most commonly cited problems are the failure to recognize the positive effects of a systematic approach, financial means, long waiting lists, systematic delays of first aid providers, lack of the competent staff due to "brain-drain" and insufficient preparedness of organizations for the implementation of structural changes at all levels (70). Some health centers, clinics, hospitals are funded by the state or county budget revenues (the Beveridge model) or partly from social insurance contributions or earmarked from citizens' wages (the Bismarck model) and consequently do not recognize the need to increase the level of quality and responsibility (71). In addition, high payroll taxes in Eastern and South European countries discourage formal employment, dampen labour demand and increase employment in the informal sector (72). A study published in the British Medical Journal estimates that medical errors are the third leading cause of death in the United States, causing a quarter-million fatalities in 2013 alone (73). This obviously means that the reduction of risks of all kinds is an important problem to be resolved (74). Despite a relatively well-structured *lex artis* standardizing process, its efficiency in many cases remains controversial. Sometimes due to enormous amount of paperwork and bureaucracy certification can become nonsense causing a waste of time and human resources. The combination of all these factors, together with unfair competition, weak governance and corruption cause a lack of willingness for continuous quality improvement which is the ultimate precondition for the efficient functioning of standardization in health care and public health (75). Public health and health care are vital and emotive issues

and their importance pervades all aspects of social life, with not only medical but also social, political, ethical, business, and financial ramifications. Looking into the future, it is impossible to predict exactly how our world will evolve but current trends suggest that together with climate change, migration, urbanization, a growing and ageing population, poverty, emergent diseases, food and water shortages and a lack of access to health services, the future of the health sector will be very complex. New fields of expertise such as medical tourism have been on the rise (76). They create a pool of migrating specialists whose services and reliability need to be properly examined and permanently reviewed. National public health institutions should make a strategic decision to implement quality management systems based on international standards in order to meet long-term goals. If an organization wishes to use one of the worldwide-recognized norms or establish a quality system, it has to ensure the adherence to best practice in everything involved. This includes a mapping processes, setting performance targets and making sure that it continually improves and satisfies the goals of shareholders, clients, and patients. Regular audit processes and subsequent annual assessments meet the needs of health services providers, patients, and in this way guarantee the quality of services and the achievement of the maximum outcome. Standardization creates powerful tools in order to fine tune performance and manage risks while operating in more efficient ways that release time and capacities for innovation, creativity and finally lead to overall success. One of the standardized methodologies that can be implemented for a healthcare system is called Life Cycle Assessment (LCA).

1.6 Holistic approach and Life Cycle Assessment development (LCA)

Rapid industrial development, active population growth, the extremely high level of consumption of resources with the entailed pollution of air, water and soil have induced increasing interest in new eco-friendly tools and technologies. In modern science there is increasing awareness of the concept of social responsibility, which means the obligation to act so as to society at large and a duty for every individual to perform in such a way as to maintain a balance between the economy and the environment (79). Forming the basic patterns for modern science, researchers solved many problems of humanity. Nevertheless, it is necessary to emphasize that since Democritus' reductionist approach was ideologically preferred in the western science, much effort has been directed to the excessive value of details and analysis of processes from the point of view of their decomposition into constituent elements, parts, or small particles. This

has resulted in an underestimation of the interrelations and interdependence of system components and led to the loss of understanding of the systems "holistically". Holism was an idea firstly introduced by Plato, later developed by anthropologists who stated that all the properties of a given system could not be determined and explained by its component parts alone (80). The different aspects of humanity were taken into account. There were the physical (biology) and cultural (archaeology, linguistics), the cross-cultural, looking at what it meant to be human. Therefore, the system as a whole determined how the parts behaved. Thus, the holistic approach was the examination of all the aspects of humanity. According to Merriam-Webster dictionary – "Holistic means relating to or concerned with wholes or with complete systems rather than with the analysis of, treatment of, or dissection into parts. Hereby, holistic ecology views humans and the environment as a single system" (34). In the course of time the concept migrated to medicine and in the 40s was actively popularized by the prominent public health leader Andrija Stampar. He wrote the introductory declaration of the Statute for the recently established World Health Organization and defined health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (81. pp. 697-708). In as much as our fast-developing society requires quick responses to problems and challenges, modern managerial systems have to be not just well structured, so as to exactly facilitate the studying of main subjects, but also integral, fast performing, adaptable, sustainable and capable of being holistically analyzed. The reference frame should be structurally expanded with preservation of objectivity and scientifically reliable conclusions. Thus, through the application of outstanding new tools and technologies inside the boundaries of the proposed enhanced framework, appropriate new and effective methods should be introduced. Among such numerous approaches of a complex analysis we draw attention to the Life Cycle Assessment. Primarily it was adopted for environmental studies with the purpose of resolving environment-related problems of institutions, corporations, and organizations with a more holistic approach. The method was introduced in 1960s, developing until late 90s, when it was organized as an ISO standard; it became a practical method for product stewardship in industry. It is a method that ultimately helps to advance the sustainability of products and society's economic activities. A life-cycle approach takes into consideration the spectrum of resource flows and environmental interventions associated with a product or organization from a supply, consumption chain perspective. Such an approach is essential for effective management. While an established and tested step-by-step methodology exists, there are a number of ways to conduct LCA. The complexity of different environmental systems has led to the development of new alternative impact models.

Translocation of the methodology from products onto processes reveals an opportunity for application to organizations and units in the social sphere, where it would be used to great advantage because of the social roles involved. Performance of LCA in a healthcare system highlights new factors and parameters that should be of a great importance for the development and implementation of an effective public healthcare system model based on principles of careful use of resources, social responsibility, improvement of patient recovery and economic efficiency. Being scientifically proven, it allows the quantification of the environmental damage caused by the lifecycle activity of a product. The method was developed with the purpose of achieving the maximum quantification of the entire life cycle of a product (82). A comparatively short history of its emergence began with Harold Smith's report of a calculation of cumulative energy requirements for the production of chemical intermediates and products in 1960s (83). In the 70s the process of quantifying the use of resources and environmental releases of products became known as a Resource and Environmental Profile Analysis (REPA), as practiced mainly in the United States. In Europe, it was called an Eco balance. From 1975 through the early 1980s, as interest in these topics waned because of the fading influence of the oil crisis, environmental concerns shifted to issues of hazardous and household waste management. Through this period, sincere efforts to create a protocol or standard research methodology for conducting such works were made. The multi-step methodology involves a number of assumptions. During these years, the assumptions and techniques used underwent considerable review by the US Environmental Protection Agency and major industry representatives, with the aim of evolving the most reasonable methodologies. After years of development in connection with these events, the first databases were created. A broad range of practitioners and researchers across the globe has since then been further refining and expanding the methodology. The need to move beyond the inventory to impact assessment has brought LCA methodology to another point of evolution and from 1997 to 2002 led to the development of the LCA standards formalized by the International Standards Organization 14000 series (78). In 2002, the United Nations Environment Programme joined forces with the Society of Environmental Toxicology and Chemistry to launch the Life Cycle Initiative, which now is a well-known international partnership on the subject (84). Topics such as raw materials extraction, energy demand, emission and waste disposal are still important and always in the focus of the integral balancing. New programs and databases aim at putting life cycle thinking into practice and at enhancing the supporting tools through better-acquired data and indicators. One of them is the U.S. Life Cycle Inventory Database that improves global access to transparent, high quality life cycle data by hosting and facilitating expert groups whose work results in web-based information

systems (85). Another one is the Life Cycle Impact Assessment program that increases the quality and global development of life cycle indicators by promoting the exchange of views among experts, whose work results in a set of widely accepted recommendations (86). The "Life cycle assessment - Principles and framework" standard was later reviewed and confirmed in 2010 (87). Since the invention of the method, LCA has been generally used for products in industries with high-pollution outputs and consequently much attention was paid to decreasing of pollution levels in heavy industries and machinery. Many tools were designed and up to 2010 problems with pollution in those sectors were actively and effectively solved. Since then, to add to the expenses involved, health care has become a highly industrialized field. The global expansion of such sectors as pharmacy and the food industry has led to focus on problems with pollution in a healthcare system and consequently the growing demand for the regular assessment of these sectors. Although industries are of a high - priority because of the profits they generate and the wide field they present for research into impacts, a healthcare system is still important because of its social significance and influence on public health.

1.7 Methodological basics of a Life Cycle Assessment

Every product in its life cycle passes through different stages such as raw materials extraction, refinement, processing, manufacturing, distribution, use, recycling, waste disposal etc., and should be analyzed in a frame of reference known as "from cradle to grave" (Figure. 1). This means that any given product should be completely analyzed from the moment of its emergence in various systems - "cradle", to the end of a life cycle - "grave", when the product is disposed of (77).

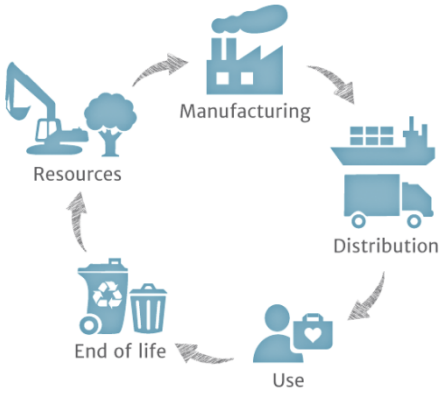


Figure 1. Stages of a product life cycle

Source: "Éco Entreprises Québec".

Our search was performed in "All databases" of the Web of Science in January 2016. From all approximately 3800 articles 1540 were concerned the emergence and development of the method, 1420 were related to the implementation to various industries, more than 780 described newly produced software for environmental impact assessments but fewer than 60 original articles and reviews in different ways addressed the use of Life Cycle methodology in health care, mostly for the pharmaceutical industry, where the levels of waste and environmental impacts are very high (77-89). The method offers a 4 stage, step-by-step assessment process. It includes: goal definition and scoping, inventory analysis, impact assessment, and interpretation as presented in Figure 2.

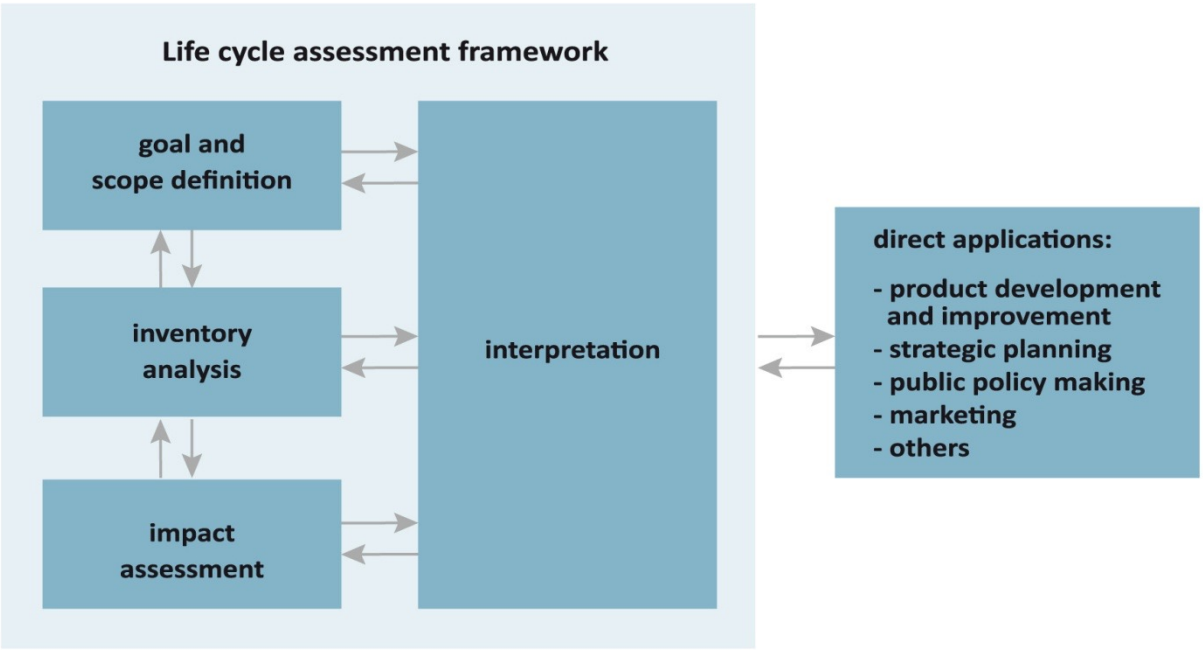


Figure 2. Stages of LCA,
Source: EN ISO 14040

In the first stage the main goal definition and scoping have to be determined. A proper description of a product or activity has to be worked out. Therefore, to obtain adequate results it is necessary to establish the frame in which the assessment is to be made with identification of the environmental effects inside system boundaries. In the second stage which is mainly the collection stage, according to standard methodology, the accurate tracking of all product/process/service cycle "in – out" flows are identified. The identification and quantification of input parameters have to be properly collected. Furthermore, in the third stage an assessment of potential human, technical and ecological effects (e.g. energy, water, and material usage and the environmental releases) identified in the inventory analysis (second stage) has to be conducted. There are various methods proposed for categorizing the life cycle impact of the flows "to" and "from" the environment (78). The reason is that the complexity of systems leads to the permanent development of alternative impact modules. Following the LCA methodology, the fourth and last stage is the Interpretation, which is designed for identification of key parameters and evaluation of results of inventory stage and impact assessment with the purpose of selecting the preferred product or process.

1.8 Life Cycle Management (LCM)

This definition allows the application of LCA to processes as well as for guidance for optimization of activities towards a reduction of resource requirements and waste and for optimization issues. One such widely developed concept of the implementation of LCA principles to different sectors of economy and social life is Life Cycle Management (LCM). In fact, a clear understanding of the LCM concept would enrich the practical use of LCA and experimentally prove the efficacy of its application to the processes, units, and departments of a healthcare system. Such parameters as labour, time, costs would be additionally taken into account. Thus, in the first stage of LCA method application to processes in a healthcare system such goals as design of recommendations for the improvement of the legal framework for environmental safety and increase of a social responsibility of subjects would be added. In the second stage, apart from the usual and accepted parameters, which have been discussed earlier, the level of training of medical staff and their accuracy in fulfilment of medical tasks could be usefully introduced. In the third stage, the main factors that significantly affect the results of research conducted would be considered. The exclusion of secondary factors, which have no significant influence, would be conducted according to the list of inputs and outputs. Therefore, the factors influencing the system with varying intensity would have to be clearly identified. As well as the possibility of establishing a point-scoring system or complex pattern-matching system for the ranking of the influence of different factors would be considered. From among the most important, the key factors that adjust the whole system or process to the optimized level would be determined. During the interpretation stage it would be necessary for researchers to summarize the results of analysis; obtain answers to questions stated in the first stage; and give the alternative approach for creation of a supportive model that based on a limited data (as in particular study) can be convenient for decision making and relationships verification and on the other hand, once formed, can be adequately structured for implementation to other systems and Healthcare units. In addition, particular approach can be used for design of recommendations concerning the development and improvement of the quality of products, services or processes with regard to the issues of sustainability and optimization. In some cases, the possibility of changing the whole life cycle of a product would be considered. Therefore, LCM is the application of life cycle thinking to modern practice with aim of managing the total life cycle of organizations, products and services toward more sustainable consumption and production. It is an integrated framework of concepts to address environmental, economic, technological, and social aspects

of products, services, and organizations. LCM, like any other management pattern, is applied on a voluntary basis and can be adapted to the specific needs and characteristics of individual organizations (89). An illustrative example of the LCM application is the surgeon and nurse initiated Green Operating Room Committee as it is called. This is an internal medical staff initiative in the premises of one hospital in the United States. Routinely used consumables were replaced with recyclable and energy efficient substitutes (single use devices, reusable gel pads instead of disposable operating room foam pads.), resulting in a decreased amount of wastewater, in solid waste reduction, electricity, and great per year spending level reduction. As a result, the ecological initiative provided significant opportunity to improve a healthcare unit's impact on the environment and save resources (90). Our aim is to apply a holistic approach with use of such methodologies as Life Cycle Assessment to a Healthcare system Unit in order to find parameters that, while being properly assessed and analyzed, may lead the Unit to optimization.

2. Hypothesis

The optimization of input parameters of a given Healthcare Unit according to sustainability principles leads to higher efficiency.

3. Aim and purposes of the research:

3.1 Aim

To prove that optimization of input parameters leads to higher economic efficiency with the possibility of application the results into the development of a strategy through which a Healthcare system as a whole should become more sustainable.

3.2 Specific Aims (Purposes):

- To define and analyse input and output parameters
- To perform modelling while changing the inputs into more environmental-friendly and cost – efficient
- To define possible parameters that would lead to optimization.

3.3 Key words

Healthcare optimization, Life Cycle Assessment, Life Cycle Management, Process optimization, Dual - parameter model.

4. Materials and Methods

4.1 Materials

Actual research was performed at the Department of Medical Biochemistry, Laboratory of Medical Biochemistry (Laboratory or Unit in the text of Dissertation) of the General Hospital Zabok in collaboration with the School of Public Health/Zagreb School of Medicine from 30.12.2014 to 30.09.2015 (duration of study including preparation and Hospital Consent acquisition – 9 months). The hospital in Zabok was chosen for the current study because it is the newest hospital in Croatia, constructed from the base according to modern building standards. According to the Croatian Bureau of Statistics (annual report 2007) the hospital is located in Krapina-Zagorje County, 40 kilometers from Zagreb. The 249-bed, 25000m2 hospital encompasses various medical facilities with modern medical equipment. Currently there are a total of 624 employees, 490 medicals, and 134 of non-medical occupations. The hospital was fully constructed in 2005, which enables the conduct of studies of various kinds, from clinical studies in e.g. Surgery, Orthopedics, Gynecology, Rehabilitation to practical experiments in Biochemistry, using the Laboratory. The ward of Medical Biochemistry is one of key units that is connected and is a primary analytical base for almost all other departments of a hospital. The high pressure from continuously ordered analyses makes it one of the most dynamic and in-demand units in the whole diagnostic infrastructure of Zagorje County. Its key position makes it a very important division in the chain of healthcare institutions and in our opinion is a reliable base for studies such as the current. All accesses and activities for the current research were performed under the supervision of qualified staff and in accordance with the Zagreb School of Medicine postgraduate education schedule (2014-2018).

4.2 Methods:

4.2.1 Life Cycle Assessment:

Keeping in focus the Aim and Purposes of the Study and taking into consideration that except LCA also other methods have been used, standardized LCA methodology stages which presented on Figure 2. were adopted as follows: Goal and Scope Definition are presented in Aims and Purposes; Inventory Analysis includes all collected data is shown in Initial phase: Data gathering; Impact Assessment comprises Analytical Phase of Data Analysis and Modeling. Interpretation Stage corresponds to Results and partially to Discussion and Conclusions.

i) Initial phase: Data gathering

1. General list of the tests

According to the Unit offer of tests, at the time of the actual research consisted of 62 tests. The offer of the Laboratory is regularly updated with the constant development of general service for patients.

2. Reagents used for tests, Expenses/Purchased (total per reagent, total per period)

An audit of all reagents and chemical substances “in the field” and using the official purchasing documentation such as invoices, order confirmations, warehouse receipts, and product delivery statements was performed. Expenses/costs for the purchasing of reagents have been taken from the Hospital Accountancy Dept. All substances/reagents/dyeing agents were ordered from the licensed dealers, where the price range is limited according to State Norms and Regulations with strict restrictions and regular control.

3. Number of tests/period

We performed a detailed calculation of the tests performed over the period of the particular study. It gives comprehensive information about the number of tests performed together with quantity of reagents used.

4. Duration of urgent/general sample processing

Concerning the duration of a sample processing we followed a step-by-step Sample circulation process starting from the registration of a patient at the registration desk, over the whole processing cycle and until the final stage when the sample is validated. Usually, duration of every stage was accurately calculated using a digital timer. We repeated the calculation of every process three times to get a time-based confirmation and in order to calculate the average and decrease the level of any biases and incorrect results.

5. Equipment used for testing (list of the diagnostic equipment and tools)

The Laboratory has new ordered and installed equipment presented in the Table 1. It shows that in total 42 machines are in usage for sample analyzing.

Table 1. Equipment used for testing

№	Device specification	Assignment
1	CENTRIFUGE LEICA SP 1400	Analytical equipment
2	CENTRIFUGE TECHNICA CENTRIC 322 A	Analytical equipment
3	CENTRIFUGE EPPENDORF 5810	Analytical equipment
4	CENTRIFUGE ROTOFIX 32A	Analytical equipment
5	OLYMPUS CX31	Microscope
6	OLYMPUS CX31	Microscope
7	LEICA DME	Microscope
8	CARL ZEISS STANDARD 20	Microscope
9	ROCHE URISYS	Urine analyzer
10	ROCHE Cobas u 411	Urine analyzer
11	DIESSE VES MAIC 3.0	Sedimentation processor
12	SYSMEX CA 500 I	Coagulation analyser
13	IL TOP 300	Coagulation analyser
14	SYSMEX CA 500 II	Coagulation analyser

15	SYSMEX CA 1500	Coagulation analyser
16	SYSMEX XT 1800 i	Hematoanalysers
17	SYSMEX R-500	Hematoanalysers
18	SYSMEX K-4500	Hematoanalysers
19	SYSMEX XN	Hematoanalysers
20	SYSMEX XE	Hematoanalysers
21	PAPIDLAB 348 ET	Acidostatus analysers
22	PAPIDLAB 1265	Acidostatus analysers
23	RAPIDLAB 1260	Acidostatus analysers
24	MA-15 IRIS	Urine analyzer
25	MA-16 MiniCap	Protein electrophoresis processor
26	BIOMERIEUX MINI VIDAS	Immunochemical analyzer
27	ABBOTT ARCHITECT I 1000 SR	Immunochemical analyzer
28	ABBOTT ARCHITECT I 1000 SR	Immunochemical analyzer
29	OLYMPUS AU 400	Biochemical analyzer
30	BECKMAN COULTER AU 680	Biochemical analyzer
31	ZANUSSI	Refrigerator
32	KONCAR 201 E	Refrigerator
33	KONCAR HL 280	Refrigerator
34	KONCAR ZANUSSI	Refrigerator
35	MATRIX	Refrigerator
36	VIVAX	Refrigerator
37	GORENIJE	Refrigerator
38	ROLLER-5	Blood mixer
39	ROLLING MIXER RM 810 220 V	Blood mixer
40	LKC	Blood cell calculator
41	LKC	Blood cell calculator

42	VIVEL 12	Blood cell calculator

6. Input data: water consumption, natural gas consumption, electricity, fuel oil

The premises of the Laboratory occupy 684 square meters of the total Hospital area of 23,000 m2 or 2.97%. Taking into consideration that there are no installed counters in every Hospital Unit we used the percentage of 2.97% and total expenses of the Hospital/per energy source, to estimate the consumption of electricity, natural gas, water and fuel oil by the Laboratory. Calculations were performed on a monthly basis as shown in the Table with the cumulative results in the local currency (HRK means Croatian kuna - Croatian local currency) shown in Table 2.

Table 2. Input data: water consumption, natural gas consumption, electricity, and fuel oil

MONTHLY EXPENSES/COSTS for:	in Croatian Kuna (HRK) for the entire Hospital (23.000m2)	in Croatian Kuna (HRK) for the Laboratory (684m2)
Electricity	200,000.00HRK	5.940,00HRK
Natural gas	130.000,99HRK	3.861,00HRK
Water	35.000,00HRK	1.039,50HRK
Fuel oil	2.400,00HRK	

7. Output data: hazardous waste, municipal waste (marked by color labels according to intra-laboratory classification.

Part of the Laboratory premises is a room for waste accumulation. Technical staff have limited access to it and are responsible for waste to be separated and stored in different containers, each of them labelled according to the Regulation of Classification of waste in the Republic of Croatia e.g. Pharmaceutical waste (in our case there are packages, boxes of urine strips) is marked with green label, hazardous waste and contaminated packaging with light yellow, products of artificial fibers and plastic – deep yellow, Mixed communal waste is black, Infectious waste – with red marking. In addition, there are important notes on some containers as presented in

Table 3. The table also provides information about the quantity of waste per day or month during the 6-month period of study.

Table 3. Output data: hazardous waste, municipal waste, etc.

Specification	Label colour	Packaging	Waste quantity per day for the Period of Study						Notes
			April	May	June	July	August	Septem-ber	
Pharmaceuti-cal waste (packages, boxes of urine strips)	Green	25l, 12x3x3cm, 4 lines x 17pcs	30	31	30	31	30	31	Rea gents
Hazardous waste glass	Light Yellow	60x30x40cm, V=72L	1	1	1	1	1	1	Rea gents, Petrol, Etha nol
Artificial fibre	Yellow	60x30x40cm V=72L	2	2	2	2	2	2	-
Mixed com-munal waste	Black	70x110cm	30	31	30	31	30	31	-
Infectious waste	Red	70x110cm	30	31	30	31	30	31	to the inci nera-tor, tubes
Plastic packag-ing	Yellow	70x110cm	8	8	8	8	8	8	-
Contaminated packaging	Light Yellow	70x110cm	8	8	8	8	8	8	Danger-ous! Toxic! Poiso-nous!

Glass	Green	70x110cm	1	1	1	1	1	1	Usual, clean
Infectious waste	Red	70x110cm	60	62	60	62	60	62	-

8. Working environment quality measurement: noise, temperature, and humidity

We paid attention to such parameters as noise levels, temperature and humidity. For this purpose, 5 working rooms were proposed as locations. As tools for accurate measurements the devices UNI-T, Sound level meter UT350 (351) series and Peak Tech, 5040 "3 in 1" temperature/humidity meter were used. Measurements are presented in a Table 4.

Table 4. Quality test

Parameters	Room 1	Room 2	Room 3	Corridors	Room 5
Noise, dB	65	66,7	56,5	67,7	57,2
Temperature, C	20,5	21,5	19,8	19,8	20
Humidity, % Rh	22	17,7	20	20	24

Laboratory consists of 4 departments - test rooms and connecting corridors. We performed quality test with the measurements of noise, temperature and humidity on a one-day basis. Data presented in a Table 4 below.

9. Number of employees

This group of the data collected was related to the staff of the Laboratory. The collection was carried out in order to acquire as many input parameters as possible, able to be used for later findings. During the period of Study there were 25 employees at the Laboratory. For the purposes of this study International Standard Classification of Education (ISCED) was used (153).

10. Level of education

From all employees of the Laboratory there were 7 persons with bachelor degrees (ISCED 6), 14 technicians – ISCED 4.5, 1 doctor of science (ISCED 8) and 3 persons with post-graduate education backgrounds (ISCED 7). According to the Law of Labour of Croatia there is 8 hours working day but in a hospital these working hours are shifts, which are scheduled in a random manner. There are day and night shifts and sometimes, when an employee is on sick leave or maternity leave, shift substitutions and prolongations are possible. In such cases on the day of salary payment, the employee receives additional wages, which are calculated according to the internal procedure of the hospital. The working hours during the study period are presented in Table 5.

11. Working hours/employee in the period

Table 5. Working hours/employee in the period

№	Working hours per months					
	April	May	June	July	August	September
1	Sick leave (SL)	40	216	184	164	Sick leave (SL)
2	168	160	150	184	160	166.8
3	168	160	148	188	160	168.4
4	168	163	150	192	160	170.5
5	232	192	200	216	192	189.6
6	224	146	180	192	187	177.4
7	SL	224	111	223	224	SL
8	182	168	182	184	176	179.6
9	200	235	159	264	176	201.1
10	168	91	152	184	160	174.1

11	163	164	152	184	164	172
12	168	160	150	184	148	157.2
13	240	176	224	264	176	204
14	172	Maternity leave (ML)	ML	ML	ML	172
15	192	176	175	184	188	183
16	168	143	147	184	160	167.9
17	156	160	148	188	168	179.6
18	239	200	224	209	232	219.3
19	168	160	80	184	160	152.8
20	168	162	160	183	164	171.3
21	216	224	216	264	72	124
22	201	191	174	184	180	171.3
23	172	184	172	184	176	180
24	168	152	152	184	160	168
25	168	160	152	184	160	167.2
Total	4269	3991	3974	4775	4067	4329.2

12. Gross expenses per employee in the period

Monthly salary structure in Republic of Croatia is based on the Net component – the initial sum that every employee can find in his or her bank account after a month of work, generally on the 15th day of the following month, and a second part consisting of taxes such as local tax, salary tax, medical insurance and retirement contributions. This second component together with the net one forms a Gross salary amount, which is presented in the Table 6. Data are based on the period of study, 4.2015-9.2015. Numbers 1-25 corresponds to particular employees. According to GDPR it is forbidden to publish private data of employees without their permission (154) and so we have decided to keep the data anonymous.

Table 6. Gross expenses per employee in the period

№	Education level of the employee	Gross Income per period in HRK
1	ISCED 6	34423.31
2	ISCED 5	45668.45
3	ISCED 5	45291.27
4	ISCED 4	48946.34
5	ISCED 7	116127.25
6	ISCED 6	75878.75
7	ISCED 7	135444.59
8	ISCED 6	57104.97
9	ISCED 7	141321.9
10	ISCED 4	51351.03
11	ISCED 4	46503.49
12	ISCED 4	42826.31
13	ISCED 8	190110.89
14	ISCED 6	0
15	ISCED 6	68657.86
16	ISCED 4	42141.99
17	ISCED 4	46154.84
18	ISCED 6	124440.88
19	ISCED 5	33135.64
20	ISCED 4	45268.69
21	ISCED 7	110078.29
22	ISCED 6	64158.11
23	ISCED 6	57081.65
24	ISCED 4	29387.33
25	ISCED 4	31067.92

For the purposes of this study International Standard Classification of Education (ISCED) was used (125). From all employees of the Laboratory there were 7 with bachelor's degrees (ISCED 6), 14 technicians – ISCED 4,5, 1 with a doctorate (ISCED 8) and 3 persons with postgraduate backgrounds (ISCED 7). In brackets, educational level is presented in Croatian according to the national classification of educational levels. We have left the personnel titles in Croatian for reasons of clarity. The names or titles of working positions often differ in South Eastern European Countries and other countries of European Union, which also has a potential for standardization. Here are correspondences of titles according to ISCED: Glavni inženjer odjela (vss) – ISCED 6; Laboratorijski tehničar (kv, sss) – ISCED 4,5; Magistar medicinske biokemije (vš̌s, mag.) – ISCED 7; Magistar medicinske biokemije, specialist (dr., vš̌s, mag) – ISCED 7; Stručni prvostupnik laboratorijske diagnostike (sss) – ISCED 4; Stručni referent u financijama (sss) – ISCED 5; Voditelj zdravstvenog odjela, lječnik specijalist, (vš̌s, dr.sc.)– ISCED 8.

13. Level of satisfaction with working conditions: financial satisfaction, people/environment satisfaction (typical enquiry, responses ranged from 1 to 5 points.

The ongoing methodology of the current research demands, in addition to quantitative data, the acquisition of qualitative data. The method of a simple anonymous questionnaire was chosen. Every employee with exclusion of those being on a sick or maternity leave was asked 2 questions: the first was about satisfaction with financial conditions of his work and second – employee satisfaction with the environment conditions and colleagues' attitude. For the purposes of this study a structured interview in a form of 'guided conversation' was chosen. To begin with we had a few questions, which stated the purpose and direction of the interview. They were open-ended questions that every employee interviewed was asked in the same order. Following the classic LCA methodology initially designed for environmental studies, we would assess the impacts after inventory analysis. For the purposes of this study we missed out the metrics of environmental influences and paid attention primarily to revealing the key parameters that influence our system and that consequently can be used for optimization of the Laboratory.

ii) Analytical phase: Data analysis

We used a total of 62 tests with adequate reagents data, test prices and number of tests delivered in lab. The time frame was six months. Our sample includes lab's staff working and processing including wage data. As additional data, waste and equipment and quality and energy expenses were analyzed. For Process optimization of hospital units using life-cycle assessment methods we used data collected from the 6-month period from our facility. Raw data collected include: General list of the tests performed, Reagents used for tests, Number of tests in the period, Duration of urgent/regular sample processing, Equipment used for testing (list of the diagnostic equipment and tools), Input data: water consumption, natural gas consumption, electricity, consumption of heavy fuel oil, Output data: hazardous waste, municipal waste (marked by color labels), Working environment quality measurement: noise, temperature, humidity, Number of employees, Level of education, Working hours/employee in the period, Gross expenses per employee in the period, Level of satisfaction with working conditions: financial satisfaction, people/environment satisfaction (typical enquiry, responses ranged from 1 to 5 points). According to or plan we gathered all possible data from financial department of the Hospital but taking into consideration specificity of state owned organization and partially restricted access to financial data such as the Balance Sheet and Initial Income Statement we were unable to perform a classic financial analysis with such estimations as adequacy of income, depreciation costs, etc. The same is valid concerning such data as emissions of waste heat, CO2, wasted water. Due to methodological reasons caused by the diverse and often heterogenous data elements which were difficult to logically connect and find any mathematical relations and to obtain the diagnostically satisfactory prediction we did not perform classic modeling. In order to overcome this technical bias we used the option to perform other type of analysis enabling us to follow the aim and purposes of the study and to obtain adequate results. Data processing started with basic data engineering process known as ETL. ETL is a type of data integration that refers to the three steps (extract, transform, load) used to blend data from multiple sources. It's often used to build a larger data samples however we used similar technique for our research. During this process, data is taken (extracted) from a source system, converted (transformed) into a format that can be analysed, and stored (loaded) into a structured data file. In order to prepare data for visualisation, we followed more sophisticated technique called DAD (Discover / Access / Distill) commonly used by data scientists when preparing heterogeneous data samples to be visualised in clear way.

Acronym DAD stands for:

- Discover: Find, identify the sources of good data, and the metrics. Sometimes requires the data to be created (work with data engineers, business analysts)
- Access: Access the data. Sometimes via an API, a web crawler, an Internet download, a database access or sometimes in-memory within a database.
- Distill: Extract essential from data, the stuff that leads to decisions, increased ROI and actions (such as determining optimum bid prices in an automated bidding system).

It involves exploring the data (creating a data dictionary, exploratory analysis), cleaning (removing impurities), refining (data summarization, sometimes multiple layers of summarization - or hierarchical summarization), and analysing: statistical analyses (sometimes including stuff like experimental design which can take place even before the Access stage), both automated and manual. The last step might or might not require: statistical modeling (many predictors are now model-independent), presenting results to management (less important if the purpose is to design a machine-to-machine communication system, instead a proof-of-concept or prototype might be required first), or integrating results in some automated process. Documenting is always part of all these steps.

Data sets were stored in logical data model using Microsoft Excel composed of:

- Entity Types
- Attributes
- Relationships; and
- Domains.

Each instance of these object types is uniquely identified and defined in business terms. The definitions supply the semantic content for a data model.
Entity types

An entity type is a representation of a test, reagent or concept of interest to a researcher. Within the data model each entity type is defined in business terms. In an entity

diagram, entity types are represented as rectangles. Each entity type has a unique, singular noun phrase assigned as its name. In a relational data model, each entity type instance is uniquely identified by a primary key. A primary key is one or more attributes that have values used to uniquely identify and distinguish each entity type instance from each other.

Attributes

An attribute identifies, names and defines a characteristic or property of an entity type. For example, an Item entity type will have an Item ID attribute to uniquely identify it. It will have a Name attribute to use in catalogs and labels. It will have a Description attribute, etc. Attributes are the most atomic parts of a data model. They cannot be decomposed into lower level components. In a relational data model, an attribute cannot exist independently from an entity type. Accordingly, all attributes are always identified and shown as part of entity types. As discussed under entity type, a primary key is composed of one or more attributes and serves as a unique entity type instance identifier. Attributes used to compose a primary key are listed above a horizontal line in the entity rectangle.

Relationships

A relationship identifies, names and defines an association between two entity types. A relationship always associates two and only two entity types. Relationship names are represented as verb phrases. A relationship verb phrases may be established for both directions of a relation between two entities. The entity types associated through a relationship fulfil two roles: One entity is a parent entity. The second entity is a child entity. The parent entity shares it identity with the child entity. The child entity inherits the primary key of the parent entity type and is referred to as a dependent entity type. The attribute shared from a parent to a child entity type is called a foreign key. In an entity diagram an attribute name that is a foreign key is designated with a "(FK)" suffix.

In a relational data model, there are two ways a parent and child entity type may be related. The first way is an identifying relationship. An identifying relationship means that the child entity's primary key inherits its parent entity type's primary key. That means that the child entity type's existence is dependent on its parent entity type's existence. If

the parent entity type is deleted in this scenario, the child is deleted. Conversely a child entity type cannot be inserted until the parent it references is inserted. In an entity diagram, an identifying relationship is signified by a solid line between the parent and child entity types. The second way parent and child entity types may be related is through a non-identifying relationship. In a non-identifying relationship, the parent entity primary key is inherited by the child entity as a non-primary key attribute. This means that the child entity references its parent entity type but is not dependent on the parent's existence for its own existence. From a relational database point of view this means that the inherited attribute may be null - that is point to nothing. In an entity diagram, a non-identifying relationship is signified by a dashed line between the parent and child entity types. Relationships incorporate an additional property between parent and child entity types called cardinality. Cardinality expresses the count of child entity type instances that may exist for a parent entity type.

Domain

A domain is a named type of data representation that may apply to one or more attributes. Data representation defines a data type such as integer, string, floating point, date, time or other standard data type or an extended definition that assigns custom properties and constraints to a base data type. Domains enable retail-specific data types to be derived from structured data types. The creation of domains can also be used to define constraints that values assigned to an attribute assigned to a domain.

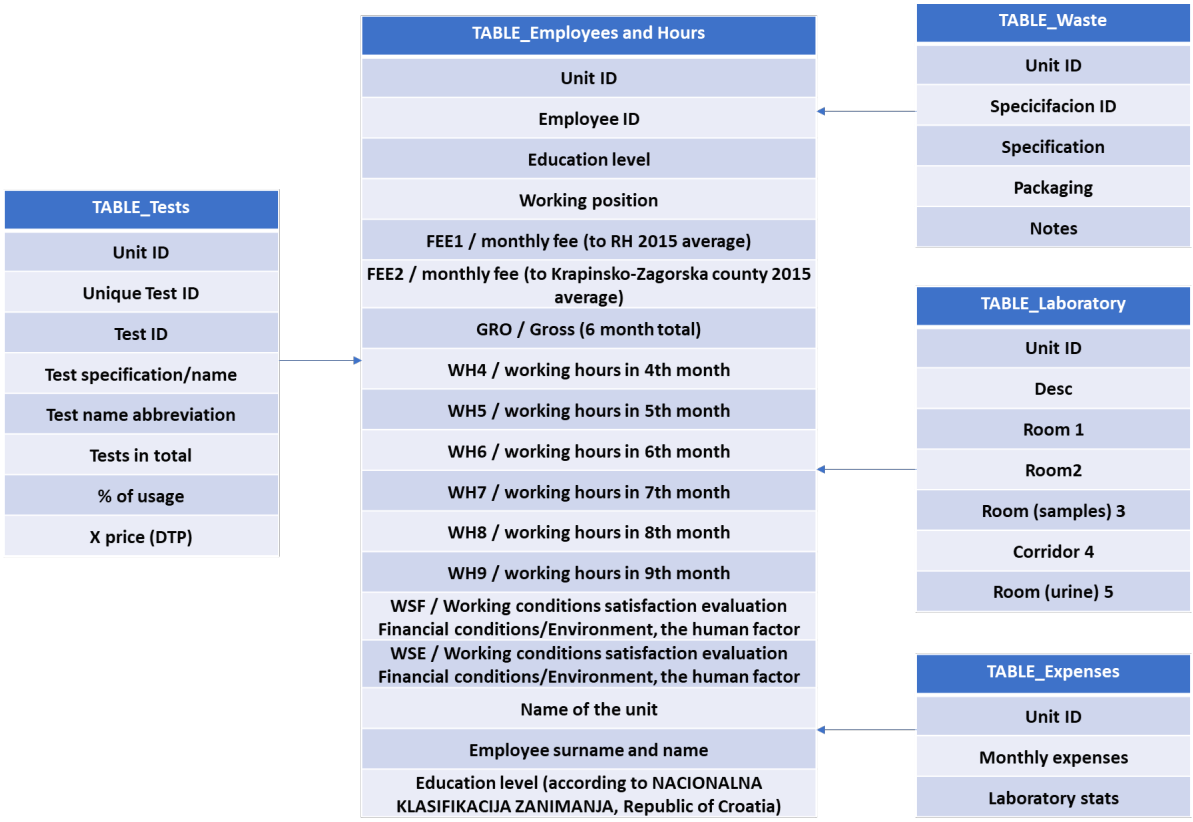
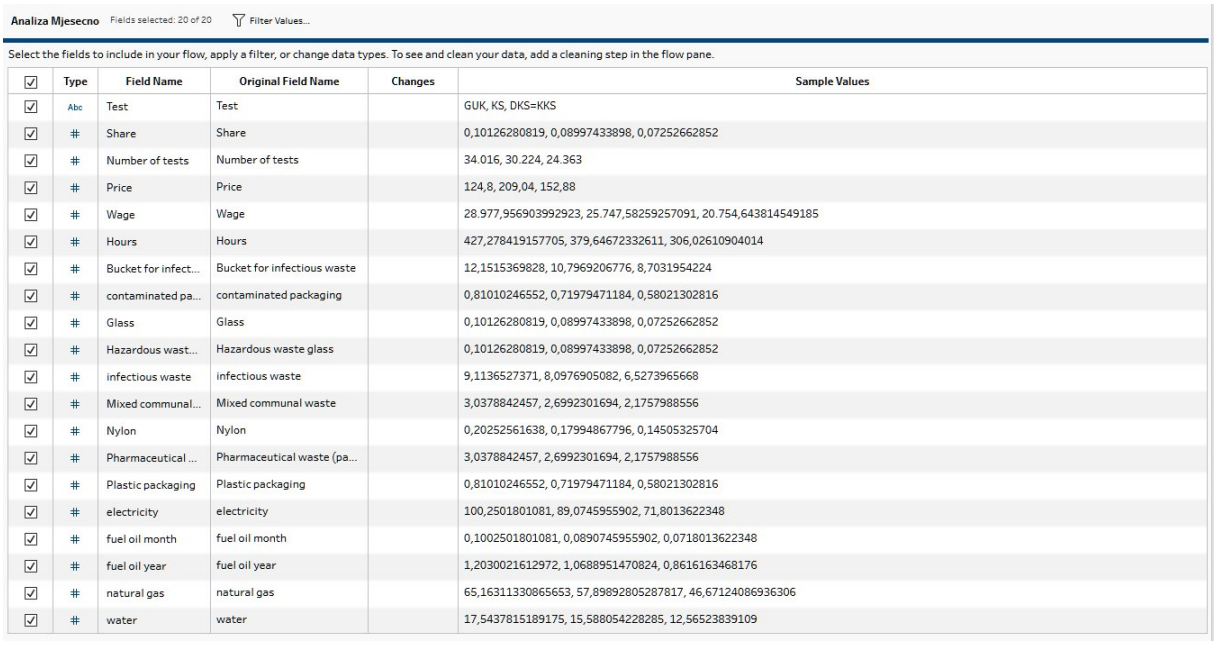


Figure 3. Logical data model (E/R entity relationship database model)

Test	Share	Wage	Hours	Bucket for infectious waste	Contaminated packaging	Glass	Hazardous waste glass	Infectious waste	Mixed communal waste	Nylon	Pharmaceutical waste (packages, boxes of urine strips)	Plastic packaging	Electricity	Fuel oil month	Fuel oil year	Naural gas	Water
GUK	10,13%	173.867,74	2.563,67	72,91	4,86	0,61	0,61	54,68	18,23	1,22	18,23	4,86	601,50	0,60	7,22	390,98	105,26
KS	9,00%	154.485,50	2.277,88	64,78	4,32	0,54	0,54	48,59	16,20	1,08	16,20	4,32	534,45	0,53	6,41	347,39	93,53
DKS=KKS	7,25%	124.527,86	1.836,16	52,22	3,48	0,44	0,44	39,16	13,05	0,87	13,05	3,48	430,81	0,43	5,17	280,03	75,39
KREA	5,44%	93.445,73	1.377,85	39,19	2,61	0,33	0,33	29,39	9,80	0,65	9,80	2,61	323,28	0,32	3,88	210,13	56,57
K	5,24%	90.046,68	1.327,73	37,76	2,52	0,31	0,31	28,32	9,44	0,63	9,44	2,52	311,52	0,31	3,74	202,49	54,52
Na	5,03%	86.320,51	1.272,79	36,20	2,41	0,30	0,30	27,15	9,05	0,60	9,05	2,41	298,63	0,30	3,58	194,11	52,26
CRP	4,76%	81.781,63	1.205,87	34,29	2,29	0,29	0,29	25,72	8,57	0,57	8,57	2,29	282,93	0,28	3,40	183,90	49,51
UREA	4,76%	81.658,96	1.204,06	34,24	2,28	0,29	0,29	25,68	8,56	0,57	8,56	2,28	282,50	0,28	3,39	183,63	49,44
PV	3,79%	65.118,62	960,17	27,31	1,82	0,23	0,23	20,48	6,83	0,46	6,83	1,82	225,28	0,23	2,70	146,43	39,42
AST	3,73%	64.029,90	944,12	26,85	1,79	0,22	0,22	20,14	6,71	0,45	6,71	1,79	221,51	0,22	2,66	143,98	38,76
ALT	3,72%	63.897,01	942,16	26,79	1,79	0,22	0,22	20,10	6,70	0,45	6,70	1,79	221,05	0,22	2,65	143,69	38,68
GGT	3,29%	56.408,88	831,75	23,65	1,58	0,20	0,20	17,74	5,91	0,39	5,91	1,58	195,15	0,20	2,34	126,85	34,15
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Figure 4. Final data set (after ETL/DAD)



Analiza Mjesecno Fields selected: 20 of 20 Filter Values...

Select the fields to include in your flow, apply a filter, or change data types. To see and clean your data, add a cleaning step in the flow pane.

Type	Field Name	Original Field Name	Changes	Sample Values
Abc	Test	Test		GUK, KS, DKS=KKS
#	Share	Share		0,10126280819, 0,08997433898, 0,07252662852
#	Number of tests	Number of tests		34.016, 30.224, 24.363
#	Price	Price		124,8, 209,04, 152,88
#	Wage	Wage		28.977,956903992923, 25.747,58259257091, 20.754,643814549185
#	Hours	Hours		427,278419157705, 379,64672332611, 306,02610904014
#	Bucket for infect...	Bucket for infectious waste		12,1515369828, 10,7969206776, 8,7031954224
#	contaminated pa...	contaminated packaging		0,81010246552, 0,71979471184, 0,58021302816
#	Glass	Glass		0,10126280819, 0,08997433898, 0,07252662852
#	Hazardous wast...	Hazardous waste glass		0,10126280819, 0,08997433898, 0,07252662852
#	infectious waste	infectious waste		9,1136527371, 8,0976905082, 6,5273965668
#	Mixed communal...	Mixed communal waste		3,0378842457, 2,6992301694, 2,1757988556
#	Nylon	Nylon		0,20252561638, 0,17994867796, 0,14505325704
#	Pharmaceutical ...	Pharmaceutical waste (pa...		3,0378842457, 2,6992301694, 2,1757988556
#	Plastic packaging	Plastic packaging		0,81010246552, 0,71979471184, 0,58021302816
#	electricity	electricity		100,2501801081, 89,0745955902, 71,8013622348
#	fuel oil month	fuel oil month		0,1002501801081, 0,0890745955902, 0,0718013622348
#	fuel oil year	fuel oil year		1,2030021612972, 1,0688951470824, 0,8616163468176
#	natural gas	natural gas		65,16311330865653, 57,89892805287817, 46,67124086936306
#	water	water		17,5437815189175, 15,588054228285, 12,56523839109

Figure 5. Data model description and testing

Data table was prepared and uploaded in the software for advanced visualization “Tableau Public” - a computer platform for visual presentation of the data (231). We used data visualization for the graphical representation of information and data. Data visualization methods refer to the creation of graphical representations of information. Visualization plays an important part of data analytics and helps interpret big data in a real-time structure by utilizing complex sets of numerical or factual figures. With the seemingly infinite streams of data readily available to today’s businesses across industries, the challenge lies in data interpretation, which is the most valuable insight to the individual organization as well as its aims, goals, and long-term objectives. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data as shown in Results section (116-118).

iii) Analytical phase: Modeling

The purpose of the study is to define the parameters and reveal the ways in which the modelling of the influencing parameters could lead to optimization of defined processes and complete the Laboratory as a single system enclosed within system Boundaries. According to the OED, the definition of a process is that it is "a series of actions or steps taken in order to achieve a particular end". A process consists of particular steps with a goal in a chain that has its cumulative goal at the end. A process could be linear and circular, with a feedback and without. In our particular case the process has the metrics shown in Figure 6.

Legend:

S - step in the process

C - goal which corresponds to particular step (S).

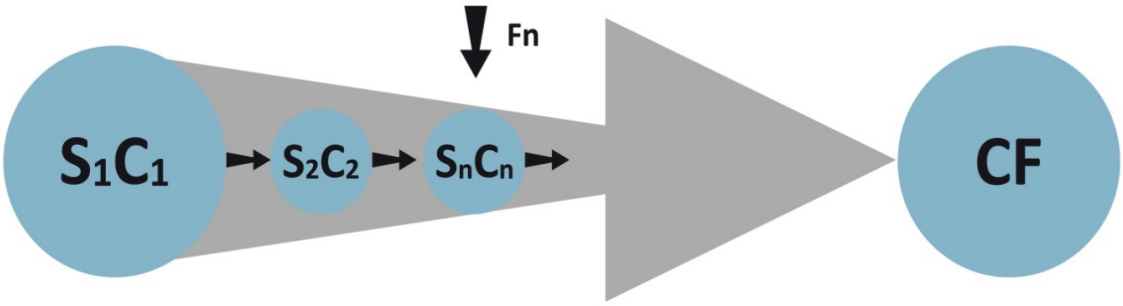
F - final

Numbers and symbols (1,2,n) - sequence in a process

Figure 6. Classical linear process without feedback

Source: Author's artwork. ©Vitaliy Sarancha, 2019

Figure shows the classic linear process without a feedback where S is a step in a process with its number in a sequence. C is a goal corresponding to every particular step and CF is the final general goal of the complete process (142-144). The whole sequence lies within certain boundaries, which means that the process forms a closed system without external disturbances where the chance of bias is close to 0, which can be possible under ideal conditions. According to LCA methodology these are the system boundaries. In this particular case a process is a sequence of operations of processing a blood sample with the main goal of test delivery and interpretation, using just a single sample processing sequence in our healthcare system unit. In the focus was 1 process = 1 test = 1 analysis interpretation and the assessment of a Life Cycle was based on this presumption (Figure 7).



Legend:

S - step in the process

C - goal which corresponds to particular step (S).

F - final

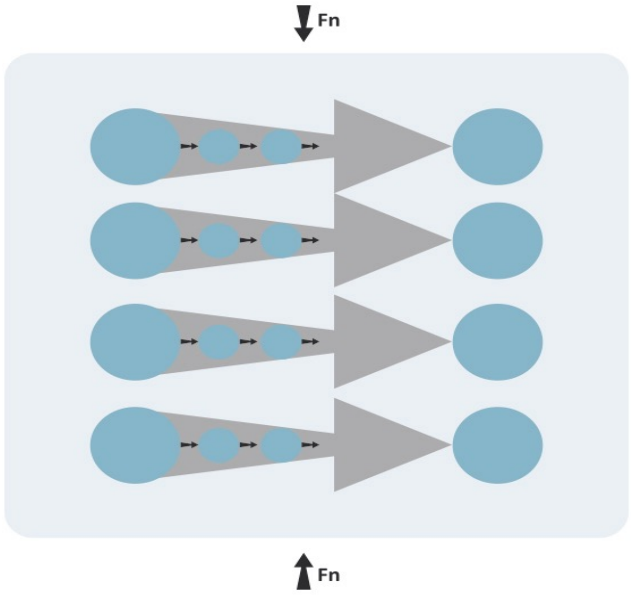
Numbers and symbols (1,2,n) - sequence in a process

fn - Cumulative influence of various factors

Figure 7. Blood sample processing chain.

Source: Author's artwork. ©Vitaliy Sarancha, 2019

The one single process is a blood sample processing chain starting from the registration of a patient in the laboratory, sample extraction, technical processing through the chain of manipulations with the use of a special laboratory equipment. "Fn" stands for factors that influence the process. At the end is the validation of a sample, the interpretation, which will be transmitted to the hospital specialist by whom it has been initially ordered. Taking into consideration that we have multiple tests the assessment of a complete unit will have appearance as shown on Figure 8.



Legend:

Multiple processes (from Figure 7.) are enclosed in boundaries (grey colour rectangle)

Fn - Cumulative influence of various factors

Figure 8. Multiple processes assessment system with system boundaries.

Source: Author's artwork. ©Vitaliy Sarancha, 2019

This diagram presents also the assessment scenario, which may be implemented for the unit. In this scenario all processes are analysed independently as shown in figure 4 and afterwards we also assess the cumulative output of the sum of processes and reveal the key influencing parameters. In this particular case "Fn" are influences, which affect the whole system. Consequently, a figure with product life cycle stages as used generally in industries (Figure. 1) but adapted to our sample processing will have the form presented in Figure 9.

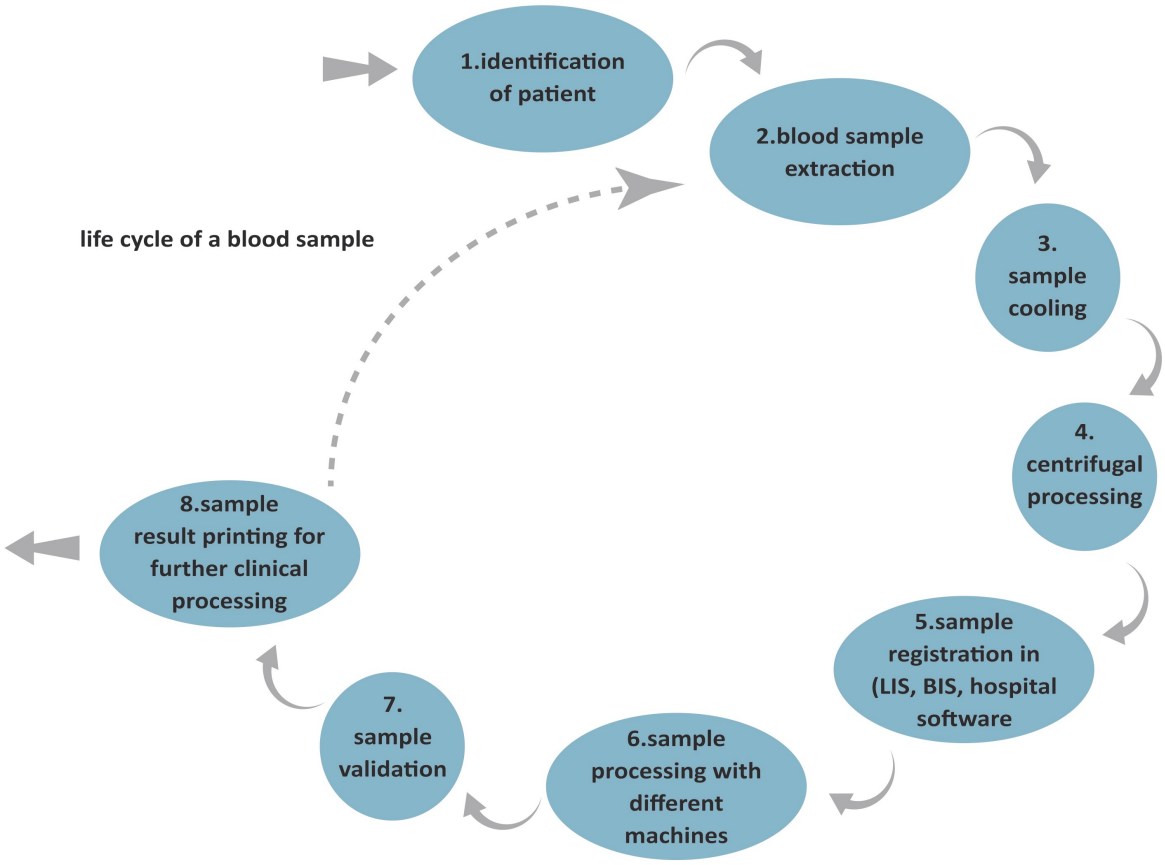


Figure 9. Life Cycle diagram adapted for the unit inside a System Boundaries.

Source: Author's artwork. ©Vitaliy Sarancha, 2019

The cycle (sample processing) is performed in a Laboratory and is subject to the influence of various external factors, which will be described later as parameters in this study. These parameters may lead to various scenarios of the final result and in the best case would lead the whole system to optimization. Optimization in our study is the management of every particular step in a process and control of all influencing parameters with the aim of conducting it more efficiently. Efficacy means to do/perform something the best way possible.

4.2.2 Inquiry

The ongoing methodology of the current research demands the acquisition of not only quantitative but also qualitative data. The method of a simple anonymous questionnaire was chosen. Every employee except those on sick or maternity leave was asked 2 questions: the first was about satisfaction with the financial conditions of his or her work and second – employee satisfaction with the environment conditions and colleagues' attitude.

4.2.3 Structured interview with Direct Content Analysis

For the purposes of this study a structured Interview in a form of 'guided conservation' was chosen. Before the interview proper, we put a few questions that stated the purpose and direction as an interview schedule. These were open-ended questions and were posed in a set order. For the following decoding we used methodology of direct content analysis/qualitative content analysis (DCA or QCA). As one of today's most extensively employed analytical tools, content analysis has been used fruitfully in a wide variety of research applications in information and library science (123). The process of qualitative content analysis consists of such phases of 1) data preparation, 2) development of categories and a coding scheme, 3) coding of the text, 4) assessment of coding consistency and drawing of conclusions from the coding data (126-140). Following the accepted practice of DCA an interweaving of 3 staff members with different level of education and qualification was done. There were ISCED 5 (Laboratory Diagnostician with a bachelor's degree), ISCED 4 – Laboratory Technician – with a sub - bachelor degree) and ISCED 7 - a master's in biochemistry. The interviewing process was accurately recorded, and a precise transcript protocol was created. We analysed the interviews (=1) with 3 basic questions: "Please reveal technical routine problems emerging on a daily basis"; "Please reveal organizational routine problems emerging on a daily basis"; "What would you recommend to improve the general functioning of the Laboratory?". Coding categories were as follow: Equipment and IT issues and Organizational issues (subdivided by a Communication subcategory and Work system subcategory) (=2). Precise codification of the interviews was done (=3) and assessment with conclusions was performed (=4).

Ethical consent

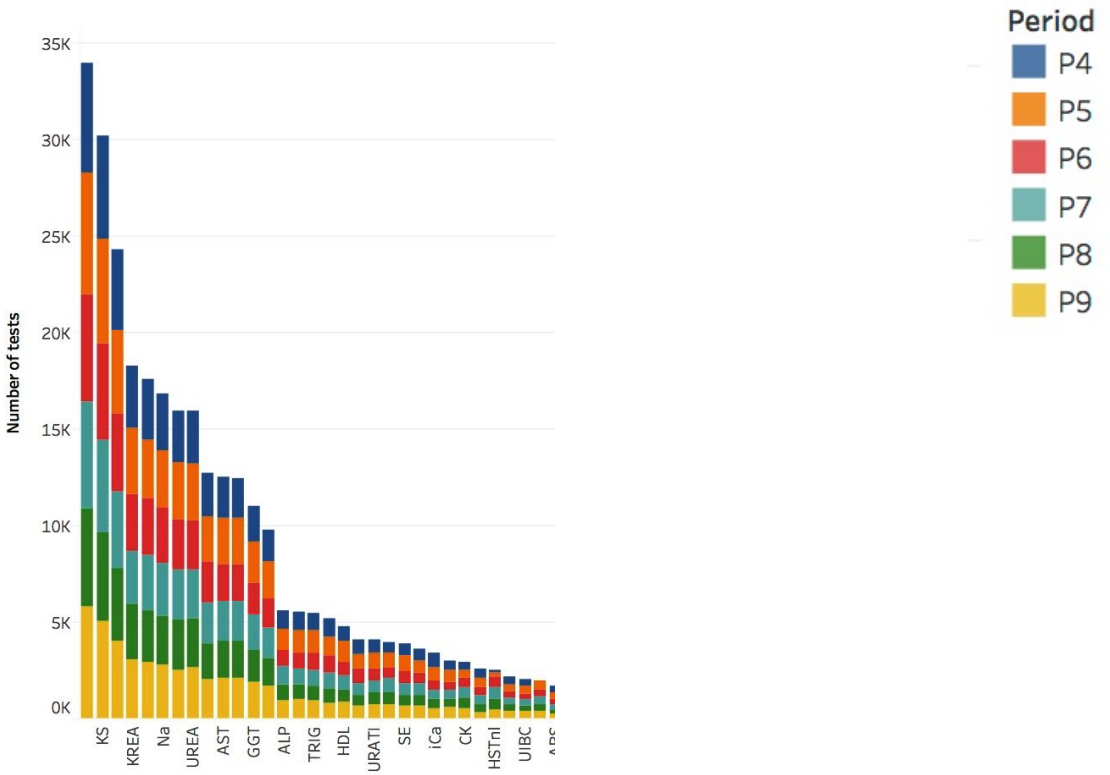
Current study "Process optimization of hospital units using life-cycle assessment methods" was performed according to the Croatian Laws and Regulations, in particular the Law of Medical Care and Law of Patients Rights together with accepted directories of a good practice and WMA Declaration of Helsinki (150, 151, 152). Before performance of any activities with materials, reagents, technical equipment, liquids, samples according to the aims and purposes of the current research, Informed Consent was obtained. All activities in the field of this research were approved by the Ethical Board of the General Hospital of Zabok (on 30.12.2014).

5. Results:

5.1 Data analysis:

While analysing relationships between number of delivered tests and average price per test the figure shows the most likely tests delivered as well as the ratio between price and number of tests delivered. We can assume in general that expensive tests are rarely performed. Larger amount performed are in a price range starting from HRK 18 to HRK 70 average; according to DTP (dijagnostičko-terapijski postupci – Diagnostic and Therapeutic Procedures of the Croatian Health Insurance Institution), the highest peak is HRK 267.8 and is the most expensive. Another group consists of tests in a price range from HRK 18 to 20 average according to DTP. Figure 7. shows seasonal characteristics through studied periods showing number of particular tests per period. In total data was collected and analyzed through the 6 month period from 4th and to the 9th month of the year inclusive.

Figure 10. Period of study



Legend:

(P) - Period and is applied as: P4 - April, P5 - May, P6 - June, P7 - July, P8 - August, P9 - September. Number in brackets means the consequent month of the year. Due to technical reasons data about tests abbreviations are presented in both Croatian and English as follows: ABS (Acidobazna ravnoteža) - Acid - Base Balance, ALP (Alkalna fosfataza) - Alkaline phosphatase, ALT (Alanin - aminotransferaza) - Alanine amino - transferase , AMY-u (α - amilaza - U) - α-amylase - U, APTV (Aktivirano parcijalno tromboplastinsko vrijeme) - Activated partial thromboplastin time, AST (Aspartat - aminotransferaza) - Aspartate aminotransferase, Ca (Ukupni kalcij - S) - Total calcium - S, CK (Kreatin - kinaza) - Creatine kinase, CRP (C-reaktivni protein) - C-reactive protein, DKS=KKS (Diferencijalna krvna slika) - Differential blood cells count, Bibr (Fibrinogen-aktivnost) - Fibrinogen activity, GGT (γ-glutamiltransferaza) - Glutamin transferase, GUK (Glukoza) - Glucose, HDL (Kolesterol) - HDL Cholesterol, HSTnl (Visoko osjetljivi Troponin I) - Highly sensitive Troponin I, iCa (Ionizirani kalcij) - Calcium (Ca2+) ionised, K (Kalij-S) - Potassium S, Kol (Ukupni kolesterol) - Total cholesterol, KREA (Kreatinin klirens) - Creatinine clearance, KS (Kompletna krvna slika) - Complete blood cells count, LDH (Laktat-dehidrogenaza) - Lactate dehydrogenase, Na (Natrij-S) - Sodium S, OKULT (Hemoglobin - okultno krvarenje) - Hemoglobin occult bleeding, PV (Protrombinsko vrijeme - omjer) - Prothrombin time ratio, T4 (Ukupni tyrosine) - Total tyrosine, T-BIL (Ukupni bilirubin) - Total bilirubin, TRIG (Trigliceridi) - Triglycerides, TROP (Troponin I) - Troponin I, TSH+TSH DT (Tireoidni stimulirajući hormon - Tireotropin) - Thyroid stimulating hormone (Thyrotropin), UIBC (Nezasićeni kapacitet vezanja željeza) - Unsaturated iron binding capacity, URATI (Urati-S) - Urates S, UREA - Urea, SE (Brzina sedimentacije eritrocita) - Erythrocyte sedimentation rate, Fe (Željezo) - Iron, COHb (Karboksi-hemoglobin) - Carboxyhemoglobin.

Figure 11. shows distribution of total number of tests showing most frequently ordered tests in Laboratory.

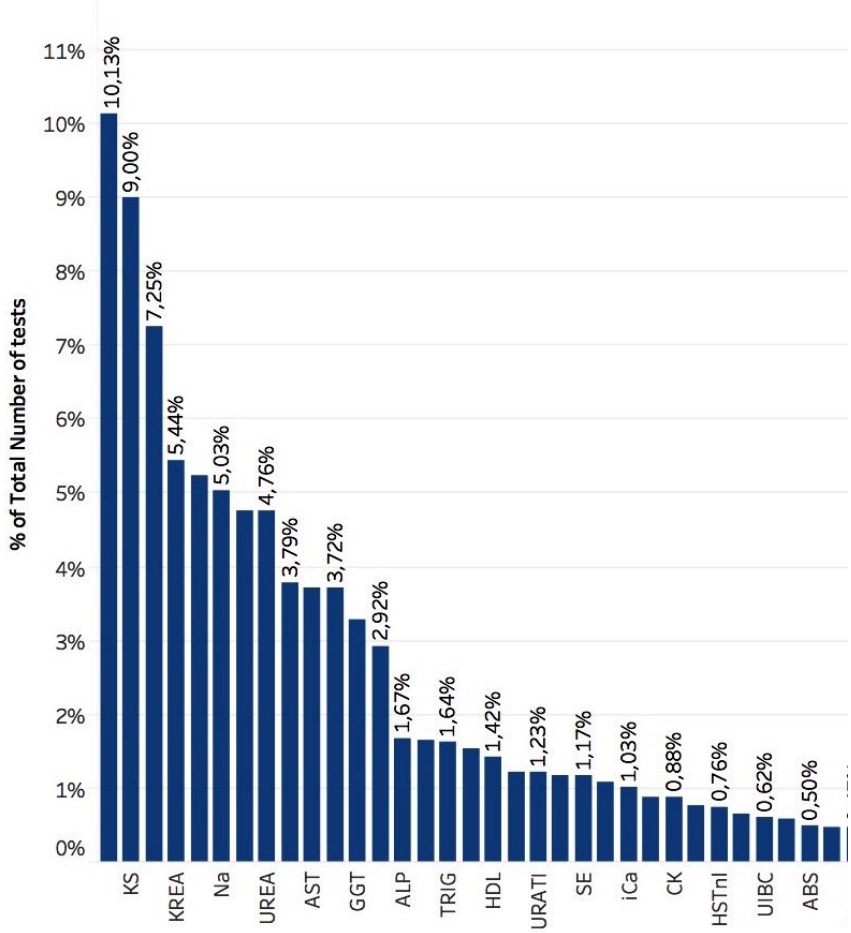


Figure 11. Distribution of total number of tests

The most frequently ordered tests are defined as those that are ordered often and/or in larger volumes over the period of study. According to the graph they are KS, KREA, Na, UREA, AST, GGT, ALP, TRIG, HDL, URATI, SE, iCa, CK, HSTnl, UIBC, ABS.

Figure 12. shows the distribution of total number of tests, showing the most frequently ordered tests from the lab divided by period.

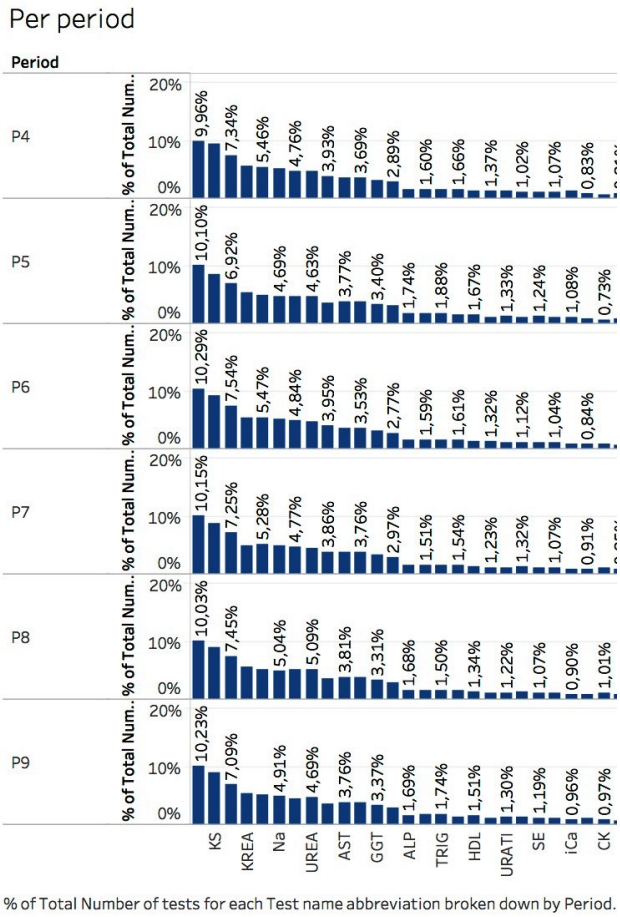


Figure 12. Distribution per period

As in the previous Figure 11., but in this case we were looking for relations while analysed per every month of the study. It shows that frequency is similarly distributed over the periods of the study.

Figure 13. shows the relationships between test frequency and price.

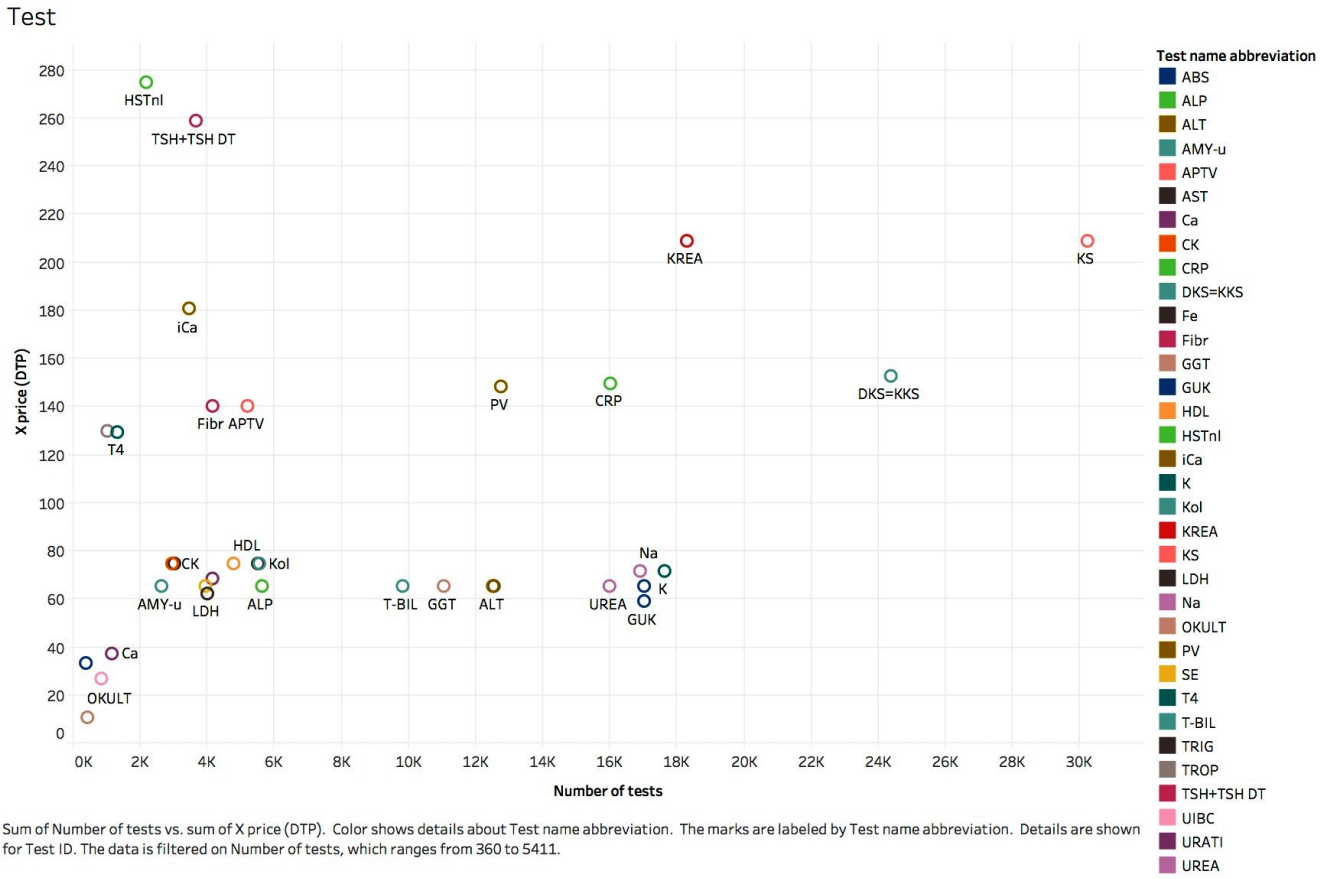


Figure 13. Tests in Laboratory

We can see several clusters of tests in sectors (coordinates net x,y): x=0-40HRK,y=2K; x=60-80HRK,y=6K; x=50-80HRK,y=18K. Other clusters are much smaller; alternately, we can see the absence of clusters for some ranges. In our opinion cluster analysis can be used for optimization.

x - number of tests

y - price of tests

Figure 14. shows statistics of working staff hours per period.

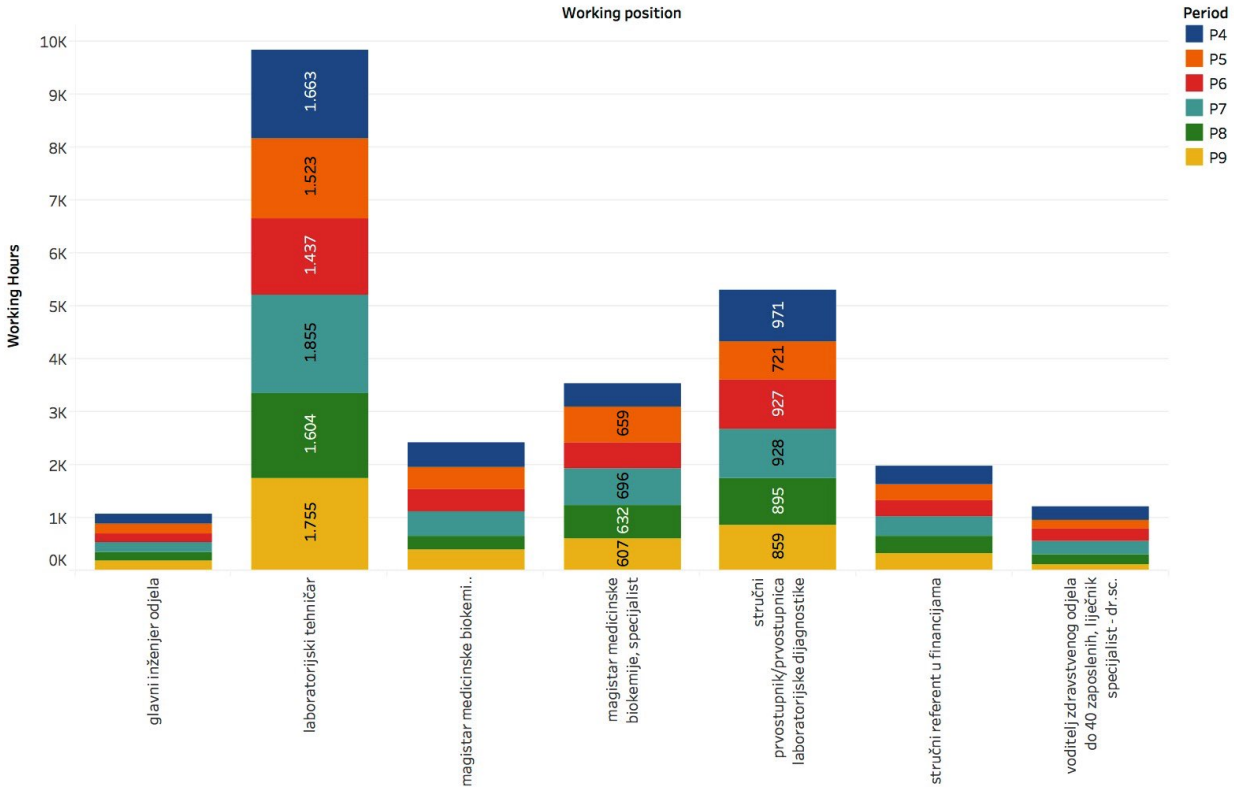


Figure 14. Employees' educational background in relation to working hours

The Figure gives information about the distribution of working hours, which depends on educational background.

Figure 15. shows relationships between working hours versus working hours with relation to working position.

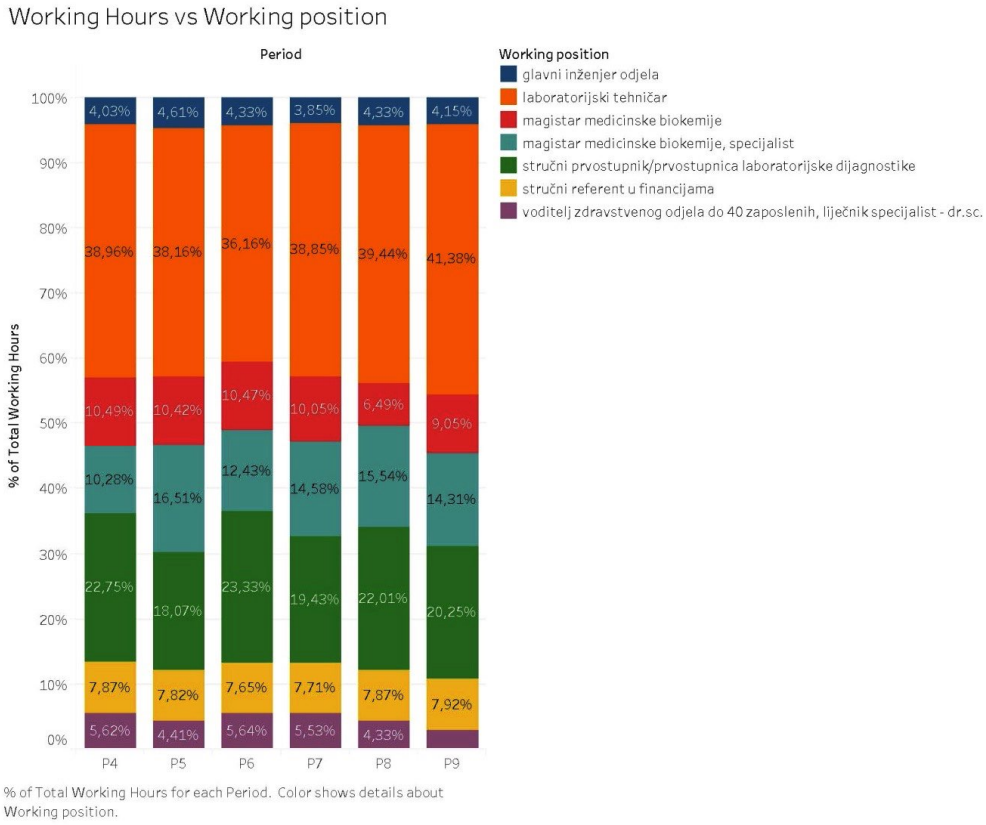


Figure 15. Working hours versus working hours with relation to working position

Figures show that employees with upper educational levels such as head engineer, magister of medical biochemistry, head of the department with scientific degree, etc. taking into account the time frame of the 6 month period of the current study have higher gross salaries than their colleagues with bachelor degrees or lower technical school qualifications. Figure shows 2 peaks of 9937 hours/6 months for – laboratorijski tehnicar (ISCED 4,5) and of 5301 hours/6 months for strucni prvostupnik laboratorijske diagnostike (ISCED 4) as a dominant share in 6 months period of a total working hours and on the other hand - the inverse relation for glavni inzenjer odjela (ISCED 6) and voditelj zdravstvenog odjela (ISCED 8).

During period of study general waste data for total period of 6 month includes: 540 kg of Infectious waste, 48 kg of contaminated packages, 6 kg of used glass, 6 kg of a hazardous glass, 180 kg of mixed communal waste, 12 kg of a used nylon, 180 kg of pharmaceutical waste and 48 kg of various plastics. General waste data for the total period was taken into consideration only quantitatively. We can see that the main components of the total WASTE during the period of study are infectious waste, mixed communal and pharmaceutical waste - 540 kg, 180 kg and 180 kg respectively.

General expenses of the Laboratory data for total period are presented in Table 7.

Specification	Monthly Expenses in HRK
Electricity	5940,00
Fuel oil	6,00
Natural gas	3861,00
Water	1040,00

Table 7. Monthly expenses in Laboratory

General expenses data for the total period were taken into consideration only quantitatively. Unfortunately, we could not use these data and compare them with those of other medical institutions but actually this was not an objective of this particular study.

In Table 8. and Table 9. we present duration of sample processing recorded in three iterations together with average duration.

Table 8. Regular blood sample processing

Process	Duration of a Sample Processing, sec.			
	First check	Second check	Third check	Average
Identification of patient	16	14	18	16
Blood sample extraction	27	23	26	25,3
Sample Cooling	1800	1800	1800	1800
Centrifugal processing	600	600	600	600
Sample registration in (LIS, BIS, Hospital Software)	180	240	180	200
Sample processing with different machines:				
Sysmex XN 1000 (KKS)	1680	1680	1680	1680
Vesmatic cube 30 (Sedimen-tation)	1980	1980	1980	1980
610 Rad D10 (Glycolised Hemoglobin)	300	300	300	300
Architect i 1000 SR (Brain nitrite peptide)	1800	1800	1800	1800
Sample validation	180	230	200	203,3
Sample result printing for further clinical processing	30	25	30	28,3

Table 9. Urgent blood sample processing

Process	Duration of a Sample Processing, sec.			
	First check	Second check	Third check	Average
Identification of patient	12	11	16	14,3
Blood sample extraction	25	20	20	
Sample cooling	600	600	600	600
Centrifugal processing	600	600	600	600
Sample registration in (LIS, BIS, Hospital Softwares)	160	220	180	186,7
Sample processing with different machines:				
Sysmex xn 1000 (KKS)	1680	1680	1680	1680
Vesmatic cube 30 (Sedimen-tation)	1980	1980	1980	1980
610 Rad D10 (Glycolised Hemoglobin)	300	300	300	300
Architect i 1000 SR (Brain nitrite peptide)	1800	1800	1800	1800
Sample validation	160	200	180	180
Sample result printing for further clinical processing	24	20	27	23,7

5.2 Level of satisfaction with working conditions

Based on the Inquiry of the staff (see 4.2.2. in Methods). Answers have been ranged from 1, which is the lowest score and means a negative answer, to 5 the highest score indicating complete satisfaction. Data are presented in Table 10.

Table 10. Level of satisfaction with working conditions

Codes of employees	Working conditions satisfaction evaluation	
	Financial conditions (x)	Environment, the human factor (x)
1	5	4
2	3	4
3	3	5
4	3	5
5	2	3
6	5	5
7	5	5
8	4	4
9	3	4
10	4	4
11	3	4
12	2	2
13	3	2
14	5	5
15	3	4
16	3	3
17	4	3
18	3	5
19	3	5
20	3	4
21	4	4
22	3	5
23	employee was absent	
24	employee was absent	
25	employee was absent	

x - *Answers have been ranged from 1 to 5. One is lowest score, meaning a negative answer; and 5 the most positive.*

The highest score in a Table 10 indicating complete satisfaction of a interviewed. Below it is shown in a Table 11. with the system of Points.

Table 11. Working conditions satisfaction evaluation

Points (from 1 to 5)	Working conditions satisfaction evaluation	
	Financial conditions	Environment, human factor
5	4	8
4	4	9
3	12	3
2	2	2
1	-	-

In our study there were 22 employees interviewed. If we take 12 employees, which is more than a half of a total and constitutes the mathematical median value (read 50%), the survey about environmental and financial conditions and general satisfaction of the laboratory staff showed that 50% of employees rated their financial conditions as satisfactory (3 of possible 5) which mean that wages are relatively good for this kind of work/responsibility. The 8 and 9 employees that rated the situation 5 and 4 points respectively constituted 17 employees in total (that is, 77%) who were more than satisfied with working environment (Table. 11).

5.3 Structured Interview with Direct Content Analysis

We emphasize that precise research into the field of staff analysis and management are not within the timeframe of the current research, however these factors do influence the results and should be mentioned in discussion. Here we present a coding scheme with categories and sub-categories with conclusions and proposals with relation to optimization issue.

ISCED 6 interview coding scheme:

- Category:

- Equipment and IT issues:

Codes (key words found in the script):

"PCs do not work properly"

"Printers and scanners do not work properly"

"IT network"

"Working environment"

"Technical issues are out of order"

"Problem with a value transition"

"Problem with the information flows"

Resulting codes:

"Results delay"

"Dissatisfaction with the job"

- Organizational issues:

B1) Subcategory:

Communication

(+) Positive statement codes
Participation
Good communication

B2) Subcategory:

Work system

(+) Codes
Relatively good location

Schedule in accordance with background
Monthly schedule
Meetings
General hospital meetings
Meetings minutes
Evidence
Plan

2. ISCED 4 interview coding scheme:

- Category:

- Equipment and IT issues

Codes:

"IT is out of order"

"Problem with data distribution"

"PCs are out of date, uncontrolled switch off"

Resulting codes:

"There are not enough PCs for the existing work volume"

- Category:

- Organizational issues:

B1) Subcategory: Communication

(+) Codes
Relationships are good
Regular meetings

Open talk about problems
Problem solving

B2) Subcategory:

Work system

(-) Codes
Work under pressure
Irritating competitive environment
Stress causes mistakes
Pressure
Problem solving on delay
Deficit
Deficit of employees
Big work volume
No vacant positions
Delays

3. ISCED 7 interview coding scheme:

- Category:

- Equipment and IT issues:

Codes:

"IT delays"

"Information flow sharing problem"

"PCs are out of date"

“Unreliable versions of software”

“Too weak PCs”

“Inefficient communication: a) between analyser and LIS, b) between BIS and CEZIH

“Communication with other departments on delay”

“PCs and software are incompatible”

Resulting codes:

“We can’t change… material issue”

- Category:

- Organizational issues

B1) Subcategory:

Communication

No codes found

B2) Subcategory:

Work system

(+) Codes
well organized
good liquidity
Hierarchical structured is well followed
Schedule for every employee
Responsibility
Good quality control and management
Employees do their best to fulfil tasks

(-) Codes
Human resources are on demand
Increasing patient flow
Increasing number of analyses and procedures

As it shown in our Direct Content Analysis the efficiency of fulfilling routine tasks depends on the mood, satisfaction and will of our interviewees. Of the 33 codes, which were distinguished in course of DCA – 21 (63.6%) are marked positive and 12 (36.4%) are marked as negative. Those marked as positive mainly address such factors as communication inside the system, working environment but on the other hand those marked as negative concern technical issues, out of date computers, delays in processing, insufficiency of professionals for particular laboratory tasks.

5.4 Defined Input parameters that lead to higher efficiency (optimization)

Interpretation of acquired data in particular research is descriptive which main characteristics is observation and conclusions. The alternative approach is proposed with aim to construct a decision support model that will be able to analyse limited amount of data on the one hand that are considered to be important for decision making and relations verification, and on the other hand is simple and easy to use for decision makers at different levels of a Healthcare system. Due to the mentioned approach to data collection and simplicity of procedure, producibility and replicability can be plainly achieved. Complete procedure how the Results have been obtained in particular study is classic Life Cycle Assessment methodology which is presented on the Figure 2., with adaptation described in Methodology and consists of data collection and its inventory, data sets assessment with the impacts of various input parameters in the borders of particular Health care system Unit - Laboratory, and finally the modeling where the parameters were grouped according to their quantitative or qualitative characteristics. Therefore quantitative parameters that have an impact on the particular healthcare system unit, and may lead to optimisation are Tests, Reagents, Prices, Patients, Sample processing time, Waste, Equipment, Quality measurements and Energy expenses. All obtained parameters have their number values and can be precisely analyzed. We marked these parameters as *Hard*. The second type of parameters we distinguished are qualitative and look for a deep description and analysis. We

marked them as *Soft*. *Soft* parameters are parameters that can be evaluated qualitatively and in our study they are crystallized from the answers obtained from: 1) survey about environmental and financial conditions, general satisfaction of the laboratory staff and 2) the structured interview. Parameters such as Financial condition satisfaction, Working environment, Equipment functionality, Information flow, Communication, General organisational issues, General satisfaction are descriptive and are a starting point for deeper content analysis and for future studies on similar subjects. With reference to optimization, which is the aim of the study, these parameters are the key qualitative factors that in our opinion have important effects on a little studied system. In a perspective so called hard parameters can be grouped, modeled, analysed using modern IT software (142-144). It makes the whole analysis much more precise and quantitative with possibility to "copy/paste" onto other systems in various healthcare institutions and units. An example of such new software-based solutions that can be implemented to the optimization of the life cycle of health care unit is visualized
in Figure 16.

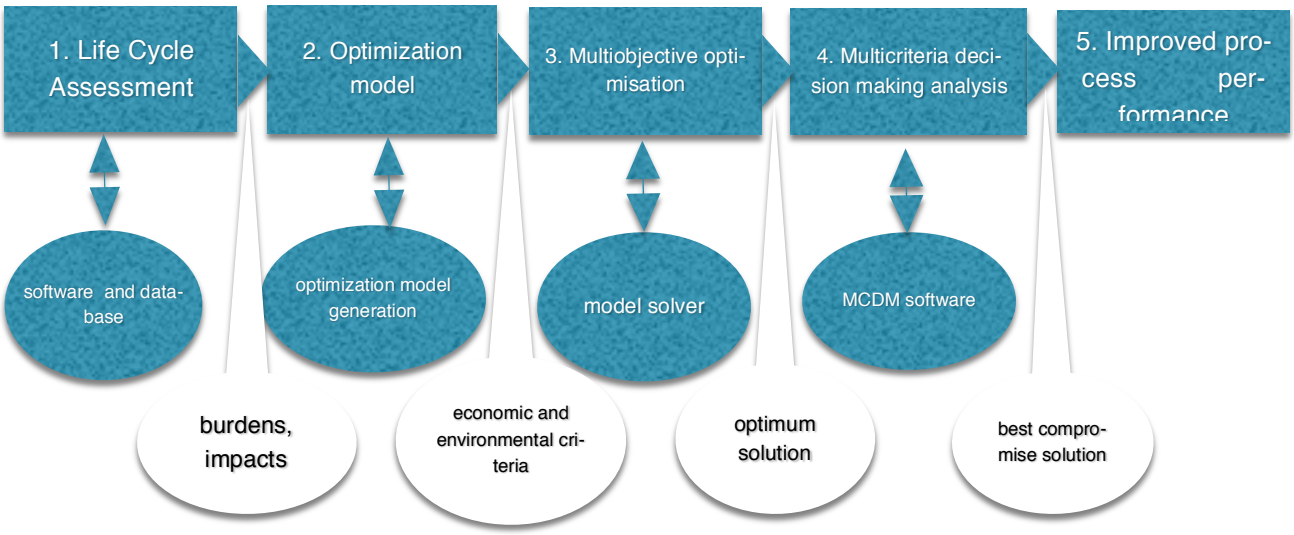


Fig. 16. The methodological framework for Optimum LCA Performance.
Source: The methodological framework for Optimum LCA Performance (OLCAP).

Figure presents a generic methodological framework in which it can be seen that after LCA performance, a technically based optimization model is applied (119). It can be designed taking into account economic, technical and other constants. Adding the economic and environmental criteria the multi-objective optimization scenario can be generated. Decision makers constantly

analyse performance and choose more applicable solutions according to the aims and purposes of the analysis. The final group of constants/parameters (which can be marked *Hard or Soft* as in the present study a result of the modeling are used as feedback and for multi-criteria decision-making (MCDM) software calibration and development with the subsequent finding of a best compromise solution which is relevant to the particular Life Cycle optimization.

6. Discussion

Some relations among the variables have been detected and are in the focus of current study. The numbers prove that for best performance management, the ratio between price/cost and volume of performed tests is crucial. In terms of financial efficiency it would be preferable for the laboratory to perform more tests at higher prices. Finding such a "sweet spot" on a graph with distribution of tests versus price can be used for marketing purposes to find a "niche" and to target that segment to create sales growth. Because the General Hospital of Zabok is a state owned institution and patients are mainly the subject to the rules of the state insurance policy it would be difficult to increase the volume of more expensive tests in which the profit margin is higher but in privately owned laboratories this recommendation could be effectively implemented, resulting in higher profit margin and financial sustainability. On the other hand it would be difficult to manage the volume of frequently ordered tests in a state owned healthcare system unit because it would result in additional demand for new facilities, technical equipment and staff. Looking through the 36 open access publications on similar subjects we have found that a large number of them have analysed private healthcare units and institutions, but relationships and conclusions are similar to the results of our study (88, 89). Unfortunately, it is not an easy task to address the issue in the current situation in Croatia where lack of resources together with ineffective money relocation is obvious (72, 74). Seasonal activity can also be helpful in life cycle managing. For example, a laboratory may postpone a non-urgent tests to the next period and increase the efficacy while prioritizing the volume of urgent tests. This would increase liquidity during the "non active" months and decrease the pressure during "active" periods. This point of view is supported by several publications addressing similar issues to access to clinics and duration of sample processing with optimization using Lean philosophy and Six Sigma principles (101, 107). It may be helpful also for personnel working time planning and distribution and in managing the life cycle in the waste disposal activity. We can see that the main components in waste disposal during the study period are infectious waste and mixed communal waste. In terms of optimization this may be used for planning of processing and recycling. Also, the figures show that employees with upper educational levels such as the head engineer, the holder of a master's degree in medical biochemistry, head of the department with scientific degree and so on, taking into account the timeframe of 6-month period of the current study, have higher gross salaries than their colleagues with bachelor's or lower technical schools qualifications. Actually, this inverse correlation follows the general trend in health care in Croatia (72). The situation is different at privately owned institutions in which the owners

and CEOs are in positions of authority irrespective of their level of education. Anyway, understanding of staff overall wages and analysis of wage to working hours ratio can help in the managing of staff expertise and HR-management. Furthermore, in our study we cannot see any relation between the tests performed and the working hours of employees. This is probably due to the specific features of a state-owned unit. In this particular situation the staff have scheduled working shifts and the number of tests conducted is not important. We suppose that situation is completely different in case of private ownership where in general performance and working hours are positively correlated. It is difficult to compare results with any others since it was not possible to find any study particularly relating to this topic in any scientific publication. General expenses data for total period are taken into consideration just as a quantitative factor. In terms of optimization they may be used for planning of expenses and effective budgeting. An important option is to consider general or partial substitution with alternative energy sources such as solar or geothermal. Unfortunately, we were not able to use these data and make comparisons with other medical institutions in Croatia; nor was it an objective of this particular study. But the obtained results show that after a proper analysis of the acquired data using Dual Group Based Parameter Model it is possible to define parameters that under certain circumstances may lead the system, a healthcare system unit – the Laboratory of Medical Biochemistry of the General Hospital of Zabok, in our particular case, to optimization. Parameters are classified as *Hard* and *Soft,* meaning that hard parameters have number values and are quantitative, while on the other hand soft parameters can be evaluated qualitatively through the analysis, codification and description of staff opinions. Every step is under the influence of the *Hard* and *Soft* parameters and for the purposes of the optimization of the whole system their influence can be modified, improved or eliminated if necessary. We have no found traces in the literature addressing these hard and soft parameters in similar researches, which enables us to claim originality for the present study. Besides the modification of hard parameters, optimization can be reached through the implementation of better managerial solutions, improvement of ethical issues, introduction of more effective and less time-consuming internal policies, instructions and regulations, industry and working position specific manuals and explanatory documents (33, 34, 107). Analysis of the codes of Direct Content Analysis gives us the understanding of main problems occurring in the routine work of the employees of the laboratory and this is the crucial point for making assumptions concerning the improvement and optimization of the work processes and relationships in general (123, 124). With respect to state owned institutions where the annual budgeting process is strictly predefined with limited resources, it is complicated to

find an *ad hoc* solution concerning the purchasing of modern and updated computers and software but it is highly recommended to make all possible relocations, for example, to relocate PCs with high speed processors and software to departments where their necessity is obvious and to decrease the level of purchasing of discounted and used appliances. In the long term this practice influences the whole system in a negative way. We have searched through 13 publications from PubMed where the indicated problems are shown as having been solved with use of a Six Sigma and Lean methodology regarding medical institutions, supportive to our point of view (107). Concerning the procedures, they should be implemented in such a way as to help to plan, organize, perform and control the processes but not in any way to create additional workload and bureaucracy, which can just complicate the processes and misuse the workforce. The same opinion was found in Croatian publications and is a good sign of the recovery of a local healthcare system (72). As a recommendation for a positive working environment the engagement in the process of a professional time-planning trainer or coach can be considered, for this can create effective models of behavior for work under pressure and in stressful conditions (78). As it can be seen, one of the important issues is to pay attention to the best sides of individuals, to get as many as possible from the existing human resources, to find triggers for staff motivation and the will to bring the best results, to find a proper model for different backgrounds and qualifications and to arouse the enthusiasm of the employees. It is necessary to emphasize that quantitative hard parameters can be regulated and standardized in their perspectives for units of the same size and with similar inputs inside similar system borders. Such a search for similarities and groupings of objects with similar characteristics with the following regulation and creating an "Etalon" molded item is used in design of standards. With relation to health care, standards are designed to encourage healthcare organizations to improve internal quality and performance, minimize the risks, including measures to protect and improve the safety of patients, to promote a culture of continual improvement, support efficient exchange of information and data protection while benefiting the environment and become close to the etalon. Depending on the scope of responsibilities and areas of activity every organization is able to choose voluntarily among standards to implement. ISO alone created about 1200 health standards that are grouped in families. Some of them such as Environmental Management ISO 14000, Occupational Health & Safety OHSAS 18000, Guidance on social responsibility ISO 26000, Environmental management 14000 are featured as much applicable to public health and health care. A family contains a number of standards each focusing on different aspects of a corresponding topic. According to 2012 ISO Press release the most commonly used standard is

Quality Management Standard ISO 9001 (which belongs to the family ISO 9000 - Quality management systems). Due to its generic basis, it is applicable to all types of organizations. It enables a company to develop a Quality Management System (QMS) which implies the introduction of quality planning, quality assurance, quality control and quality improvement (65, 66) and is a perfect tool for measurement and determination of the ultimate way of development of health services. ISO 9001 has been currently updated and together with Cooperation for Transparency and Quality (KTQ) for Hospitals has become the most acknowledged "brand" for quality recognition in healthcare. KTQ certification is aimed at hospitals, medical practitioners and institutions, rehabilitation centers, nursing homes, hospices, and emergency medical services (67). It displays that the focus is primarily on patient satisfaction, from preparation of stay until discharge. In the literature, the definition of quality management is widely using as a methodology that substitutes for or goes hand in hand with Life Cycle Assessment, which in recent times more often is used for processes in service industries and health care. A good example of such practical application of LCA management in a combined clinic is perfectly demonstrated by Eckert H. and Schulze U., (2004) (68). In spite of widely the accepted practice of implementing Life Cycle Assessment methodology mainly to industries with outrageous environmental impacts and relatively small number of publications, with relation to the implementation of the method for healthcare unit assessment, using the example of the findings from the current study, we proposed in principle a holistic approach to the topic. A handful of relatively small studies concerned with LCA for public health were published in the 1980s and 1990s but as far back as the 1970s, none was found. This means that LCA method is relatively new and has a potential for development in the future (86). Some studies that review LCA implementation attempt to provide figures solely concerned with assessment of waste resulting from processing and are for obvious reasons not representative because they reflect a fragmented approach that is not in the spirit of the LCA concept. Eleven studies provide insight in the perspective of LCA development in general and are theoretical approaches; they are review articles and do not give any quantitative data. We identified no publications investigating holistic data acquisition based on the work of a particular healthcare system unit. From the late 90s, more than 1880 publications concerned with rigid rules, procedures and standards development were found. Not one of them addressed health care implementation issues. In the indicated timeframe we identified one publication investigating the life cycle management (which is a life cycle assessment-based management rules) in an outpatient clinic where LCA was effectively introduced for staff management. Its approach was closer to "lean philosophy" than to classic LCA. Research revealed considerable variation in staff capacity utilization between two schedules and huge economies

were made when appropriate changes and improvements related to staff shifts and use of materials were made. The researches also reflect the need of clinicians and managers to attempt to evolve their traditional functional responsibilities and work together to integrate clinicians into the management process. Several articles are critical, and researchers expresses their disappointment that the substantial scheduled and planned knowledge of the methodology in the field has, over the 20 years since its introduction, been hardly applied in healthcare practice at all. Of great importance is the possibility of unit optimization when delays in access to polyclinics and duration of sample processing are addressed. Eight studies analysed the relation between delays in access to outpatient clinics and the duration of sample processing (92-99). All studies are from abroad, not from Croatia, and involved relatively small populations, most often of one hospital. Five publications report a positive relation (92-96). Two studies report no relation (97, 98). One study found no relation between outcomes but found a relation between continuity of care and clinical outcomes (99). Since 2001 the number of publications in relation to delays in access to polyclinics/outpatient clinics has suddenly strongly increased. Almost all concern the application of Advanced Access together with options for urgent sample processing as a strategy to improve access and outcomes (101-103). The first publications were only aimed at primary care while later contributions addressed specialty care. Unlike earlier publications, these are all come from care providers themselves, often physicians. The articles have a practical application, with references to queuing theory, industrial engineering and "lean thinking", the Theory of Constraints and the Toyota Production System, but with little further theoretical substantiation. General practitioner Mark Murray created the model of Advanced Access. The aim of advanced access is to eliminate delays in access. The basic assumption is that it can be achieved by optimizing the way demand and supply are matched and by increasing the efficiency with which supply is delivered (103). Six core elements are proposed to enable this: a) balance supply and demand. The researcher proposes to use data for population calculation, level of patient demand for visits and number of appointment slots available. Demand is measured prospectively: what appointments patients actually ask for and what follow-up appointments clinicians actually request. Supply is measured as available clinician time. Supply and demand must be brought into balance for advanced access to work. This requires mainly reallocating return appointments in such a way as to smooth out the overall flow of demand with physicians having to adjust their schedules to make the most time available when demand is highest; b) backlog reduction. The proposal is to organize a one-time extra session to eliminate backlog; c) reduce the variety of appointment types, which means for proposing only two types of appointments with two appointment lengths that can be booked for any available slot. It

would develop simple and flexible schedule; d) developing the contingency plans for unusual circumstances needed to deal with inevitable variations in demand and supply. Strategies can restrict prescheduled appointments or increase capacity; e) adjusting demand profiles can maximize the effectiveness of each visit by e.g. covering multiple issues during one sitting, using GSM, emails and group medical visits. Taking into consideration that it addresses the ethical component, such strategies can be used for fewer individual appointments than have been agreed to previously; f) increasing the availability of bottleneck resources means the reallocation of some clinical assignments. This can maximize the physician's efficiency. After 2008, successful study researches conclude that the implementation of advanced access is influenced by intentionally spread activities as well as organizational factors including local management support, staff capabilities (level of education, expertise, will for improving tasks, etc.) and facility context and availability. Two factors showed a strong correlation for practice: management support and unit team knowledge and skills. Four factors showed a strong correlation for specialty practices; they are a month working on advanced access, availability of advanced access resource materials, staff review of advanced access performance data and use of consulting physicians. Two factors showed a strong correlation for primary practices and they are examination rooms for clinicians and patients on wait list (100). There are not enough studies to draw general conclusions, but there are indications that there can be some relation, which can be transferred to the situation with similar delays in sample processing in the laboratories of Croatia. Moreover, quality of sample processing in the laboratory is directly correlated with the efficacy of patient care and clinical outcomes as a consequence. Based on the mentioned researches we are also free to conclude that leadership involves not so much personal advocacy, but, rather, the establishment of supportive structures and internal procedures (145-147, 149). This includes the appointment of an oversight body, incorporating procedures into facility priorities, holding managers accountable for improvement-related performance, designating leaders for each area, reporting progress and targeting resources to remove obstacles to implementation that are beyond the reach of local departments. The team's knowledge and skills share empower the staff members to work together to make successful changes. This includes seeking information and effectively using that information to design, validate, and feedback process improvements, regularly assess progress and learn from the efforts and mistakes of others. In our opinion much more attention should be paid also to the psycho-emotional state of the staff and general satisfaction. Such environmental factors as noise, temperature, and humidity inside the system borders also have influence but we did not focus the attention of this research on a deep analysis of such influences. The results attained prove that the working environment and

staff satisfaction in the unit contributes to the whole system's efficacy and aids in the creation of a healthy and comfortable atmosphere, which consequently gives new opportunities for development and process optimization. Content analysis was developed primarily in anthropology, qualitative sociology, and psychology, in order to explore the meanings underlying physical messages. Content analysis has been defined as: "research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (124). Content analysis goes on to examine meanings, themes and patterns that may be manifest or latent in a particular text. It allows researchers to understand social reality in a subjective but scientific manner and is mainly inductive, grounding the examination of topics and themes, as well as the inferences drawn from them, in the data. Direct/Qualitative content analysis (DCA/QCA) pays attention to unique themes that illustrate the range of the meanings of the phenomenon rather than the statistical significance of the occurrence of particular texts or concepts. Results concerning the general satisfaction of staff obtained during DCA and those from evaluation of structured interview are different. We may conclude that DCA is a more precise method of evaluation than structured interview and enables us to go much deeper into details while looking for the answers. Understanding of staff's overall workload pressure can help managing staff expertise and HR management of the unit. Much more profound experiments should be done on the subject of the influence of psychological states on physical reality (126-130). As Nikola Tesla mentioned in his Autobiography: "The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence" (120). For the last four hundred years, an unstated assumption of science is that human intention cannot affect what we call "physical reality". But the experimental research of the past decade conducted by William A. Tiller in "Psychoenergetic Science" shows that, for today's world and under the right conditions, this assumption should be corrected and reassured. Despite global digitalization and the regular use of virtual reality we would like to emphasize the importance of regular communication and interviewing of a staff (121, 122). We would distinguish three main reasons for that. First of all, for the effective fulfilment of working tasks it is necessary to reveal the unproductive and ineffective models of behavior and attitude which have a direct influence on relationships inside the system, on the patients and on the efficacy of the performed responsibilities at the end. The second component is the one-time feedback of what goes well and what should be corrected, improved or illuminated. The third and more important component, which we would like to underline, is the distribution of knowledge and experience that has a crucial impact on the system in a whole. All these topics were revealed in the course of our LCA performed with respect

to the Laboratory, which may lead to confirmation of the effectiveness of such holistic approaches as LCA for this kind of unit assessment and scientific studies. The introduction of such approaches, leading staff members, from a fragmented perception, to awareness of the system as a whole, is in our opinion a necessity for the effective existence of modern systems and units. The consequences of staff dissatisfaction with working conditions and salary levels in Croatia is the drain of staff abroad to other European Union countries mainly to Germany, the Netherlands, Austria, Scotland. This leak is known in the literature as "Brain-drain" syndrome. This problem is one of the key negative factors affecting the efficiency of functioning of various industries and services. Unfortunately, it affects the Croatian healthcare system much more than other professional fields. As a result, hospital units and the whole healthcare system of Croatia are understaffed. According to the Statistic Board in a period from 2007 to 2015 the total number of medical professionals of different levels was and still is constantly decreasing and these levels show the impossibility of maintaining the performance of the whole system at an adequate level. The problem is reflected in lower number of medical staff per capita, which results in the regular exhaustion of human resources, queues and delays in access to medical facilities, loss of efficiency with the subsequent overloading and dissatisfaction of medical and technical staff (72-74). We can see that this problem cannot be solved without a complete remodelling and reorganization of whole healthcare system of Croatia. Taking into account the financial and administrative dependence of the Croatian national healthcare system units on upper level institutions, we would propose a strategic approach in which a top-down approach for both management and front-line operatives (148). For upper management e.g. the Ministry of Health of Croatia, a large portion of strategic problem solving involves predicting problems that subordinates e.g. hospitals and units might encounter and documenting procedural solutions in advance, often through manuals or logic tree flowcharts. Another dimension of strategic planning in management requires that a leader know the strengths and weaknesses of staff, assigning personnel to tasks that play to their personal strengths; for example, an outgoing staff member might do well in either customer service or maintenance, but putting him in customer service takes advantage of his communication skills. In our strong opinion, horizontal level staff communication only is not sufficient. While solving the above-mentioned problem we should be confronted by another problem, commonly distributed throughout the healthcare systems of former states of Yugoslavia and other former socialist countries, which is a rigid bureaucracy (72). Unfortunately, it is impossible to solve this issue ad hoc because it depends on total shift of the established system, working traditions, mental habits and perception of people.

But sooner or later this shift will become a necessity for obvious reasons: population is becoming more and more concerned and responsible with relation to sustainability and efficacy topics; many of old fashioned economic, behavioral and business models do not work anymore; modern working tasks and responsibilities require less time consuming, self-sustaining, cost saving and more effective approaches (37, 38). Everything listed above is impossible without the growing concern and attention to studying and implementation of a system thinking and problem solving. All these crisscrossed relations and correlations, the processing of big volumes of data, multiple factors, which influence systems and relationships require new methodologies, concepts and a new worldview. In addition to Life Cycle Assessment, which is the main methodology used in the current study, one such holistic route, based rather on philosophy than on a scientific approach, which addresses the optimization and improvement of processes more and more frequently, is the so-called "lean" philosophy. This management philosophy improves quality by continuously removing wasteful materials, tools, practices and working habits. Research on process improvement by applying lean philosophy reports many positive outcomes defined as increased safety, quality and efficiency. It requires that healthcare system units develop integral systems that combine methods for process design with continual improvement of steps in processes chains with associated forms of people management. Vital is a holistic view when staff members take the lead to manage and improve processes integrally. "Lean philosophy" is based on the Toyota Production System the effects of which in quality, safety, flexibility and cost reduction have been proven (104, 105). A 1987 study showed that Toyota was building cars with half of the problems in quality, in half of the throughput time, half of the inventory and with a half of the people of other car manufacturers. The involved researches labelled this "Lean" (efficient and agile production) (105). Toyota Corporation spoke of a system aimed at improvement of quality while continuously reducing "waste" (106). Waste by their definition was every step, which did not add value for the customer and in this approach, waste, is the root cause of quality problems. In the course of development "lean philosophy" grew into a collection of principles, methods and tools for the design, control and improvement of processes. This "lean philosophy" distinguishes seven forms of waste and their reduction can increase the value for customers and while applied to the healthcare – to the patients (106). Value for patients is every action/step/process that directly or indirectly contributes to improving health conditions or tools leading to the improvement of health conditions. "Lean philosophy" doesn't work if waste is removed just locally. It requires a systemic approach. In reality, care processes run through different departments and multiple processes require time often of the same people and innumerable resources. This implies that the improvement of one process

can negatively affect another process. Managing the system holistically is the core of process improvement (108). According to the philosophy of Toyota, company culture is based on the fundamental values of "respect" and "kaizen", meaning that everybody improves everywhere always. In laboratories, for example, this integral approach implies that people from other units have more influence on your processes to manage and improve the total process (109). Some operations and working decisions depend on other departments, for example the financial and the technical and can be separately improved or managed without approvals and permits. Several hundred studies have been published on the application of the philosophy in hospitals, more than 200 of them being related to laboratories. Most studies have been performed in the last 7 years, mostly in United States and a handful in the Netherlands. To our knowledge, none have been performed in Croatia or the former Yugoslavia. The studies show identical patterns of positive outcomes defined as safety, quality and efficiency. Due to methodological shortcomings, a lack of rigorous evaluations and the risk of bias it cannot yet be determined what the impact is of lean-philosophy process improvement. . Several studies conclude that despite the integral approach, the application of "lean" merely results in local improvements within departments of for specific processes without their being a systemic impact on the whole laboratory (108, 109). This is ascribed to over focus on the instrumental application, a lack of integration in the total system and a lack of attention to the human dimensions (108). In Germany, for example, lean is primarily applied just for cost reduction, while most of the core value of the philosophy is lost (112). A few hospitals claim substantial results for the entire system. Virginia Mason Medical Center ranks in comparison with 1160 hospitals on both quality and efficiency in the top 1% and ascribes this to the implementation of "lean-philosophy" (113). ThedaCare, a "health system" that includes five hospitals, claims to have achieved a productivity improvement of 12% in 3 years and to have a downtrend in delays and optimization of duration of sample processing (114). So far both hospitals have published studies showing an improvement in partial processes. The only Dutch publication that describes the philosophy at hospital level also claims a hospital-wide impact but has the same methodological limitations that prevent definite conclusions (115). In comparison Life Cycle Assessment methodology is much more precise and has a well-designed methodological basis. Moreover, it is a standardized method. In our case we also started from the assessment of one process but later transposed it to the whole unit. The same principle can be used for application of the method and consequent optimization on the whole hospital or even health care system of, for example, Croatia. We understand that it is difficult to completely rely on LCA based on one sample processing and took as a reference point the data based on a summary of tests during a one-month or even

a six-month period in a laboratory. However, with the approach of complex data acquisition and system analysis we elevated the LCA to the level of a health care system unit – laboratory in a particular case. We distinguished a new system with its boundaries where the LCA of a multitude of processes comprises the cumulative LCA of the healthcare system unit. "Lean-philosophy" is not a toolbox to reduce costs and improve efficiency. The core idea is a continuous sustainable improvement with an integral system approach. It concerns the management of relations between processes, the combination of methods for process design and improvements with tools for personnel management that includes values like "respect" and "kaizen" (110). Synergy has to be aimed at and achieved so that root causes can be addressed without the risk of sub optimization, the risk of changes that result in particular improvements but create unsustainable biases and reduce quality in general. Very often, fast results works are achieved at the expense of the required climate to integrate process improvement in the routines of the organisations (107). Summarizing all proposed holistic concepts and tools we understand that from the start a holistic view will in some way frustrate many professionals because it requires much higher level of responsibility with relation to the routine tasks but according to a well-known saying "We can't solve problems by using the same kind of thinking that was used when we created them"; this means that without new initiatives and tools which can provide leverage for changes it is impossible to improve the systems and modernize the world as a big multilevel and multitasking system. Vital for the success of the application of holistic philosophy is the common understanding of its necessity and common wish, will, attempt and drive to eliminate waste and create new surroundings for sustainable and continual growth. In addition, all described innovative solutions would be the drivers for creating more advanced work frames and guidelines for the development of a normative - legal framework; guidelines for setting limits for certain hazardous emissions, effects and impacts on human health, working procedures and behavioural models. Introduction of LCA refers to one of the building blocks of the Europe 2020 Strategy – "Roadmap to a Resource Efficient Europe" and proposes ways to increase resource productivity and to decouple economic growth from both resource use by units and environmental impacts, taking a life cycle perspective. LCA is a relatively new approach with a constantly developing methodology. It would be a convenient backstop for holistic description of the life cycles of products and services, specifically in healthcare, where the use of sustainable technologies, materials and processes is extremely important. Taking into account the permanent scarcity of resources, materials and emphasis on cost-saving procedures in the social sphere, the method would be an efficient way for the optimization of economic and environmental performance of a healthcare system. Inside the proposed framework new factors

should be identified and should lead to the creation of new models and techniques for the assessment of complex units. On a governmental level LCA should be successfully applied to the analysis of a healthcare system as a whole and of particular units (e.g. departments, laboratories, hospitals, ambulances, governmental institutions), for the study of the life cycle of a single process, the efficiency of medical staff as well as for analysis of the performance of the entire healthcare system of a particular country etc (141, 148). In addition, the rising social responsibility, corporate social responsibility and Life Cycle Management principles would be drivers for development and widespread application of such methods to processes and activities of healthcare institutions as a whole (33, 34). It would be of great importance the development and implementation of an effective public healthcare system model based on relevant, meaningful, robust, results and principles of careful use of resources, improvement of recovery of patients and economic efficiency of units. Besides, we expect a great potential for development of the concept of life cycle assessment methodologies implementation in a healthcare in similar studies and publications in the future.

7. Conclusions:

1. The Dual Base Parameter Model revealed the parameters which were marked as *Hard* and *Soft* parameters.

2. The modelling of *Hard* parameters leads to the optimization of the Unit.

3. *Hard* parameters have numerical values and can be used for development of a software package with its subsequent implementation with the purpose of optimizing various working processes.

5. *Hard* parameters can be helpful for the design of an effective legal framework, which can helpful in cases of voluntary accreditation or standardization.

6. Qualitative *Soft* parameters are descriptive and can be effectively utilized as an additional variable for optimisation and development of principles of quality management for the particular healthcare system unit.

7. *Soft* parameters are necessary for the design of a convenient working environment with maximum realization by every employee of her or his professional skills and capacity. Together with effective communication it can reveal the problems and weaknesses during their emergence and in different phases of the life cycle.

8. Both *Hard* and *Soft* parameters can be used for the design of a "Check list" that can be used for a complex audit of healthcare system units and subsequent analysis. This reflects a new trend that permits acceleration and simplification of data acquisition as well as acquisition of statistical data for the purposes of the healthcare system of a particular region or country.

9. Utilization of a standardized and regulated checklist can be adopted to healthcare system units of all kinds in Croatia and abroad.

10. Dual Base Parameter Model is helpful for analyzing any healthcare system unit and furthermore for the development of an effective model that can be applied not only to individual units but also to larger health care institutions, hospitals, clinics, rehabilitation centers and the entire healthcare system of a region or country.

11. For some units it can be relatively difficult to define System Boundaries because the system is not under ideal conditions, which means that it is "open" and many processes and expenditures are interconnected or shared with other departments and units. For example, in state owned healthcare institutions such as the General Hospital of Zabok, some expenses such as electricity, water consumption and migration of staff among various departments create bias and in consequence the inability to define strict system boundaries and influencing factors.

8. Abstract in Croatian

Svrha je ovog istraživanja dokazati da optimizacija parametara određene jedinice sustava zdravstvene zaštite prema načelima održivosti povećava njezinu učinkovitost. Za potrebe ovog istraživanja jedinicu sustava zdravstvene zaštite predstavlja Odjel za medicinsku biokemiju pri Medicinsko biokemijskom laboratoriju Opće bolnice Zabok. Istraživanje za ovaj rad provedeno je u Školi narodnog zdravlja „Andrija Štampar“ Medicinskog fakulteta Sveučilišta u Zagrebu od 30.03.2014. do 30.09.2015., te bolnici u Zaboku. Bolnica u Zaboku odabrana je za ovo istraživanje jer je jedna od vodećih ustanova u Hrvatskoj, a laboratorij u kojem je provedeno istraživanje smješten je u potpuno opremljenim prostorijama s dovoljnom količinom materijala, novom opremom i profesionalnim osobljem, što znači da sadrži dovoljno komponenti za predmetno istraživanje. Kvantitativne i kvalitativne metode korištene su u svrhu postizanja općenitog cilja koji se sastojao u ispitivanju hipoteze prema kojoj optimizacija ulaznih parametara donosi veću ekonomsku učinkovitost. Istraživanje je provedeno u skladu s planom rada i prikupljanjem podataka, a sastojalo se od početne faze, faze modeliranja i analitičke faze s naknadnom obradom podataka. Služili smo se metodama kao što su procjena životnog ciklusa (Life Cycle Assessment = LCA), strukturirani intervju, računalno modeliranje i direktna analiza sadržaja. Metodologija procjene životnog ciklusa učinkovito je primijenjena u svrhu analize jedinice sustava zdravstvene zaštite, a riječ je o prvom istraživanju implementacije LCA u zdravstvenom sustavu u Hrvatskoj. Tijekom istraživanja izračunati su inputi i outputi, kao što su kemijski reagensi, otopine, tehnička oprema, uvjeti u radnom okruženju, količina različitih tipova otpada u određenom razdoblju, radni sati i troškovi. Uključeni su i intervjui s medicinskim osobljem koji su potom transkribirani i obrađeni direktnom analizom sadržaja s ciljem dobivanja dubinskih kvalitativnih podataka. Provedeni su modeliranje i dubinska računalna analiza podataka u svrhu pronalaženja parametara koji bi mogli rezultirati optimizacijom jedinice. To je bila prilika i za obavljanje računalne podatkovne analize parametara u okvirima laboratorija. Nakon precizne analize identificirali smo ključne parametre koji konstantno utječu na sustav, a čije bi modeliranje moglo rezultirati optimizacijom sustava u cjelini. Označili smo ih kao tvrde i meke. Dobiveni rezultati potvrdili su našu početnu hipotezu. Tijekom istraživanja otkrivena je važnost mentalnog stanja djelatnika i odnosa među kolegama, koji pozitivno ili negativno utječu na obavljanje radnih zadataka. Obzirom da oni nisu cilj istraživanja od samog početka, smatramo da bi o toj konkretnoj temi trebalo provesti dodatna istraživanja. Uvođenje LCA u zdravstvo jedan je od elemenata Strategije Europa 2020 – “Roadmap to a Resource Efficient Europe”. Stalna oskudica resursa, materijala i naglasak na postupcima uštede troškova

u društvenoj sferi dovode nas do pokušaja pronalaženja učinkovitih načina optimizacije ekonomskih i okolišnih učinaka zdravstvene zaštite. Identificirani parametri mogli bi u predloženim okvirima rezultirati stvaranjem novih modela i tehnika u svrhu konačne optimizacije jedinica. Metodologija procjene životnog ciklusa trebala bi se uspješno primjenjivati u analizi jedinica sustava zdravstvene zaštite (npr. odjela, laboratorija, bolnica, ambulanti i operacijskih sala), proučavanja životnog ciklusa pojedinačnih procesa, učinkovitost zdravstvenih djelatnika, kao i u analizi uspješnosti zdravstvenog sustava određene regije ili čitave države. Osim toga, rastuća društvena odgovornost, društvena odgovornost tvrtki i upravljanje životnim ciklusom biti će pokretači razvoja i široke primjene takvih metoda u procesima i aktivnostima zdravstvenih ustanova širom svijeta. Stoga bi bilo od iznimne važnosti razviti i primijeniti učinkovit model optimiziranja sustava u zdravstvu utemeljen na relevantnim, značajnim, pouzdanim rezultatima, prema načelima pažljivog korištenja resursa, poboljšanja oporavka pacijenata i ekonomsku učinkovitost jedinica. Sektori javnog zdravstva i zdravstvene zaštite mogli bi na taj način postati održivi i pouzdani socijalni partneri s visokom razinom odgovornosti što bi djelatnike učinilo predanijima i motiviranijima, a pacijente zadovoljnijima.

9. Abstract in English

The purpose of this study is to prove that the optimization of parameters of a given healthcare system unit according to sustainability principles leads to higher efficiency. In this study, Department of Medical Biochemistry at the Laboratory of Medical Biochemistry of the Zabok General Hospital was chosen to represent a healthcare system unit. The actual research for this thesis was performed at the University of Zagreb School of Medicine Andrija Stampar School of Public Health from 30.03.2014 to 30.09.2015 (duration of study – 6 months). The hospital in Zabok was chosen for the current study because it is one of the leading institutions in Croatia and the laboratory where the study was performed occupies fully equipped premises with plenty of materials, innovative equipment and professional staff, accordingly presenting sufficient components for the present research. Quantitative and qualitative methods were employed to reach our general aim of testing the hypothesis that the optimization of input parameters leads to higher economic efficiency. The study was performed according to the working plan of data acquisition and consisted of Initial Phase, Modelling phase and Analytical phase with the subsequent data processing. We used methods such as Life Cycle Assessment, structured interview, computer modelling, and direct content analysis. Life Cycle Assessment methodology was effectively adopted for the purposes of health care system unit analysis and it is the first study of LCA implementation in health care in Croatia. In the duration of the study the given inputs and outputs such as chemical reagents, solutions, technical equipment, conditions of the working environment, quantity of different types of waste over a period, working hours, expenses were calculated. Also the interviews with medical staff with subsequent transcription and Direct Content Analysis were introduced with the aim of obtaining a deep-level qualitative data. Modelling and deep-level computer data analysis was performed, in order to find parameters that could lead to optimization of the unit. It shows an opportunity to perform computer based Data analysis of parameters inside the boundaries of a Laboratory. After precise analysis we distinguished the key parameters that may lead to optimization the whole system. We labelled them as Hard and Soft. The results obtained confirmed our initial hypothesis. Recommendations are given. In addition, in the course of the study, the importance of the mental condition of the staff and relationships among co-workers, which positively or negatively affect the performance of their professional tasks were revealed. Introduction of LCA to healthcare refers to one of the building blocks of the Europe 2020 Strategy – “Roadmap to a Resource Efficient Europe” and proposes ways to increase resource productivity and to decouple eco-

nomic growth from both resource use by units and environmental impacts. The permanent scarcity of resources, materials and the emphasis on cost-saving procedures in the social sphere lead us to try to find effective means for the optimization of economic and environmental performance of a healthcare. Inside the proposed framework the identified parameters may lead to the creation of new models and techniques for the final units' optimization. Life Cycle Assessment methodology should be successfully applied to analysis of healthcare system units (e.g. department, laboratory, hospital, ambulance, and operating theatre), the study of a life cycle of a single process, the efficiency of medical staff as well as for the analysis of the performance of the healthcare system of a particular region or a whole country. Furthermore, the rising social responsibility, corporate social responsibility and Life Cycle Management will be drivers for the development and widespread application of such methods to processes and activities of healthcare institutions worldwide. As a result, it would be of great importance to develop and implement an effective public healthcare system model based on relevant, meaningful, robust results of and principles for the careful use of resources, improvement of patient recovery and economic efficiency of units. As a result, public health and health care sectors may become sustainable and reliable social partners with a high level of responsibility encouraging committed and motivated employees and satisfied patients.

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11. Brief curriculum vitae:

Vitaliy Sarancha, MD was born and grew up in Ukraine. He graduated from National Medical University and later Institute of Business Management in Kiev (Ukraine). From 2005 until 2008 he worked at different positions at Kiev Regional Council where he was responsible for Sector of Innovations and Investments primarily in a Healthcare. In 2009 he was appointed as a Chief Executive Officer at Kiev Regional Investment Company and effectively managed the company until 2013 when he together with his family relocated to Zagreb (Croatia). Here he established private consultancy company and started writing thesis for the acquisition of a doctoral degree in Biomedicine and Health sciences at the Zagreb School of Medicine University of Zagreb. His scientific activity covers such fields as Life Cycle Implementation in a Healthcare, Quality Systems Integration in a Healthcare, Leadership and Management, Innovations in Public Health Sector, etc. He is fond of music, is a passionate traveller and adventurer.