Life Cycle Assessment and Management in Hospital Units Using Applicable and Robust Dual Group-Based Parameter Model

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Abstract Introduction: Complexity of hospital healthcare systems make it hard to manage using traditional statistical methods both in terms of describing their characteristics and in terms of the importance of qualitative parameters which have to be combined with quantitative ones. The aim of this work is to demonstrate robustness of dual group-based parameter model, following life cycle assessment and management principles (LCAM), with a goal to improve the efficiency of the Hospital Unit. Methods: This study was performed at the Department of Medical Biochemistry of the County Hospital. In the course of the study, we used elements of a LCAM principles combined with parametric analytics, structured interview with medical staff and direct content analysis (DCA). Study was conducted in two phases: data acquisition and analysis using dual group-based parameter model. During the first phase, the raw data were collected with total of 79 tests with adequate reagents data, test prices, number of tests delivered and duration of the sample processing, laboratory's staff working hours and wage data per period. In addition to the waste statistics, equipment, quality and energy expenses have been taken into account. Acquired data samples were pre-processed and adequately analysed. Results: We

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discovered the dual group-based parameter model elements consisted of quantitative "hard" and qualitative "soft" parameters. The "hard" parameters consist of: "tests", "reagents", "prices", "patients", "sample processing time", "waste", "equipment", "quality measurements" and "energy expenses" and "soft" parameters which include "financial conditions satisfaction", "working environment", "equipment functionality", "information flow", "communication" and "general organizational issues". Conclusion: Research proved applicability and robustness of dual group-based parameter model, following LCAM principles, with the goal to improve the efficiency of the Hospital Unit. Current methodology can be used to study a life cycle of a single process, chains of processes and can be successfully applied to assess the efficacy of Hospital Unit. As being the first study of LCAM, implementation in healthcare system in the Republic of Croatia as such can be used as a pilot project to support efforts in the well-recognized need to increase the efficiency of the healthcare units. Methodology can be extended as concept to any similar unit (e.g. laboratory, hospital, ambulance and operating theatre) or to healthcare system as a whole.

1 Introduction

Rapid industrial development and the extremely high level of the consumption of resources in a healthcare with the entailed pollution of air, water and soil have induced increasing interest in new optimization tools and methodologies. Despite the general problems in healthcare, 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 development and implementation of such tools. Among them, we draw an attention to the life cycle assessment (LCA). Primarily, it was adopted for environmental studies with the purpose of resolving environment-related problems of corporations with a more holistic approach. LCA is a holistic view of interactions that covers a range of activities, from the extraction of raw materials from the Earth and the production and distribution of energy, through the use, and reuse and final disposal of a product. LCA is a relative tool intended to help decision-makers compare all major environmental impacts when choosing between alternative courses of action. The method was initially introduced in 1960s, developing until the late 90s, when it was implemented as a 14,000 series Standard of International Standards Organization [1]. A lifecycle approach takes into consideration the spectrum of resource flows and environmental interventions associated with a product or company from a supply, consumption chain perspective. In this context, we introduce additional key concept called life cycle management (LCM). LCM is a derivative and practical approach of LCA application to different sectors of economy. It emerged in a course of time and reflects the application of LCA to modern practice with an aim of managing the total life cycle of units, organizations, products and services towards more sustainable production and consumption. It is an integrated framework to address environmental, economic, technological and social aspects of

products and services. LCM, like any other managerial pattern, is applied on a voluntary basis and can be adapted to the specific needs and characteristics of particular organization [2]. An illustrative example of the LCM application is the surgeon and nurse initiated Green Operating Room Committee. This is an internal medical staff initiative on the premises of one hospital in the USA. 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 the decreased amount of wastewater, in solid waste reduction, electricity, and great per year spending level reduction. As a result, the initiative provided significant opportunity to improve a healthcare unit's impact on the environment and generally save resources [3]. Following life cycle assessment and management (LCAM) foundations in a focus of this paper is the demonstration of applicability and robustness of novel dual group-based parameter model with the aim to assess and consequently improve the efficiency of the Hospital Unit. This paper is based on actual research which was performed at the Department of Medical Biochemistry (Hospital Unit), Laboratory of Medical Biochemistry of the General Hospital of Zabok (Croatia).

2 Methods

A general methodology was chosen a life cycle assessment (LCA) method and an approach that considers all aspects of resource assessment "from cradle to grave". According to that the data were acquired as follows: (i) documentation for all reagents and chemical substances needed for 79 test performance with the use of the official purchasing documentation such as invoices, order confirmations, warehouse receipts and product delivery statements, (ii) detailed calculation of the tests over the period of the study. It gives comprehensive information about the number of tests performed together with quantity of reagents used, (iii) 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. 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 in order to calculate the average and decrease the level of any biases and incorrect results, (iv) estimation of the consumption of electricity, natural gas, water and fuel oil by the Unit, (v) quantity of hazardous waste and municipal waste per period of study, (vi) environmental parameters such as noise levels, temperature and humidity, (vii) data related to the staff of the laboratory. 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 [4], (viii) working hours of employees and gross salary expenses per period of study, (ix) anonymous questionnaire was used for data acquisition about level of satisfaction with working conditions: financial satisfaction, people/environment satisfaction (typical enquiry, responses ranged from 1 to 5). Every employee with an exclusion of those being on a sick or maternity leave was asked 2 questions: first was about satisfaction with financial conditions of his

work and second-level of employee satisfaction with the environment conditions and colleague attitude. It was followed by additional qualitative data acquired with the help of structured interview in a form of "guided conversation". For this purpose, we chose three employees with different background and asked few open-ended questions in the same order: "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?" The interviewing process was accurately recorded, and a precise transcript protocol was created. Afterwards, the codification of the interviews was done and assessment with conclusions was performed. For codification, we used the methodology of direct content analysis (DCA) [5]. 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 can be potentially used for the optimization of the Unit. In the next phase, we performed computerized data mining to find main correlations among input data and to reveal the ways in which the identified parameters lead to optimization.

3 Results

After the acquired data samples were pre-processed and cleaned into data sets, we have revealed the following logical relations: (i) number of delivered tests combined with average price per test, (ii) seasonal characteristics through periods showing number of tests per period, (iii) correlation between test popularity and price, (iv) statistics of working staff hours per period, (v) correlation between staff wages and working hours, (vi) correlation between working hours versus working position, (vii) general waste data for total period of study, (viii) correlation of total tests and total staff working hours. Together with the assessment of acquired codes in result of the performance of DCA, we have found the key parameters that have an impact on the particular Unit. They are as follows: "tests", "reagents", "prices", "patients", "sample processing time", "waste", "equipment", "quality measurements" and "energy expenses". Current parameters have their number values and marked as "hard" (Fig. 1).

The second group of parameters is qualitative. These parameters crystallized from the responses obtained from: survey about environmental and financial conditions of staff, general satisfaction of staff and the structured interview. In our study, there were 22 employees interviewed. If we take 12 employees, which is 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 (i.e. 77%) who were more than satisfied with working environment (working conditions and relationships among the personnel). As a result,

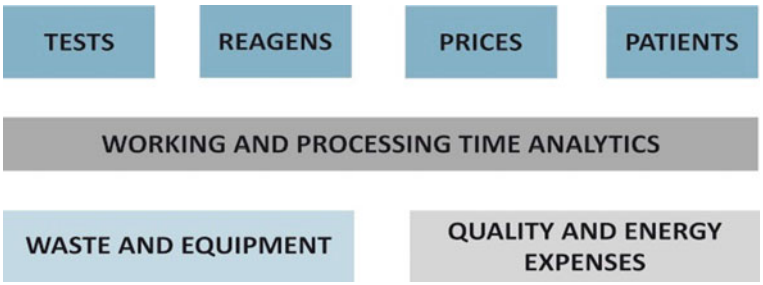

Fig. 1 Hard parameters. ©Vitaliy Sarancha, 2019

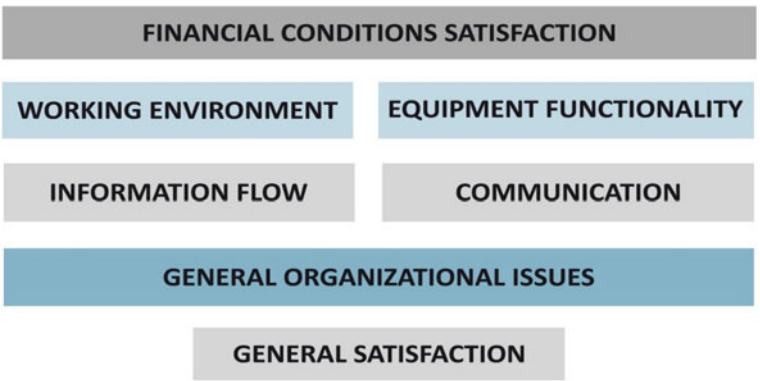

Fig. 2 Soft parameters. ©Vitaliy Sarancha, 2019

we defined parameters which are descriptive and we marked them as "soft". They are as follows: "financial conditions satisfaction", "working environment", "equipment functionality", "information flow", "communication", "general organizational issues" and "general satisfaction". As we mentioned above, these parameters are descriptive and in our opinion and are the key qualitative factors having obvious influence on the Unit functionality and efficiency (Fig. 2).

4 Discussion

Complexity of hospital healthcare systems makes them hard to manage using traditional statistical methods both in terms of describing their characteristics and in terms of the importance of qualitative parameters which have to be combined with quantitative ones. Research proved applicability and robustness of dual group-based parameter model, following LCAM principles, with goal to improve efficiency of the Hospital Unit. Dual group-based parameter model seems to be a convenient tool

for analysing particular Unit through its quantitative and qualitative characteristics, influencing every step of the process or multiple processes. After proper identification and assessment of parameters, their influence can be modified, improved or decreased for the purposes of the optimization of the whole system. Optimization can be reached through the implementation of better managerial solutions according to LCAM principles some of them are improvement of ethical issues, introduction of more effective and less time-consuming internal procedures and manuals, working position-specific manuals and explanatory documents [6–8]. Analysis of the codes of DCA 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 [5, 9]. 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. 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. As a recommendation for a positive working environment, the engagement in the process of a professional time-planning trainer or coach can be considered, and this can create effective models of behaviour for work under pressure and in stressful conditions [1]. As it can be seen, one of the important issues is to pay attention to the best qualities 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. The presented methodology can be used to study a life cycle of a single process, chains of processes and can be successfully applied to assess the efficacy of Hospital Unit. As being the first study of LCAM implementation in healthcare system in the Republic of Croatia, as such can be used as a pilot project to support efforts in the well-recognized need to increase the efficiency of the healthcare units. “Hard” parameters can be grouped, modelled, analysed using modern IT software [10–12]. It makes the whole analysis much more precise and quantitative with possibility to be extended as a to any similar unit (e.g. laboratory, hospital, ambulance and operating theatre) or to healthcare system as a whole. Similarities and groupings of “hard” parameters are used in design of standards. With relation to healthcare, 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 and Safety OHSAS 18000, Guidance on social responsibility ISO 26000, Environmental management 14000 are featured as much applicable to public health and healthcare. 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 [13, 14] and is a perfect tool for measurement and determination of the ultimate way of development of health services. In addition obtained results prove that for effective LCM 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" throughout the 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. Seasonal activity can be also helpful for process optimization. The Unit may postpone 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 [8, 15]. It may be helpful also for personnel working time planning and distribution and in managing the life cycle in the waste disposal activity. We determined 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, figures prove 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 healthcare in Croatia [16]. 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 correlation between the tests performed and the

working hours of employees. This is due to the specific features of a state-owned unit. In this particular situation, the staff has 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 in Croatia 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. 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. 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. As it shown in our direct content analysis, the efficiency of fulfilling routine tasks depends on the mood and 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. 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. 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. 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 behaviour 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 LCAM performed with respect to the Unit, which may lead to confirmation of the effectiveness of such holistic approaches as LCAM 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. 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 the application of the method and consequent optimization on the whole hospital or even healthcare system of, for example, Croatia. We understand that it is difficult to completely rely on LCAM 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 LCAM to the level of a healthcare system Unit—the laboratory in a particular case. We admit that the LCAM of a multitude of processes comprises the cumulative LCAM of the healthcare system unit and consequently see feasible results. 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.

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