Process Quality Monitoring and Optimization: A Case Study for a Smart City Health Domain[1]

MAJA PUŠNIK, BOŠTJAN ŠUMAK AND MARJAN HERIČKO, University of Maribor
GORDANA RAKIĆ AND ZORAN BUDIMAC, University of Novi Sad

The quality of Information Technology (IT) solutions can be measured on several levels, among them focusing on data, software, as well as finally – the human user. Since IT solutions are one of the essential elements used in actual business or production processes, the quality of the business process and its validation is one of the important high-level quality assessments. There have been many attempts to measure or quantify the quality of business processes, respectively their models. However, a general, an overview has not been provided of the combination of several possible approaches . In this paper, a few, seemingly different approaches from different fields/domains are joined together, analysing the same process, providing a framework and insight for business process quality evaluation, analysis and improvement. The included methods are modelling, definition of key performance indicators, risk and waste assessment, root cause analysis and simulation. The process of quality-oriented validation and optimization is demonstrated on a case study from the field of Smart City Health Domain, presenting the transformation of the blood donation process from the AS-IS to the TO-BE process. From the listed methods, simulation provided the most quantifiable benefits, although descriptive analysis provided guidance as to which process elements should be addressed to achieve the most optimal final status.

1. INTRODUCTION

Each complex business organisation, consisting of several business processes, includes a strategy, respectively a broad formula for how a business is going to evolve, what its goals are and what policies will be needed to carry out these goals [Armon 2014]. Goals are general statements that describe what the company wants to achieve and must be measurable (they can describe income, sales, profits etc.). Measures refer to how specific types of data are to be evaluated [Armon 2014]. Continuous measurement and improvement are necessary, checking the defined measures and taking action when there are deviations. An organisation`s performance depends upon the collective ability of its business process to achieve its fundamental objectives [Heidari 2015][Escobar 2018]. There are also other steps to improve the process, the so- called SixSigma approach (defined in the auto manufacturing process in the 80'). Today, its doctrine is well spread in other domains as well. The phases of this approach are well incorporated into the existing case study and are presented in the sections that follow (The Case Study). The redesign methodologies are many, however, this is not the case of this paper's goal. In this paper, an overview (supported by a case study) of some methods for process improvement are presented, resulting in a renewed process, optimised based on the presented approaches.

Business processes optimization is becoming increasingly more important, since stakeholder demands are growing, and there is an ever-increasing amount of new regulations and legislation, as

Author's address: M. Pušnik, B. Šumak, M. Heričko, UM FERI, Koroška cesta 46, 2000 Maribor; email: maja.pusnik@um.si, bostjan.sumak@um.si, marjan.hericko@um.si; G. Rakić, Z. Budimac, Department of Mathematics and Informatics, Faculty of Sciences, University of Novi Sad, Trg Dositeja Obradovića 4, 21000 Novi Sad, Serbia email: goca@dmi.uns.ac.rs, zjb@dmi.uns.ac.rs.

In: Z. Budimac (ed.): Proceedings of the SQAMIA 2018: 7th Workshop of Software Quality, Analysis, Monitoring, Improvement, and Applications, Novi Sad, Serbia, 27–30.8.2018. Also published online by CEUR Workshop Proceedings (http://ceur-ws.org, ISSN 1613-0073)

well as continuing technological advances [Paivaa 2018]. In smart cities especially, new concepts are introduced, such as big data, industrial internet of things, Artificial Intelligence and machine learning [Escobar 2018]. It is increasingly more difficult to identify Quality Control and observable quality characteristics must be defined. To validate if business processes work correctly and if they fulfil the strategy and requirements of **Key Performance Indicators (KPIs)** demands, can be evaluated through testing, however, this approach is often inefficient, expensive [Paivaa 2018] and not applicable to all fields. There are some tools on the market providing test case generation based on the **BPMN (Business Process Model and Notation)**, UML model, **BPEL (Business Process Execution Language)** diagram or XSD schema [Paivaa 2018]. However, there is a lack of a more holistic and intuitive approach including more than one method. Therefore, we propose an approach basing on model simulation, supported by a few analysis techniques. The concept of smart living in a smart city is not emphasised in this paper; we address one process in one of the countless domains within smart cities, improving the lives of its citizens.

Measuring process quality is important in several domains, not merely the health domain. The authors in [Hacid 2017] focused on quantifying social qualities of business processes. A Quality evaluation framework was presented in [Heidari 2014], identifying quality factors relevant to business processes, as well as metrics that provide means for measuring the quality of business processes objectively. Automatic business process validation is also discussed in [Paivaa 2018]. The authors in [Escobar 2018] present a strategy for process quality monitoring , designed based on empirical learning and the data gathering capabilities of the Big Data environment, offering opportunities for learning and quality improvement. According to [Moreno-Montes de Oca 2015], research in the field of Process Quality is focused more on addressing the quality of the business process model, less on the modelling process itself. Based on the systematic literature review conducted in [Paivaa 2018], a more comprehensive quality framework should be conducted on investigating the knowledge and development layer and on the process of modelling itself. In this paper, we would like to focus on the process quality (regardless of the modelling technique), whether it includes all optimally dispersed elements, connections, human tasks and sequences. The additional entity, the product itself, is not included into the measurement approach, rather the process itself, regardless of the domain. We will evaluate the process as an optimal service, fine-tuned to achieve optimal values for its KPIs, as suggested in [Baroudi 2010]. The evaluation approach of business processes is proposed in this paper, since, until now, little research has been documented on assuring and understanding business process modelling quality [Moreno-Montes de Oca 2015].

The paper is outlined in the following sections. After the introduction and brief literature review section, the methods of process quality evaluation are presented in Section two. Section three presents the case study in the smart city health domain, where the presented methods are applied. Followed by section four, including a discussion of the results and limitations of this paper. The Conclusion in section five presents the future work, which is followed by acknowledgments and references.

2. METHODS

There are several process understanding approaches, but they have one thing in common: To be able to analyse process characteristics properly, we have to document them, model them, if possible simulate them and evaluate several possible alternative scenarios. The documentation should include specifications of the selected process and the characteristics of the area to which the process belongs (values, expectations, risks, critical properties). The process's main elements include:

- roles (whether human tasks or automated),
- tasks (activities performed by the according person),

- sub processes (a combined set of conceptually related tasks).

In this paper, we gathered existing knowledge and presented a combination of several methodologies respective approaches, anticipating that the process optimization approach consists of several possible steps, described in the following section.

2.1 Key Performance Indicators

KPIs are the most known metric system in measuring business process quality. Based on the identified risks and possible problems in the process, indicators are defined to help measure the success or effectiveness of the process (usually numerical values such as time, cost, profit, number of complaints, number of rejections). Each KPI must include a definition, how is it measured, when is it successful and when unsuccessful.

KPIs express how to increase efficiency dramatically, representing a multitude of measurements that focus on the aspect of organisational performance that is most critical to the current and continued success of the business process [Shaw 2007], respectively, the organisation.

2.2 The Six sigma approach

Improving the process through lean management (identification of load, imbalances and non-added value activities). In the process, several irregularities are acknowledged:

- Burdens and imbalances are identified and excessive load scenarios are recognised. A protocol is described that will prevent overloads.
- The possibilities of imbalances between the activities within the process are predicted, focusing on potential bottlenecks or other imbalances.
- A list of potential unnecessary activities is defined.

In addition, the activities that do not have any added value are described as wastes. Wastes can be categorised in the following groups: (1) Defects - products or services that do not meet the specifications, (2) Overproduction - overproduction over the possibility of selling, (3) Waiting - for the previous activity to end, (4) Non-utilised talent - employees who are not involved in the process effectively, (5) Transportation - transfer of items or information that are not necessary for execution, (6) Inventory - sources or information that are not used in the process, (7) Motion - unnecessary movement of people, information or equipment due to inadequate position or storage, (8) Extra processing - performing activities that are not necessary for the performance of the required product or service.

2.3 The root cause analysis

The root cause analysis is a method of problem solving used for identifying the root causes of faults or problems in a (business) process [Wilson 1993]. The problem that could arise in the process is based on past identified risks or simulation results. The analysis is conducted by using the following steps:

- In the process, a potential problem is identified, setting at least 3 questions about who / what is / is not affected by the problem.
- A causal diagram (Ishikawa or a bone diagram) is created, showing several major and minor causes in the diagram.
- Finding the causes and solutions using the technique posing 5 questions beginning with “Why”.

2.4 The TO-BE concept

The TO-BE process is the process (or rather the idea of the renewed process) after the procedure of optimization. By analysing all descriptive methods as well as simulation results, conducted by a suitable simulation tool (in our case Signavio), a quality overview in the form of a report is available. The report presents weaknesses, wastes, bottlenecks and possible options for improvement. With the help of optimization results, a renewed / optimised business process can be planned with the following possible optimization activities:

- Activity reorganisation (combining, splitting, rearranging actions),
- Reducing or increasing the number of employees,
- Automatization/informatization of suitable activities,
- Excluding unnecessary activities (including external contractors),
- Other optimization solutions.

All of the above mentioned approaches are incorporated in the case study presented in the next section.

3. THE CASE STUDY

An example of the described approach in the smart city health domain is presented in the case study section. The health domain was analysed within the EkoSMART programme, the purpose of which is to develop an ecosystem with all the supporting mechanisms necessary for efficient, optimised and gradual integration of individual areas into a unified and coherent system of value chains [Baloch 2017]. One of the most important objectives of the programme is to integrate solutions from different domains into a common ecosystem.

Smart cities are marked with locations that have a high level of accumulation and concentration of economic activities, they are spatially complex and heavily connected with transport systems. The fundamental paradigm of the present world is the continuous technological advancement, which, on one hand, represents a certain proportion of new problems, but on the other hand, technology is precisely the place where key solutions for this problem can be found. Since the world cannot be "reversed", it is necessary to look for suitable new or optimised existing solutions that would facilitate modern pressures to focus on the core of new life, which is represented largely by Information and Communication Technologies (ICT). The quality services provided by ICT can relieve people greatly, help them with time optimization and organisation, as well as motivate them. In this paper, the simplified process of blood donation was used as an example.

3.1 The example process description (AS-IS)

Blood donation is one of the noblest forms of helping a human being who needs blood, which is an irreplaceable medicine in his treatment. According to the Centre for Transfusion Medicine in Maribor, in Slovenia, of approximately 2 million inhabitants, blood is needed every 5 minutes, daily 400 blood donors are necessary and the average person needs a transfusion at least once in their lifetime [Institute Service of Slovenia for Transfusion Medicine 2018]. The process is, therefore, in progress each day, and resources (people, equipment) are active every day. The AS_IS process is the process status as it is in the present moment, before the optimization. The blood donation process AS IS used presently has several supporting mechanisms (smartphone applications and mobile cloud computing among others) which are used to make the blood donation process more convenient [Mostafa 2014], although the process itself is often not optimised. In the complex and intertwined smart city environment, the optimization of this process is vital. The described and analysed process presents the blood collection procedure in the health domain, encompassing its weaknesses and quality risks.

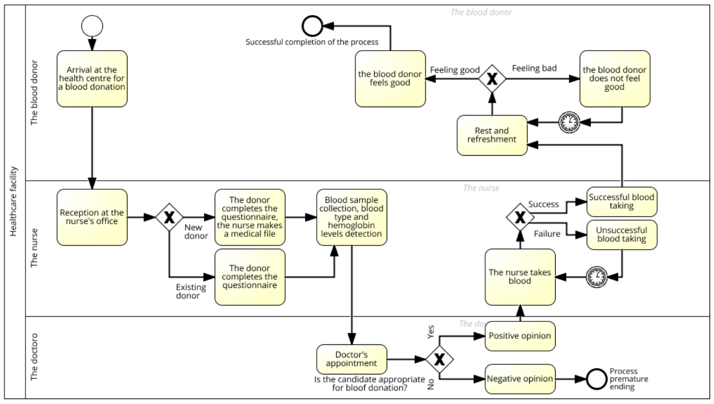


Figure 1 The AS-IS version of the blood donation process

3.2 List and description of activities and roles

The process consists of several activities, assembled in a complex process [Mostafa 2014]. **Sending an invitation to the blood donors** is one of them. When examining the Donor Register, nurses send invitations to those who have not been active for a long time. **Treatment of a new blood donor** is also common, firstly accepted by a nurse collecting personal information, entering data in the computer, and producing a Blood Donor card. The blood donor receives a questionnaire, which is then filled in and sent out by a nurse. **Treatment of an existing blood donor** is shorter, where the existing donor is first accepted by a nurse who checks the validity of personal data in the file. The blood donor receives a questionnaire, which is then filled in and sent out by a nurse **Sampling in a laboratory** includes a nurse taking the blood and determining the blood type and blood dye (haemoglobin). A laboratory report is written, later examined by a doctor. **Medical examination** includes the doctor examining the donor, reading the questionnaire and overviewing the laboratory report, measuring the blood pressure, heart, asking about health. On the basis of all relevant information, the doctor decides if the candidate can be a blood donor or not. In the case of a positive scenario, the donor is taken to the blood collection room. Otherwise, he is discharged to go home. **Blood collection** is the physical activity in the blood collection room. **Sampling** includes a nurse taking out four blood sample tubes. Three samples are sent to the laboratories, where the blood group is determined, as well as the potential presence of possible illnesses is established. The fourth sample is stored next to the blood bag and this serves for cross-examination between the blood of the receiver and the donor immediately prior to the transfusion. The process is concluded with **resting and refreshments.** After taking blood, the candidate enters the room where he will rest, and is refreshed. Special scenarios, such as donors with identified diseases (HIV, hepatitis...) were not included in the process description. The process is modelled in Figure 1 The AS-IS version of the blood donation process, including the following actors:

- **Blood donor**: The person from whom the nurse will take blood. Before starting the process, certain criteria must be met: Good health, age between 18 and 65, weighing at least 50 kg, no major operations in recent months, no reception of a transfusion in the last year, not donated blood for at least three months (or 4 in the case of a female), not pregnant in the last year.
- **Doctor**: Is the person who examines each potential candidate before taking blood, conducts the interview, and decides if the criteria are met.
- **Nurse**: The person who receives a potential donor in the office, talks with her or him and enters the donor's information into the computer and the blood donor's card, and later leads the process of blood collection.

The process was modelled in the Signavio tool, based on BPMN notation. The Signavio tool was also used to simulate business processes. While simulating, data were set according to the average values, obtained by [Institute Service of Slovenia for Transfusion Medicine 2018], such as time load of each activity and other elements, cost properties of activities and resources, as well as frequency of selection of individual branches in determinations.

3.3 The process analysis (KPI's, Root Cause Analysis)

Based on the AS-IS model (Figure 1), important KPI's (Table 1) and possible wastes were defined (Table 2). Table 1 includes the KPI's identified within the process, including values (state) of success as well as failure, extended with the planned measurement of the KPI's performance. Table 2 includes identified wastes, which could endanger the KPIs` optimum value (within the interval of success state). Among wastes, overproduction, transportation, inventory, extra-processing were not identified within the process. Identified wastes are places within the process and a proposal solution is also provided.

Table 1 List of KPI's in the analysed process

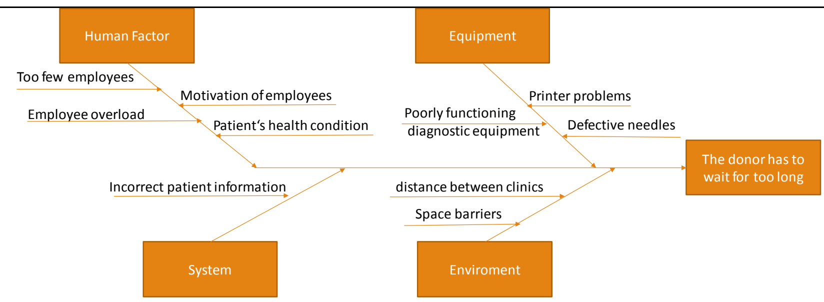
Indicator	State of success	State of failure	Performance measurement
Time (t) to implement the entire process	t < 60 minutes	t > 80 minutes	Record the time from the beginning of the treatment and to the end
Time of entering information about the donor on the computer (Nurse)	15 min / blood donor	30 min / blood donor	Measurement of venous blood donors
Percentage of successful (selected) blood donors	0%	More than 5%	Measuring how many candidates were not appropriate and therefore rejected
Record how many needle inserts are needed when taking blood	1 needle insert / blood donor	2 needle inserts or more …	Measuring the effectiveness of the blood removal, number of needed needle sticks
Percentage of accepted blood donors	100%	Less than 70%	Measuring how many candidates were taken to the blood donors
The percentage of new donors received by invitations	100%	Less than 50%	Measurement of how many new blood donors have been obtained with the sent invitation
The cost of taking blood	20 EUR / blood donor	Costs are greater than EUR 40 / donor	Measuring the number of blood events
The time needed to see the donor	15min/blood donor	30min/blood donor	Measuring the examination time of blood donors

A root cause analysis was also conducted based on the 5 why approach (Figure 2). In addition, two out of possibly three imbalances were identified: The doctor is the most burdened by the process, and presents a bottleneck. From the point of optimising the process, it would be worthwhile to employ an additional doctor. There is an imbalance in the process, especially between the nurse and the doctor. The nurse treats a number of patients so they can be examined by the doctor, causing longer waiting times.

Based on received data about the financial and time burdens, several types of simulation were conducted, with results presented in Table 3. The AS-IS process results are compared to the TO-BE propositions (the optimised version of the AS-IS process), presented in Figure 3 and Figure 4.

Table 2 Defined wastes in the analysed process

Waste	**Risk placement in the process**	**Proposal solution**
Waiting	Occasionally there is congestion because the doctor is overloaded	Additional doctor work, and job sharing.
Defects	Occasionally, unsuccessful withdrawal of blood from candidates may occur	Repeating blood retrieval after a few minutes
Non-utilised talent	Absence of a reference nurse	A reference nurse could take over tasks from a doctor
Motion	The patient must move from one office to another	Ordinations should be positioned close together, which would reduce the movement and waste of time
Waiting	Occasionally there are congestions because the nurse is overloaded and fails to process all data when entering the PC	Employment of an additional nurse and division of works.
Non-utilised talent	Unused young doctor	Reduced norm for 17min, hour price 30 €



Why was the blood donor waiting for blood too long? - Because there are more people ahead of him waiting.
Why are there a lot of others waiting for the take-off? - Because the doctor cannot examine so many candidates at the same time.
Why can a doctor not examine so many candidates? - Because he is overloaded.
Why is the doctor overloaded? - Because it works more than the norm for one doctor.
Why does it work more than the norm for one? - Because the health institution did not employ an additional doctor.

Figure 2 Root-cause diagram for the identified problem

Table 3 AS-IS and TO-BE comparison

		One Case - negative	One Case - positive	Multiple cases (20 instances per week)	Multiple cases (40 instances per week)
AS-IS	Costs	66,67€	76,67€	1740,67€	32870,50€
	Cycle time	1:05 h	1:05 h	1d 15:15 h	11d 05:55h
	Bottlenecks	no	no	no	The Doctor
TO-BE – v1	Costs	59,17€	69,17€	1549,17€	2985,50€
	Cycle time	1:05 h	1:05 h	3d 19:50 h	10d 18:30h
	Bottlenecks	no	no	The nurse	The Doctor1
TO-BE – v2	Costs	64,17€	76,67€	1344,17€	2838,33€
	Cycle time	1:05 h	1:10 h	1d 00:20 h	4d 16:30h
	Bottlenecks	no	no	no	no

4. CONCLUSION

After modelling and evaluating the process with the help of several methods, an estimation of cost, cycle time and bottleneck was made. Through simulation we were able to apply some optimization approaches where costs were reduced, as well as time. However, some bottlenecks occurred through the process of optimization and eliminating wastes. Through further steps of optimization, bottlenecks were eliminated successfully, as well as reduced time and cost KPI were able to be maintained.

Within the paper, we presented some possible methods and approaches on how to evaluate process quality and how to improve it. Although there are several benefits of using descriptive analytical approaches, the simulation approach is the most effective and provides the most accurate and metrically measurable results of the defined KPI's.

In the future work, more case studies will be repeated, and evaluation will be conducted whether, in other cases, simulation is also the best approach. A systematic metrics` definition will be provided, enabling more complete simulation of business or production processes within different domains.

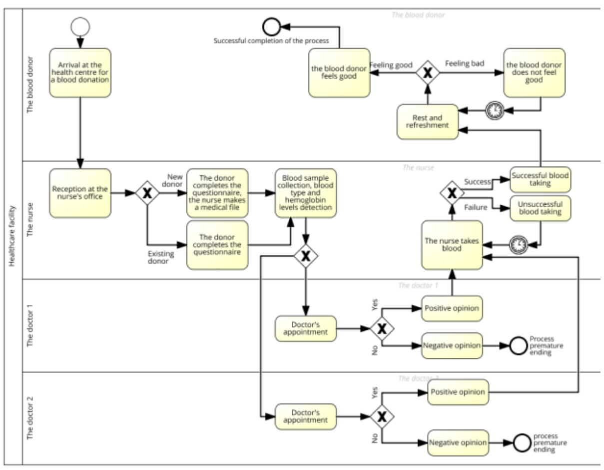


Figure 3 The TO-BE process (Version 1)

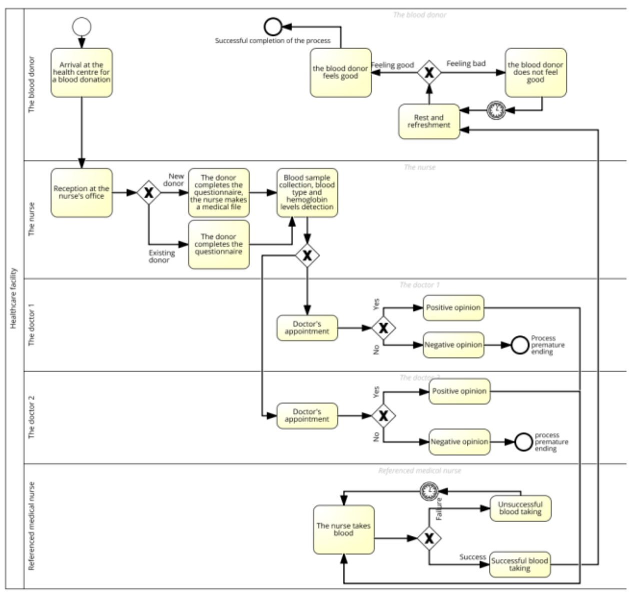


Figure 4 The extended TO-BE process (Version 2)

ACKNOWLEDGMENTS

This joint work is enabled by the Program EkoSMART - Eko Sistem Pametnega Mesta, operation number C3330-16-529007, supported by the European Union, European Regional Development Fund and Ministry of Education, Science and Sport. The case study was conducted during the Business Process Optimization course.

REFERENCES

Institute Service of Slovenia for Transfusion Medicine. 2018. *Blood donation process*. Retrieved August 25, 2018 from http://www.ztm.si/.

Shahida Baloch. 2017. *Key performance indicator*. Retrieved August 25, 2018 from https://www.slideshare.net/DrShahidaBaloch1/key-performance-indicator-78594218 (2017).

Hakim Hacid, Emir Ugljanin, Mohamed Sellami, Zakaria Maamar. 2017. Adapting selection strategies of executors of business processes based on profit and social qualities. *Computers and Electrical Engineering 63* (2017) 320–331. DOI: https://doi.org/10.1016/j.compeleceng.2017.02.018

Isel Moreno-Montes de Oca, Monique Snoeck, Hajo A. Reijers, Abel Rodríguez-Morffi. 2015. A systematic literature review of studies on business process modeling quality. *Information and Software Technology 58* (2015) 187–205. DOI: https://doi.org/10.1016/j.infsof.2014.07.011

Farideh Heidari, Pericles Loucopoulos. 2014. Quality evaluation framework (QEF): Modeling and evaluating quality of business processes. *International Journal of Accounting Information Systems 15* (2014) 193–223. DOI: https://doi.org/10.1016/j.accinf.2013.09.002

Ana C.R. Paivaa, Nuno H.Flores, João P.Fariaa, José M.G. Marquesb. 2018. End-to-end Automatic Business Process Validation. *Procedia Computer Science 130* (2018) 999–1004. DOI: https://doi.org/10.1016/j.procs.2018.04.104

Carlos A. Escobar, Michael A. Wincek, Debejyo Chakraborty, Ruben Morales-Menendez. 2018. Process-Monitoring-for-Quality—Applications. *Manufacturing Letters 16* (2018) 14–17. DOI: https://doi.org/10.1016/j.mfglet.2018.02.004

Duncan R. Shaw, Christopher P. Holland, Peter Kawalek, Bob Snowdon, Brian Warboys. 2007. Elements of a business process management system theory and practice. *Business Process Management Journal 13* (2007) 91-107. DOI: https://doi.org/10.1108/14637150710721140

Richard Baroudi.2010. *KPI mega library, 17000 Key Performance Indicators*. Scotts Valley, California, USA (2010).

Paul Armon. 2014. *Business process change*. 3rd Edition, Morgan Kaufman, The MK/OMG Press (2014).

Almetwally M. Mostafa, Ahmed Youssef, Gamal Alshorbagy. 2014. A Framework for a Smart Social Blood Donation System Based on Mobile Cloud Computing. *Health Informatics-An International Journal* (2014) vol. 3, no. 4. DOI: 10.5121/hiij.2014.3401

Paul F. Wilson, Larry D. Dell, Gaylord F. Anderson. (1993). *Root Cause Analysis: A Tool for Total Quality Management.* Milwaukee, Wisconsin: ASQ Quality Press. pp. 8–17. ISBN 0-87389-163-5.