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IMPROVING THE EFFICIENCY OF THE CENTER FOR MEDICAL BIOCHEMISTRY, CLINICAL CENTER NIŠ, BY APPLYING LEAN SIX SIGMA METHODOLOGY

POBOLJŠANJE EFIKASNOSTI RADA U CENTRU ZA MEDICINSKU BIOHEMIJU KLINIČKOG CENTRA NIŠ PRIMENOM LEAN SIX SIGMA METODOLOGIJE

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Summary: Laboratories that are part of clinical centers are faced with the inevitability that their efficiency must be on a high level. Most of the biochemical laboratories are automated, but they are still underperforming. The best approach to increase the efficiency or to improve the processes today is the Lean Six Sigma methodology. This methodology extracts many benefits from automated processes. A lean process in the laboratory focuses on the time cycle to obtain results and reduce costs, or both components at the same time. Six Sigma methodology provides that the processes take place in the laboratory without delays and defects. The process that takes place at the Center for Medical Biochemistry (CMB) can be divided into two parts: the first part takes place in the receiving infirmary (pre-analytics) and the second part takes place at the offices of the CMB from the receipt of samples (analytics) to obtained results. The paper observes both processes, identifies critical areas where they come to a halt, defines access and reviews the results obtained using the Lean Six Sigma methodology. By applying Lean tools, the places that do not add value and those that significantly increase the cycle time were identified. This paper presents the results obtained without going into detail about the application of these Lean tools.

Keywords: Lean Six Sigma, Pareto, SPC, Kaizen event, 5S, value stream mapping

Kratak sadržaj: Laboratorije koje rade u sklopu kliničkih centara suočene su sa neminovnošću da njihova efikasnost mora biti na visokom nivou. Većina biohemijskih laboratorija su automatizovane, ali i pored toga rade sa manjim učinkom nego što bi to moglo biti. Najbolji pristup za povećanje efikasnosti, odnosno poboljšanje procesa, danas je metodologija Lean Six Sigma. Ova metodologija izvlači brojne koristi iz automatizovanih procesa. *Lean* proces u laboratorijama se usredsređuje na vreme ciklusa dobijanja rezultata i smanjenju troškova, ili istovremeno na obe komponente. Six Sigma metodologija omogućava da se procesi u laboratorijama odvijaju bez zastoja i bez defekata. Proces koji se odvija u Centru za medicinsku biohemiju (CMB) može se podeliti na dve celine: prvi proces koji se odvija u prijemnoj ambulanti (predanalitika) i drugi proces koji se odvija u kabinetima CMB od prijema uzoraka (analitika), pa sve do dobijanja rezultata. U radu se istovremeno posmatraju oba procesa, identifikuju kritična mesta u procesima gde dolazi do zastoja, definiše pristup i daje pregled rezultata dobijenih korišćenjem metodologije Lean Six Sigma. Primenom *Lean* alatki identifikovana su mesta koja ne dodaju vrednost i ona koja značajno povećavaju vreme ciklusa. U radu se daje prikaz ostvarenih rezultata, bez ulaženja u detalje o primeni navedenih *Lean* alata.

Ključne reči: Lean Six Sigma, Pareto, SPC, Kaizen događaj, 5S, mapiranje toka vrednosti

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Introduction

The challenge today's laboratories are faced with is how to increase their workload and the number of patients served, without increasing resources. The results obtained by laboratory testing have a huge impact on medical diagnosis and therapy and represent an integral part of the decision-making process in the treatment of patients. In 65% of cases, laboratory tests are essential for establishing the diagnosis or treatment (1, 2).

Thus, it can be concluded that getting the correct results at the right time for the patient is a crucial requirement, which dictates the need for the implementation of quality methods and tools to increase productivity and reduce errors in laboratory processes. One of the most common methodologies that have lately been used is Lean Six Sigma, whose implementation in laboratories increases the quality of service, and the speed and efficiency of the process. Lean methodology has its roots in the TPS (Toyota Production System), whose original ideas were formulated by Sakichi Toyoda in the 1920s and 1930s, and first implemented by Taiichi Ohno during the 1940s (3). It can be defined as a systematic approach with the aim of shortening the time between the users (patient, doctor, nurse, etc.) and providing services through the identification and elimination of waste or activities that do not add value (4–6). The most commonly used Lean tools, which will be discussed later in this paper, are: 5S, Kaizen and Value Stream Mapping.

Lean methodology was first used in the process of identifying and eliminating waste in health-care facilities at the end of the 1990s. Since then, Lean has represented a key tool in the implementation of the process which has the goal to increase the quality of services and reduce costs (7). Six Sigma is a methodology that was developed by Motorola during the 1980s. This methodology uses a structural approach (DMAIC method) and statistical tools (SPC, Pareto, Ishikawa) to find the causes of the emergence of problems (8, 9). The main goal of the Six Sigma method is to reduce variation in the process, or the number of defects to 3.4 defects per million opportunities (DPMO – defects per million opportunities).

Lean Six Sigma for services is a business improvement methodology that maximizes shareholder value by achieving the fastest rate of improvement in customer satisfaction, cost, quality, process speed, and invested capital (10). The primary goal of implementing the Lean Six Sigma methodology in industry and health care is to analyse the activities flow in order to determine the waste of resources and discover opportunities to reduce time, resources and costs (11–13).

The aim of this paper is to present the results of the application of Lean Six Sigma methodology at the CMB of the Clinical Center in Niš (CCN), and show how this methodology can increase the efficiency of the process.

Processes at the Center for Medical Biochemistry (CMB)

The working process of the CMB is a process of standard models and it does not differ much from working processes in other laboratories. The CMB does the standard biochemical analyses for clinical inpatients of the CCN and specialized biochemical analyses for clinical and ambulatory patients of the CCN. Since the infirmary which directly takes material from the patients (blood testing) and the units for appropriate analyses (biochemical diagnostics unit, biochemical hematological diagnostics unit and immunochemical diagnostics unit) are part of the CMB, the paper observes these processes individually. There are 25 clinics at the CCN, and the CMB performs appropriate analyses for all of them.

Standard analyses that are done at the CMB are: substrates (glucose, urea, creatinine, uric acid, etc.), enzymes and isoenzymes (AST, ALT, ALP, γGT, LDH, CK, HBDH, CKMB, etc.), electrolytes and trace elements, parameters of the lipid status, hematological analyses and urinalyses.

The specialized analyses include: determination of specific antibodies and hormones, drugs in blood and urine, specific proteins and metabolites related to cardiac (troponin, CKMB mass, BNP, VMA), rheumatic (anti-CCP) and hematological disorders (B12, folic acid, transferrin, ferritin, haptoglobin, etc.), immunoglobulin(s), specific IgE for the group of inhaled and nutritive allergens, specific antibodies for the diagnosis of autoimmune diseases, etc.

Monitoring of the CMB processes before the application of Lean Six Sigma methodology

As far as standard processes are concerned, activities that occur in them are generally the same as in other laboratories and can be divided into: activities that produce added value and are optimally implemented, and activities that do not add value. The appropriate monitoring of all activities is done in the receiving infirmary, as well as in the offices of the CMB. Basically, the receiving infirmary is the place within the CMB where patients are received, their information is entered in the protocol and their samples are taken. After that, the samples are sent for further processing in the appropriate units.

According to the theory, we know that there are 7 wastes in the process, such as: activities that do not add value, overproduction, inventory, waiting, defects,

redundant motions and unnecessary transportation. In order to identify the waste in the process, it was necessary to measure various aspects of these processes. The measurements were performed independently in the relevant groups of activities.

In the receiving infirmary, the periods of time (cycle time) needed to conduct each task within the activity are recorded, as shown in *Table I*. Waiting (downtime) was observed between neighboring activities, and it was primarily created as the result of unequal duration of activities. Other causes of downtime can be: entry of patients and other medical staff in the infirmary, collecting health insurance cards from desks, emergencies, taking blood out of the ambulance, and others. *Table I* shows the time period (expressed in minutes) for all activities in the receiving infirmary for 8 different patients, as well as the cycle time for each patient. The measurement was carried out on 13/09/2012.

The process of receiving the sampled material from the Clinics of the CCN and from the receiving infirmary of the CMB was also observed. Here, the

Table I Observing the time of activities in the receiving infirmary (13/09/2012).

Task	Description of the task	Patient								The best time
		1st	2nd	3rd	4th	5th	6th	7th	8th	
1	Entering information into the protocol	0:52	1:25	0:39	0:43	0:53	0:47	0:50	0:46	0:39
	Waiting	1:47	0:10	0:40	5:44	0:11	0:54	1:24	0:37	0:10
2	Invoicing the services	0:55	1:05	1:05	0:35	0:22	1:13	0:54	0:22	0:22
	Waiting	0:21	1:13	0:37	1:57	3:40	0:07	0:37	0:12	0:07
3	Opening the laboratory list, etc.	1:25	1:29	1:39	1:01	0:46	0:45	3:07	0:42	0:42
	Waiting	2:43	5:59	10:20	1:42	1:26	2:05	0:39	4:07	0:39
4	Calling the patient from the waiting room, checking before taking blood	0:31	0:32	0:30	0:26	0:33	0:35	0:38	0:36	0:30
	Waiting	2:13	0:51	1:26	0:35	0:25	2:08	0:20	4:14	0:20
5	Extraction and blood sampling in the appropriate pre-marked test tubes	0:37	0:24	0:59	0:42	1:41	0:44	1:43	1:01	0:24
	Waiting	0:02	0:01	0:08	0:08	0:05	0:04	0:06	0:07	0:01
6	Disposing of the test tubes in the rack	0:02	0:02	0:04	0:02	0:02	0:01	0:02	0:02	0:01
Observed cycle time (min)		**11:28**	**11:31**	**18:07**	**13:35**	**10:04**	**11:03**	**10:20**	**12:46**	**3:55**

Table II Observing the time of activities in the biochemical infirmary.

Task	Description of the task	Sample								The best time
		1st	2nd	3rd	4th	5th	6th	7th	8th	
1	Takeover and testing of biological materials with the accompanying laboratory lists	1:06	0:35	0:55	1:05	1:06	1:10	0:50	1:05	0:35
2	Checking of the enacted biological material and consultation with biochemists	0:51	0:13	0:22	0:15	0:32	1:01	0:45	0:52	0:13
3	Marking of test tubes with relevant laboratory numbers	2:43	0:32	0:56	0:38	1:07	7:05	5:45	5:15	0:32
4	Taking and placing the test tubes in the centrifuge device	3:20	3:40	3:51	3:22	3:15	1:42	2:31	2:21	1:42
5	Centrifugation	10:00	8:00	6:40	6:42	8:00	8:54	6:17	6:41	6:17
6	Extraction of samples from the centrifuge and placing in racks	2:30	1:48	2:42	2:48	2:34	2:02	2:21	2:05	1:48
Observed cycle time (min)		**20:30**	**14:48**	**15:26**	**14:50**	**16:39**	**20:56**	**18:29**	**18:39**	**11:07**

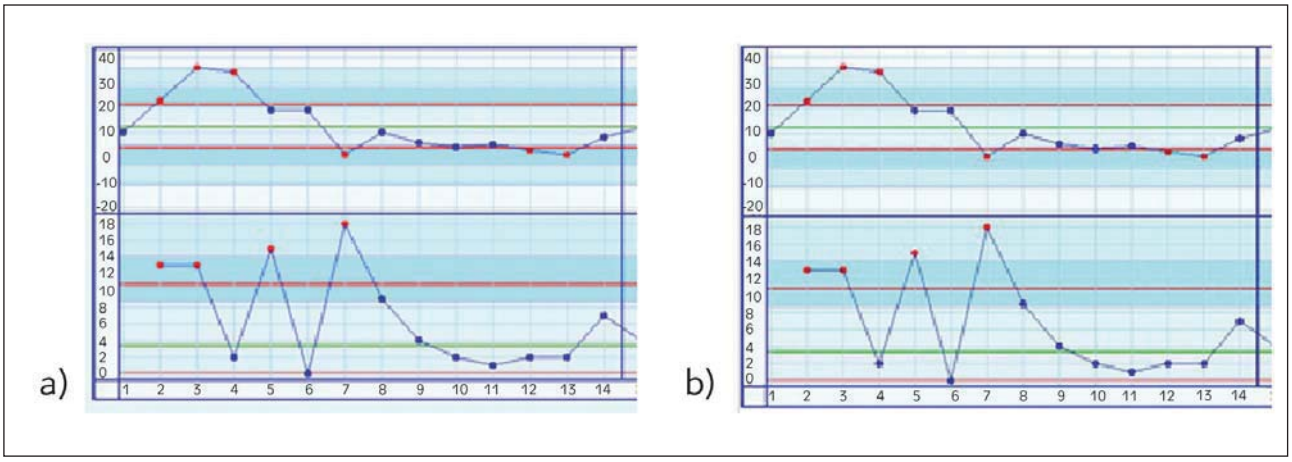

Figure 1 Receipt of the sample a) with CCN Clinics and b) from the receiving infirmary in the period from 7:00 to 20:00 (31/10/2012).

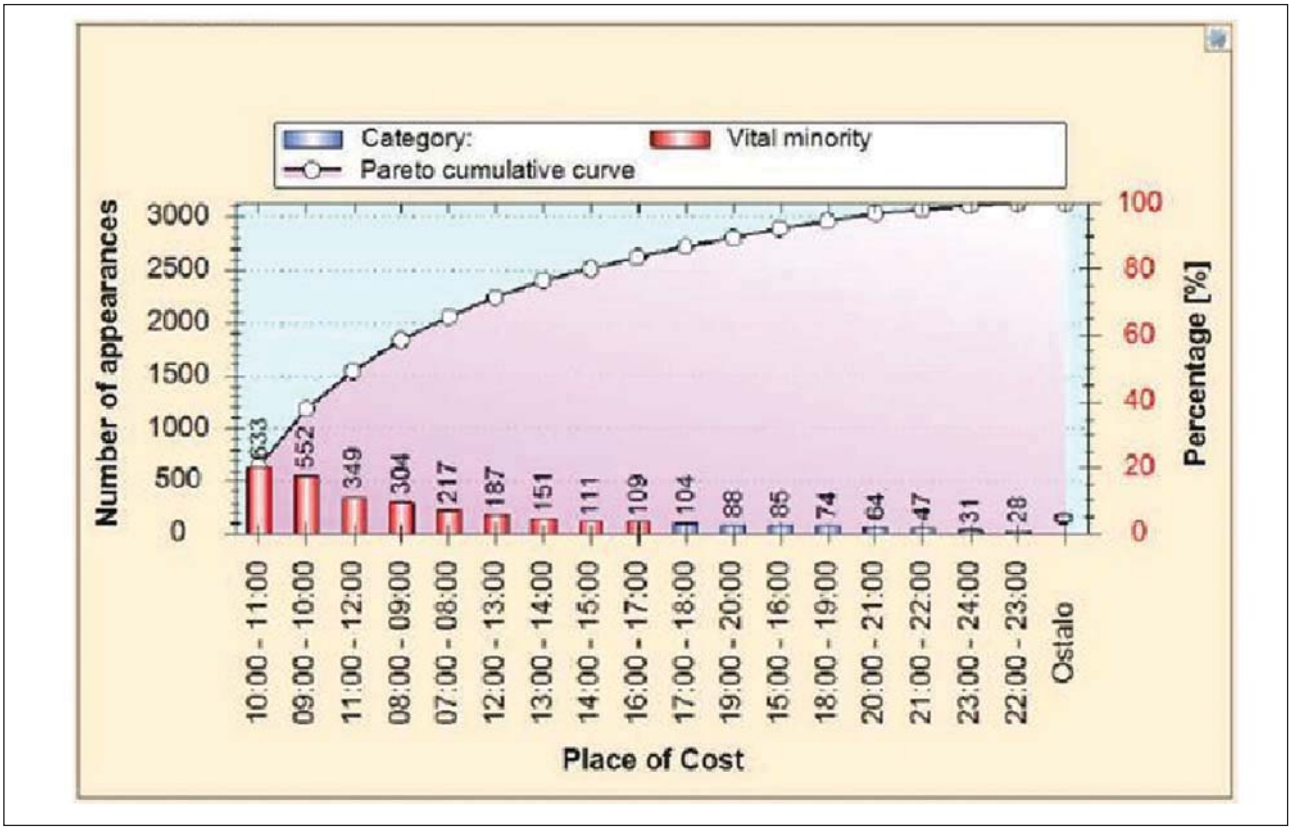

Figure 2 Number of samples received from CCN clinics in the period from 7:00 to 24:00 (for 13 days).

recorded periods of time of activities which precede the analysis of samples are presented in *Table II*. *Table II* also shows the wide range of duration of some activities caused by different arrival times of the material. Centrifugation is mostly done with 32 samples, however, if something is urgent, it can also be done with less samples. In the paper, the process was always observed with 32 samples.

Using modern methods for statistical monitoring and process control provides an insight into the current state of the system and the variation of the system, and enables tracking of the variables that affect the process. Statistical Process Control – SPC is an analytical tool for decision making that allows one to see when the process is working properly and when it is not (14).

Based on the monitoring of the quantity and time of arrival of the receiving material during the day, the diagrams shown in *Figure 1* were drawn. On the X axis is the number of measurements of received samples, i.e. time period. In this case, measurements were made every hour during the period from 7:00 to 20:00, and a total of 14 measurements were made. On the Y axis is the number of samples which are measured at appropriate time points, or the number of samples that arrive every hour.

Pareto analysis is used in the process of identifying a vital minority of 20% of the causes of the problems upon which all available resources need to be focused in order to eliminate 80% of the problems and conflicts arising in the process. By introducing appropriate corrective and preventive measures, one can prevent the problem from ever occurring in the future (15).

Pareto analysis is performed considering the number of samples received from various clinics during two weeks at the frequency of every 60 minutes – *Figure 2*.

Value stream mapping

Value stream mapping is the process of mapping the time periods required for completion of each activity, as well as the flow of materials and information. Activities in the process can be divided into activities that add value (value-added) and activities that do not add value (non-value-added). The main objective of the application of value stream mapping is to observe waste in the process and places where some improvements can be introduced to reduce the resources needed for the smooth running of the process.

Based on all the information and data collected during one month in the CMB, a map of the stream value of tested samples can be created. The *Figure 3* shows the complete map of stream value of a selected sample no. 74, which was recorded on 23/11/2012.

5S Kaizen event

Kaizen represents a business philosophy focused on continuous improvement, which is based on the fundamental belief that there will always be room for improvement, no matter how »perfect« the system, process may appear (16). A 5S Kaizen event was implemented in the CMB to minimize or eliminate the waste identified in the process.

5S is a methodology of creating and maintaining a well-organized, clean, highly efficient and safe workplace. The name is composed of the first letters of the Japanese words which represent the necessary

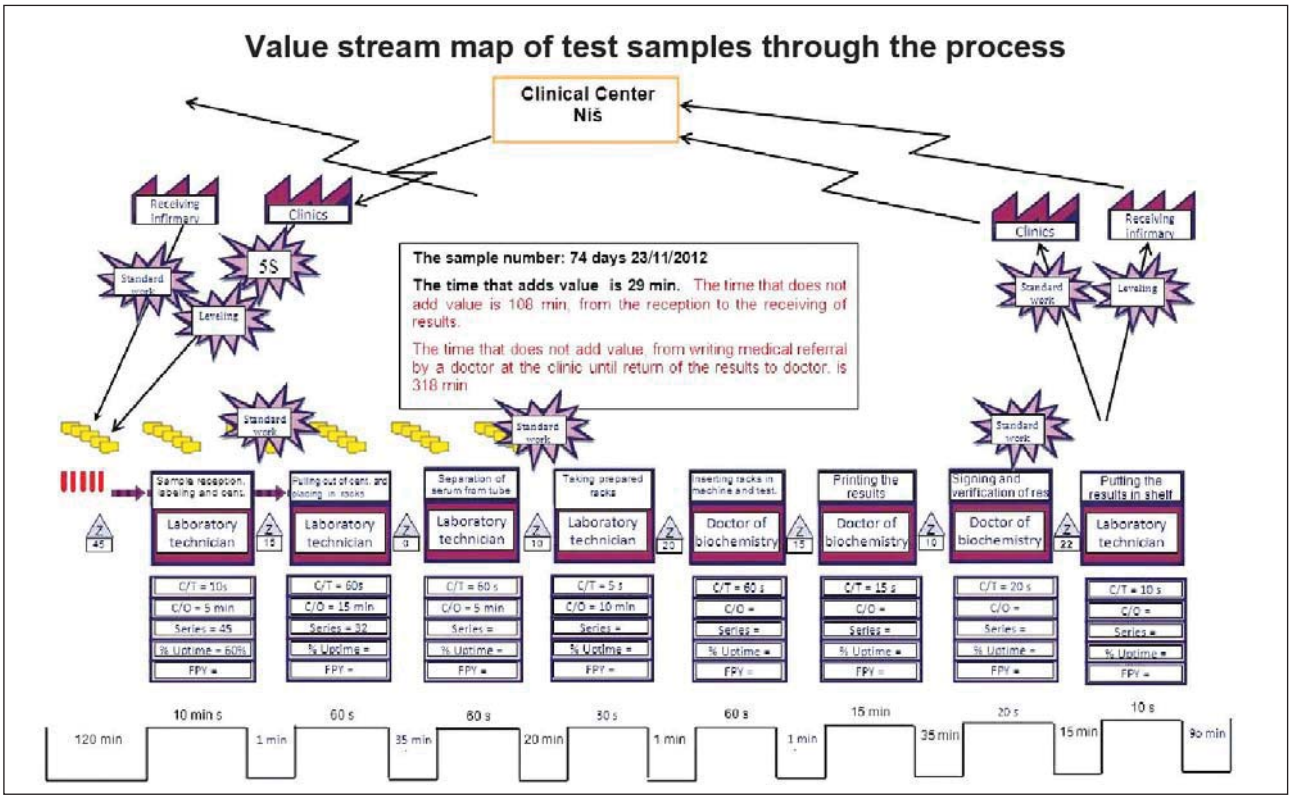

Figure 3 Map of stream value of the tested samples.

Figure 4 A Kaizen event.

conditions for the smooth functioning of a process and taking measures for their improvement:

Seiri – Sort;

Seiton – Straighten;

Seiso – Sweep, Shine;

Seiketsu – Standardize;

Shitsuke – Self-discipline, Sustain.

To obtain true picture of the current state, a 5S audit is implemented (17).

The Kaizen event implemented in the CMB consisted of the application of Lean tools – 5S, as can be seen in the following *Figure 4*.

A Kaizen event consists of two parts. The first is a staff meeting at which it is determined what will be done in a certain period of time in order to improve the picture of the current state of the workplace. The second part of a Kaizen event represents the implementation of the 5S. As it can be seen in *Figure 4*, all the devices, equipment and material marked with red cards are unnecessary and they were removed during the implementation of 5S methodology. The outcome of the Kaizen event is a clean workplace without unnecessary things that are not used in everyday work.

Monitoring the CMB processes after the application of Lean Six Sigma methodology

On the basis of the monitoring and analysis of all tasks in the receiving infirmary, it was concluded that the time was not uniformly distributed across all the tasks that were the reasons for coming to a halt. *Figure 5* shows that for most of the tasks the needed time is about 0:50 min or less, while the tasks where data is entered into the protocol and a laboratory list opened take about 2:24 min. If only two new points for simultaneous data entry, invoicing and opening of laboratory lists were introduced, the clock rate of the whole activity would be 0:53 min. This would help avoid the large waiting between tasks and increase the efficiency of the work in the receiving infirmary.

When the optimization of the tasks was done, a new observation of the time with the same tasks was performed. This time, 2 samples were processed simultaneously, and the time data are shown in *Table III*. Delays did not generally exist, although there was a slight waiting which was caused by calling two new patients in and waiting for them to prepare for blood testing. Delays of other tasks virtually did not exist.

The observed cycle time in *Table III* shows that patients, who come in and give their health insurance cards, wait for approximately 3 to 5 minutes to be called in and tested. The best cycle time is 3:22 minutes, while the longest cycle time is 5:24 minutes. In earlier records, which were obtained in September 2012 (*Table II*), the average waiting time of patients was 12 minutes (observed cycle time).

On the day of 18/12/2012, in just 80 minutes 85 patients were treated, which means that the average waiting time for each patient was 4–5 minutes. The first two patients waited to be called in for about 3 to 3 and a half minutes, followed by one patient every minute. In September, when first recorded, about 80 patients were processed in 150 minutes, which indicates that the process is now far more efficient.

Based on the Pareto analysis, considering the number of samples received from various clinics (*Figure 2*), an extensive congestion in the period from 9 to 11 a.m. was revealed. Furthermore, the number of samples arriving from certain clinics was also followed, and on the basis of these parameters a time interval was recommended to clinics concerning when each of them should bring their samples.

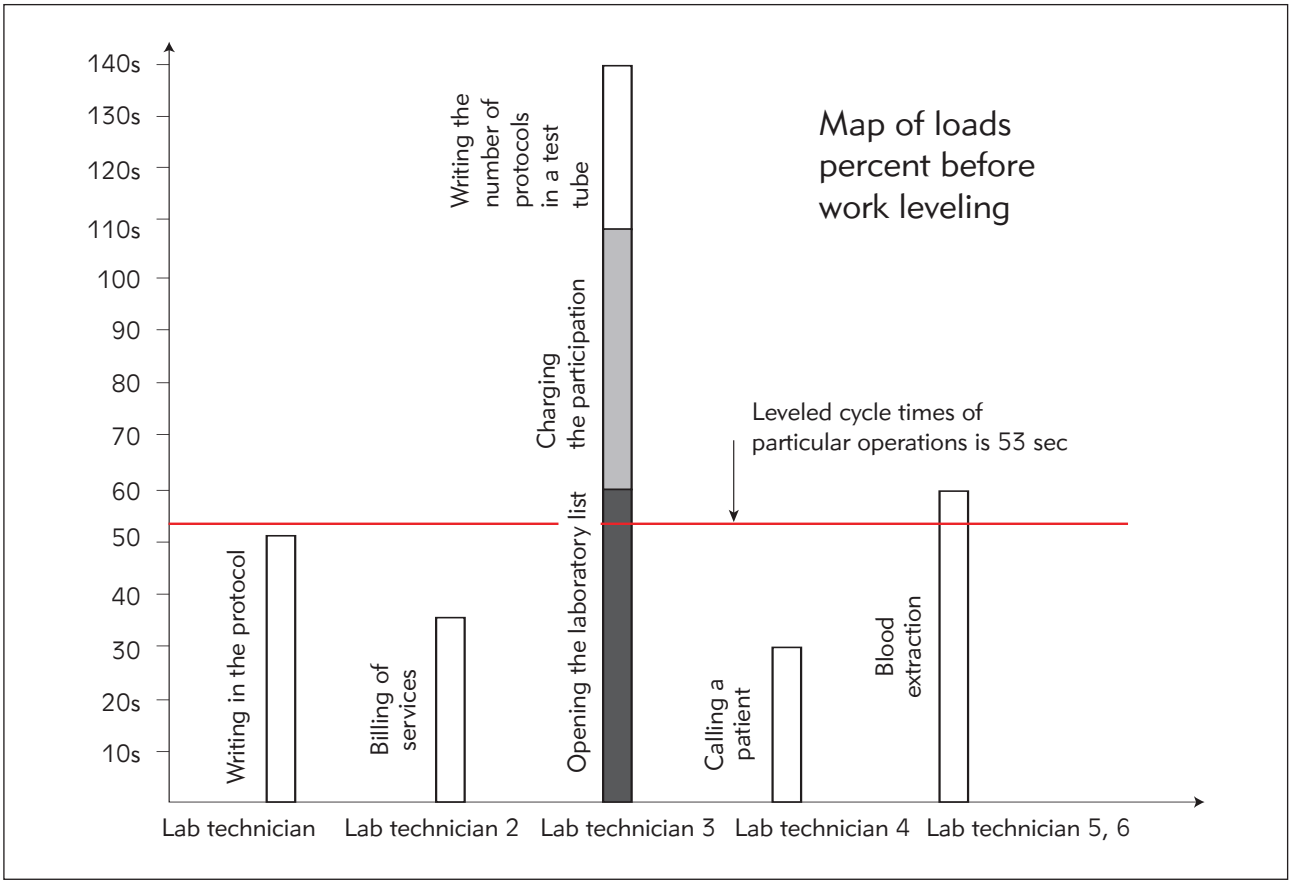

Figure 5 Map of the technician load in the receiving infirmary before leveling the load.

Table III Observation of the time activities in the receiving infirmary (18/12/2012).

Task	Description of the task	Patient								The best time
		1st	2nd	3rd	4th	5th	6th	7th	8th	
1	Entering information into the protocol	0:50	0:56	0:50	1:01	0:58	1:14	1:11	1:04	0:50
	Waiting	0:05	0:06	0:01	0:01	0:00	0:00	0:00	0:00	0:00
2	Invoicing the services	0:28	0:54	0:53	0:42	0:48	0:55	0:31	0:53	0:28
	Waiting	0:05	0:01	0:05	0:01	0:05	0:04	0:03	0:04	0:01
3	Opening the laboratory list etc.	0:32	1:04	1:13	1:14	0:55	0:50	1:02	1:00	0:32
	Waiting	0:20	0:10	0:8	0:10	0:25	0:30	0:20	0:22	0:08
4	Caling the patient from the waiting room, checking	0:26	0:25	0:25	0:28	0:24	0:30	0:28	0:25	0:24
	Waiting	0:10	0:15	0:10	0:14	0:18	0:15	0:20	0:23	0:10
5	Extraction and blood sampling in the appropriate pre-marked test tubes	1:02	1:01	0:58	0:58	0:47	1:04	0:58	66	0:47
	Waiting	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0
6	Disposing of the test tubes in the rack	0:04	0:04	0:03	0:02	0:03	0:02	0:03	0:02	0:02
Observed cycle time (min)		**4:02**	**4:56**	**4:46**	**4:50**	**4:47**	**5:24**	**4:56**	**5:19**	**3:22**

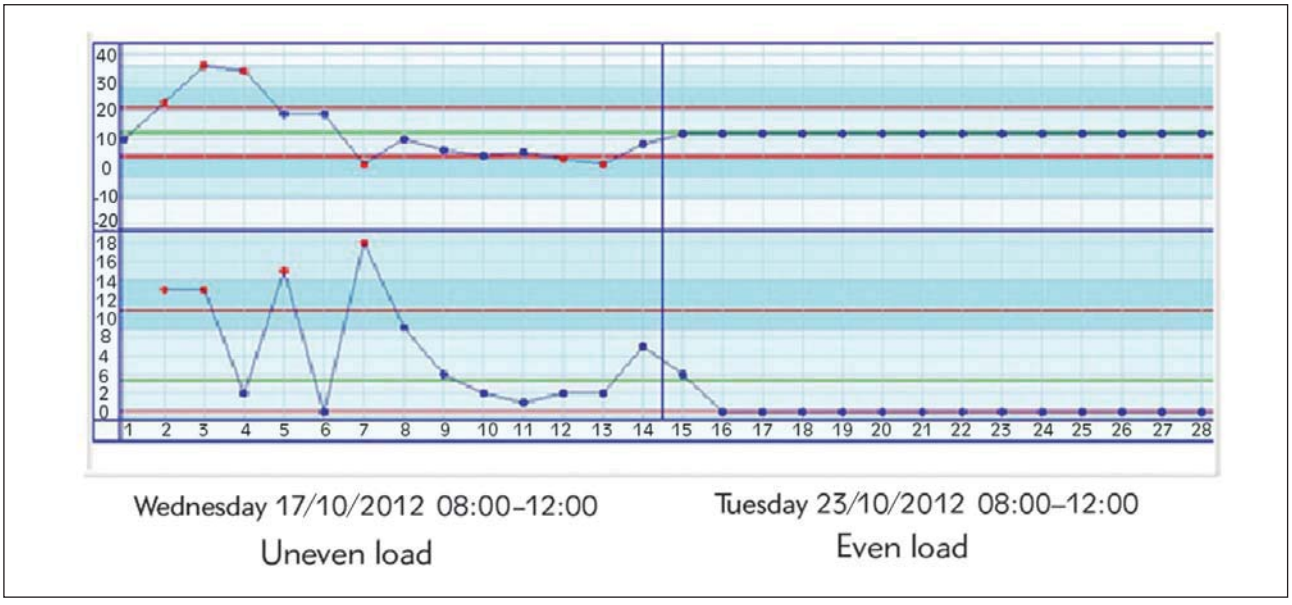

Figure 6 Uniformity of receiving samples in the biochemical infirmary from the receiving infirmary.

Consequently, there was a reduction of congestion in the receiving unit, which can be seen in *Figure 6*.

On the X axis is the number of measurements of samples received from various clinics, while the Y axis represents the number of received samples being measured at a given time.

Conclusion

Two major improvements which are presented above are, in fact, two new points for simultaneous data entry, invoicing and opening of laboratory lists and the recommended time period for delivering samples from clinics to laboratory units. These improvements have a direct impact on shortening the

patients' waiting time and reducing congestion in the laboratory units with the samples. By comparing the observed cycle times from *Table I* and *III*, it can be seen that the time required for each patient to be called in and tested has been drastically reduced, which has a direct impact on increasing the efficiency of working processes in the entire CMB.

As for the biochemical units, processes are more stable and without any delays. Uniformity in the arrival of the samples in the biochemical infirmary prevented any delay from occurring. Thus, it can be said that the processes in the CMB operate almost without any fault.

There is still room for improvement. It can be primarily found in the application of accreditation according to ISO 15189, savings in materials, the introduction of electronic documentation which would lead to a much easier process in the CMB, etc.

Based on all of the above, this paper shows that applying Lean Six Sigma methodologies can lead to increased efficiency both in the receiving infirmary and in the entire CMB.

Conflict of interest statement

The authors stated that there are no conflicts of interest regarding the publication of this article.

References

1. Kruse-Jarres JD. Labormedizin 2000 – Versuch einer Prognose. Lab Med 1994; 18: 213.
2. Felder RA, Graves S, Mifflin T. Reading the future. The increased relevance of laboratory medicine in the next century. MLO Med Lab Obs 1999; 31: 20–6.
3. Arthur J. Lean simplified: The Power Laws of Speed. Denver: LifeStar, 2006: 24 pp.
4. Jimmeerson C, Weber D, Sobek DK II. Reducing waste and errors: piloting lean principles at Intermountain Healthcare. Jt Comm J Qual Patient Saf 2005; 5: 249–57.
5. Plebani M. Pre-analytical errors and patient safety. J Med Biochem 2012; 31: 265–70.
6. Serteser M, Coskun A, Inal TC, Unsal I. How ISO-15189 laboratory accreditation assures patient safety? J Med Biochem 2012; 31: 271–80.
7. Liker JK. The Toyota Way. New York, NY: McGraw-Hill; 2004.
8. Shankar R. Process Improvement Using Six Sigma. A DMAIC Guide, ASQ Quality Press, 2009.
9. Kubiak TM, Benbow DW. The Certified Six Sigma Black Belt, Handbook, Second Edition. ASQ Quality Press, 2009.
10. George ML. Lean Six Sigma for Service. McGraw – Hill, New York, 2003.
11. Mladenović S, Milosavljević P. Put ka Lean Six Sigma preduzeću. International Journal »Total Quality Management & Excellence« 2010; 38, No. 3: 71–8.
12. Halwachs-Baumann G. Concepts for Lean Laboratory organization. J Med Biochem 2010; 29: 330–8.
13. Villa D. Automation, Lean, Six Sigma Synergies for improving laboratory efficiency. J Med Biochem 2010; 29: 339–48.
14. Stoiljković V, Milosavljević P, Ranđelović S. Six Sigma Concept within Banking System. African Journal of Business Management 2010; 4: 1480–93.
15. Stoiljković V, Trajković J, Stoiljković B. Lean Six Sigma Sample Analysis Process in a Microbiology Laboratory. Journal of Medical Biochemistry 2011; 30: 346–53.
16. Masaaki I. Kaizen: The key to Japan's competitive success. New York, NY: McGraw-Hill: 1986.
17. Stoiljković V, Stoiljković P, Stoiljković B. Implementation of Lean Six Sigma concept in manufacturing and service organizations. Total Quality Management & Excellence 2009; 37: 499–503.

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