XVII International Scientific Conference on Industrial Systems (IS'17)
Novi Sad, Serbia, October 4. – 6. 2017.
University of Novi Sad, Faculty of Technical Sciences,
Department for Industrial Engineering and Management
Available online at http://www.iim.ftn.uns.ac.rs/is17

Most used lean tools in hospitals and clinical laboratories

Majed Alkher
(PhD student, Faculty of technical sciences, Trg Dositeja Obradovica 6, Serbia, majed1215@yahoo.com)
Ivan Beker
(PhD, Faculty of technical sciences, Trg Dositeja Obradovica 6, Serbia, beker@uns.ac.rs)
Velibor Cabarkapa
(PhD, Clinical centre of Vojvodine, Hajduk Veljkova 1, Serbia, veliborcabarkapa@gmail.com)
Dragoljub Sevic
(PhD, Faculty of technical sciences, Trg Dositeja Obradovica 6, Serbia, sevic@uns.ac.rs)

Abstract

Toyota production system (TPS) or lean production has find application in almost every area of human functioning, hence, in the area of medicine, namely in the hospitals and clinical laboratories. Paper will give the literature overview of the specific lean tools that was implemented in hospitals and clinical laboratories procedures, as well as the effects of those implementations. This overview could be very helpful for any medical organization, planning to start their own lean journey.

Key words: *Clinical laboratories, lean, lean tools*

1. INTRODUCTION

The term “lean” first appeared in the book "The machine that changed the world" (Womack *et al.*) where the Womack *et al.* showed differences between the Japanese production methods and traditional mass production from the West. The book discussed approaches which the Japanese automobile industry used to take the precedence over the American automotive industry [1]. Authors Womack *et al.* show the comparison between these two approaches in production. The same authors have defined this approach as lean, under the definition that lean “*provides a- way to specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less—less human effort, less equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want*” [2].

The first pioneers of lean concept are considered to be Eiji Todoya and Taiichi Ohno who, after the Second World War (WW2), after several visits to Ford company, which was considered then as the most successful automotive industry, gained an insight into the way of doing business as well as their mistakes. One of the basic principles that guided the employees in Toyota Company during the improvement process was the elimination of “*muda*”. “*Muda*” is the Japanese word for waste, in the sense of wasted effort or time [3].

During its development, lean philosophy directed its focus on production sector, but the implementation was quite successful in service sector, too. According to the ISO standards service is a product that is immaterial, it can represent all or only a part of the whole offer, it is tied to the activities such as sales, handling, delivery, planning, improvement, training for use, maintenance or use of material products (ISO 9000:2015). Some of characteristic service industries nowadays are:

- education,
- financial services,
- business services,
- logistics,
- health services realized in hospitals, clinics, policlinics,
- state/public services,
- telecommunication etc.

This paper will give the literature overview of the specific lean tools that was implemented in hospitals and clinical laboratories procedures, as well as the effects of those implementations.

2. THEORETICAL BACKGROUND

When the definition of services is in the question, it can be concluded that there is no single definition that would be acceptable. Due to this fact some authors stress that although the service area was studied during 25 years period, there is no consensus on the issue of services [4]. Also, it is very difficult to find a product that "operates" independently without some kind of service. All products are closely related to the various aspects of services which can be represented as advertising, transportation, etc., and therefore services are considered as a very important component in the creation of the entire product or service as a standalone product. In order to understand services in better way it is necessary to identify their main characteristics, which differ from the characteristics of the products [5]:

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

Although specialized people work in health systems, as a one of the representatives of service sector, those systems are not perfect in their operations. A large number of studies indicate shortcomings that occur within health care processes [6,7,8]. One of very important authors in this research area, Graban, in his book, he explained in detail the need for implementation of lean concept in health care systems: “*Hospitals do many wonderful things but some people say that hospitals have world-class doctors and treatment but completely broken processes*” [9]. According to his opinion lean can help hospitals not to improve quality by asking people to be more careful, but to help hospitals to be more organized and managed. Lean is a method that allows hospitals to improve quality of care for patients by reducing errors and waiting times. Lean is a system for strengthening hospitals organizations for the long-term reducing costs and risks while also facilitating growth and expansions.

A review of the literature enable us to see that lean concept in health care organizations represents a growing trend. Authors Kim *et al.*, [10] describes challenges which may arise during the implementation of lean concept in health care organizations. Hawthorne and Masterson [11] in their work explain how their health-care organization succeeded to increase quality and safety of health care delivery with the implementation of lean concept. Dahlgaard et al. present lean concept which will enable an improvement of the system of health care organization. It is very difficult to find a negative attitude when it comes to the application of lean in healthcare [12].

Of course, beside successful practices of implementing lean concept in healthcare that have been published by many authors, when the application of lean concept in health care is in question [13, 14, 15, 16, 17] there are some critical views of individual researchers [18]. Burgess & Radnor research whether the lean concept is only a paradox and whether lean can help a health care system and their findings suggest that lean implementation in English hospitals tends to be isolated rather than system-wide [19].

One of the papers which emphasized that lean concept cannot always fulfill the expectations is described by the authors Radnor *et al.* [20]. The authors in their work investigated the extent to which lean concept was successfully implemented in four health institutions, with a specific focus on those segments that were successful and those which were not, and the reasons why this happened. The paper does not mention the exact systems and subsystems of health care in which lean was implemented.

It is important to note that health and production systems are composed of subsystems integrated as a whole, for example, one medical institution – hospital consists of different objects (depending on the application), laboratories, operating rooms, room for viewing, storage rooms, rooms for waste removal, etc. In each of these locations there are processes and procedures that can be improved by applying lean concept. In the continuation of this paper the authors presented a literature overview of the specific lean tools that was implemented in hospitals and clinical laboratories procedures, as well as the effects of those implementations.

3. LEAN TOOLS IN HOSPITALS AND CLINICAL LABORATORIES

As previously mentioned, the literature review show that the lean concept in health care facilities represent a trend that is increasing. Implementation of lean concept is not related just to the improvement of a medical institution as a whole, but to the implementation of lean concepts in each subsystem of a medical institution. When speaking of "subsystems" of a medical institution that is primarily related to clinical laboratories, nursing, primary care, perioperative service, emergency department, anatomic pathology, etc. In recent time, all clinical laboratories are faced with requirements to reduce the cost of procedures while providing faster and more accessible services, processing a wider range of parameters and higher frequency of samples [21]. In addition to these requirements, the clinical laboratory should work on improving the effectiveness and efficiency of the process and satisfaction of patients, quality management, research and development, etc.

A review of the available literature showed different focuses of researches, when it comes to the lean concept in clinical laboratories. The authors Rutledge and Simpsons explored the improvement in clinical laboratories by applying lean tools [22]. The authors have defined the new design of the laboratory and tried to secure the improvements that are reflected in a reduced TAT - turnaround time (reduced from 54 to 23 minutes) with increased testing volume (20%), monetary savings (4 full-time equivalents), decreased variability in TAT, and better space utilization (25% gain).

The author Halwasch-Bauman pointed to the influence of the laboratory which has been based upon the lean principles on organization of work, and its efficiency and effectiveness [21]. Persoon *et al.* investigated the improvement of a preanalitical process by using lean principles. By applying lean principles the authors successfully reduced the preanalytical process time from 29 to 19 minutes. At the same time, the laboratory achieved the goal of creating 80% of the reports of chemical analysis of samples within an hour in the following 11 months [23].

Knowles & Barnes in their critical paper tried to draw attention to the need that clinical laboratories do more with less resources by analysing the best practices from other industries [24].

An interest study was made by the authors Yerian *et al.* that determined the lost time that employees lose because of leaving the workplace in order to perform its task. In the initial stage of the recording process in clinical laboratories it has been detected that of 664 tasks 251 of them (38%) require that the technologist leave the job position in order to perform the task. After the reconfiguration of jobs the authors have succeeded that in only 59 (9%) cases (out of 664) the technologist has to leave the job position to complete the task. They managed to reduce the leaving from workplace for 3.4 times, while the times spent when leaving the workplace ranged from 8 to 70 seconds [25].

The influence of the lean methodology in health institutions, particularly in clinical laboratories, in terms of improving the capacity and workflow, and increase of customers' and patients' satisfaction have been explored by Morón-Castañeda *et al.*. The authors pointed out a reduction of the flow of patients, from the moment of entering the clinic until the moment of departure for 17 minutes, and a decrease of 60% in complaints of delay in care, high staff turnover and 38% increase in the number of patients seen [26]. Improvement of the flow of patients has been examined by the authors Chan et al. (2014). Namely, the admission of waiting time emergency medical ward (EMW) was significantly decreased by using lean technique from 54.76 minutes to 24.45 minutes [27].

A more detail overview of the implementation of lean concept in clinical laboratories (implemented lean methods and tools by different authors with a focus on the target area and the results achieved) is given in table 1.

Table 1. An overview of implemented lean methods and tools by different authors with a focus on the target area and the results achieved

Authors	Lean tools/methods	Results achieved
J. Sugianto, B. Stewart, J. Ambruzs et al. (2017) [28]	Kaizen, VSM, Kanban, SIPOC*	Process cycle efficiency of 29%. Implementation of a revised-state value stream resulted in a total process time reduction to 238 minutes, of which 89 minutes were non-value-added, and an improved process cycle efficiency of 63%.
Umut and Sarvari (2016) [29]	Lean six sigma, 5S, change management, heijunka, pull, mistake proofing, single piece flow, JIT, layout change.	Number of blood test delays was 97 before the improvement and reduced to 29. Especially creatinine test was varying between 180 to 210 minutes and after impleentation 90 mins.
Chan et al. (2014)	re-design process, priority admission triage (PAT) program	The admission waiting time of emergency medical ward (EMW) was significantly decreased from 54.76 minutes to 24.45 minutes after implementation of PAT program
Coons, 2007 [30]	VSM, Workplace Organization (5S), Batch Size Reduction, Standard Work, Root cause analysis	25-50% improvement in turnaround time 20-50% improvement in tests verified for morning rounds 10-35% improvement in productivity measure 5-15% improvement in staff and patient satisfaction
Melanson et al. (2009) [31]	Kaizen event, statistic	reduction of average patient wait time from 21 to 5 minutes, with the goal of drawing blood samples within 10 minutes of arrival at the phlebotomy station met for 90% of patients.
Yerian et al. (2012)	Kaizen, Laboratory design, Standard work, Temotoko	After improvement only 59 (9%) cases (out of 664) the technologist has to leave the job position to complete the task. They managed to reduce the leaving from workplace for 3.4 times, while the times spent when leaving the workplace ranged from 8 to 70 seconds.
Amirahmadi et al. (2007) [32]	VSM, 5S, change management, Pull/Kanban, flow layout	Reduced batch sizes, Staffing schedules matched to sample arrivals, Standardization of work processes with visual cues to help people stick with the standard, Reduced set up time for testing, Root cause analysis and mistake-proofing to reduce defects due to human error...
I. Litchfield, L. Bentham, A. Hill, R. McManus (2015) [33]	VSM, process improvement strategies	delay in phlebotomy, lack of a fail-safe to ensure blood tests are returned to practices and patients, difficulties in accessing results by telephone role of nonclinical staff in communicating results, routine communication of normal results, lack of a protocol for result communication.
Stanković, 2008 [34]	Six Sigma, Kaizen Blitz, VSM, 5S, Specimen	With Lean and Six Sigma, labs are able to recognize waste (streamline), reduce variation for consistent results, and error-proof operations-all of

Authors	Lean tools/methods	Results achieved
	Management System	these translated into enhanced quality and efficiency (turnaround time).
Rutledge & Simpsons (2010)	work cell, visual controls, single piece flow, standard work, 5S	reduced TAT - turnaround time (reduced from 54 to 23 minutes) with increased testing volume (20%), monetary savings (4 full-time equivalents), decreased variability in TAT, better space utilization (25% gain).
Persoon et al. (2006)	TPS, 1-piece flow, Baseline Cycle Time Study, VSM	reduced the preanalytical process time from 29 to 19 minutes laboratory achieved the goal of creating 80% of the reports of chemical analysis
B. White, J. Baron, A. Dighe, C. Camargo Jr., D. Brown (2015) [35]	Lean-based reorganization, process flow	screening test: troponin T TAT was reduced by 33 minutes (86 to 53 minutes) and urine sedimentation TAT by 88 minutes (117 to 29 minutes)
J. Sirvent, M. Gil, T. Alvareza, S. Martina, N. Vila (2016) [36]	VSM, survey	Demographic No. patients admitted before 697 and after 691 EMS transfer due to lack of beds No. transfers/total requested before 10/22 and 3/21 after
Novis D. (2008) [37]	VSM, process flow analysis,	patients demanding better job reducing errors in laboratories, medicare no longer reimburse hospitals for medical errors, Third-party payors and state hospital associations have followed suit
E. Dickson, S. Singh, D. Cheung, C. Wyatt (2007) [38]	VSM, 5 day Kaizen	Patient visits increased by 9.23% langht of stay LOS decreased slightly and patient satisfaction increased significantly without raising the cost per patient
René J. Buesa (2009) [39]	5S, Six Sigma, Just-In-time, First-in-first-out, Work flow analysis	largest productivity increase (2.4 times), the highest sigma value (4.8), TAT reduction (5 days), pathologists were able to sign 60% of the cases the same day
C. Michael, K. Naik, M. McVicker (2013) [40]	VSM, TPS, lean management	PT for 1,355 samples averaged 31 hours, 17 accessioning errors were detected on review of 385 random requisitions (4.4%), no labeling errors were undetected
Morón-Castañeda et al. (2015).	lean methodology	reduction of the flow of patients for 17 minutes, decrease of 60% in complaints of delay in care, high staff turnover and 38% increase in the number of patients seen
S. Agarwal, J. Gallo, A. Parashar, K. Agarwal et al. (2016) [41]	Lean six sigma, Kaizen, Genchi Genbutsu, Waste reuction	The percentage of cases with optimal turn-time increased from 43.6% to 56.6%, The percentage of cases with an aggregate on-time start increased from 41.7% to 62.8%. Manual sheath-pulls performed in the Cath Lab decreased from 60.7% to 22.7%

4. CONCLUSION

Service systems and therefore hospitals and clinical laboratories are facing with demands for continuous improvement of their working processes. Continuous improvement of the processes is primarily reflected in the reduction of operating costs with increasing the efficiency and effectiveness of the processes, while at the same time, increasing the satisfaction of the users of these services - patients and employees. One of the "philosophies", i.e. the approaches that enables the improvement of the process with all the above mentioned requirements, is Lean concept. The literature review pointed to the conclusions that the implementation of the lean concept in clinical laboratories is a growing trend. By reviewing the literature it can be concluded that the improvements obtained in clinical laboratories and obtained by implementing the lean concept are not negligible at all.

Improvements in different processes range from 5% to 63%. Some processes, time-expressed, have been upgraded even to minutes etc. All of these improvements have been achieved with the high-quality implementation of lean tools such as 5S, VSM, Kaizen, process flow, Kanban, visual controls, single piece flow, standard work and many others.

5. REFERENCES

[1] Melton, T. (2005). The benefits of lean manufacturing: what lean thinking has to offer the process industries. Chemical Engineering Research and Design, 83(6), 662-673.

[2] Womack, J., Jones, D. (2003). Lean Thinking: banish waste and create wealth in your corporation, Revised and Updated, Free Press (available on www. books.google.com, approached 05.07.2017)

[3] Hines, P., Holweg, M., & Rich, N. (2004). Learning to evolve: a review of contemporary lean thinking. International journal of operations & production management, 24(10), 994-1011.

[4] Haywood-Farmer, J. & Nollet, J., "Services Plus: Effective Service Management", G. Morin Publisher Ltd, Quebec, (1991)

[5] Grönroos, Christian (1984), "A Service Quality Model and Its Marketing Implications," European Journal of Marketing, 18 (4), 36-45.

[6] Kondrup, J., Johansen, N., Plum, L. M., Bak, L., Larsen, I. H., Martinsen, A., ... & Lauesen, N. (2002). Incidence of nutritional risk and causes of inadequate nutritional care in hospitals. Clinical Nutrition, 21(6), 461-468.

[7] Leggat, S., Bartram, T., & Stanton, P. (2008). Exploring the lack of progress in improving patient safety in Australian hospitals. Health Services Management Research, 21(1), 32-39.

[8] Bacigalupe, A., Esnaola, S., Martín, U., & Zuazagoitia, J. (2010). Learning lessons from past mistakes: how can Health in All Policies fulfil its promises?. Journal of epidemiology and community health, 64(6), 504-505.

[9] Graban, M. (2011). Lean hospitals: improving quality, patient safety, and employee satisfaction. CRC Press. (available on www. books.google.com, accessed 05.07.2017)

[10] Kim, C. S., Spahlinger, D. A., Kin, J. M., & Billi, J. E. (2006). Lean health care: What can hospitals learn from a world-class automaker?. Journal of Hospital Medicine, 1(3), 191-199.

[11] Hawthorne III, H. C., & Masterson, D. J. (2013). Lean health care. NC Med J, 74(2), 133-136

[12] Dahlgaard, J. J., Pettersen, J., & Dahlgaard-Park, S. M. (2011). Quality and lean health care: A system for assessing and improving the health of healthcare organisations. Total Quality Management & Business Excellence, 22(6), 673-689

[13] Fillingham, D. (2007). Can lean save lives?. Leadership in Health Services, 20(4), 231-241.

[14] Waring, J. J., & Bishop, S. (2010). Lean healthcare: rhetoric, ritual and resistance. Social science & medicine, 71(7), 1332-1340.

[15] Jimmerson, C., Weber, D., & Sobek, D. K. (2005). Reducing waste and errors: piloting lean principles at Intermountain Healthcare. Joint Commission Journal on Quality and Patient Safety, 31(5), 249-257.

[16] Fine, B. A., Golden, B., Hannam, R., & Morra, D. (2009). Leading lean: a Canadian healthcare leader's guide. Healthcare Quarterly, 12(3), 32-41.

[17] Robinson, S., Radnor, Z. J., Burgess, N., & Worthington, C. (2012). SimLean: Utilising simulation in the implementation of lean in healthcare. European Journal of Operational Research, 219(1), 188-197.

[18] Young, T. P., & McClean, S. I. (2008). A critical look at Lean Thinking in healthcare. Quality and Safety in Health Care, 17(5), 382-386

[19] Burgess, N., & Radnor, Z. (2010, June). Lean paradox: can lean influence healthcare?. In Proceedings of the 17th International Annual European Operations Management Association (EurOMA) Conference–Managing Operations in Service Economies (pp. 6-9)

[20] Radnor, Z. J., Holweg, M., & Waring, J. (2012). Lean in healthcare: the unfilled promise?. Social science & medicine, 74(3), 364-371.

[21] Halwachs-Baumann, G. (2010). Concepts for lean laboratory organization. Journal of Medical Biochemistry, 29(4), 330-338

[22] Rutledge, J., Xu, M., & Simpson, J. (2010). Application of the Toyota Production System improves core laboratory operations. American Journal of Clinical Pathology, 133(1), 24-31.

[23] Persoon, T. J., Zaleski, S., & Frerichs, J. (2006). Improving preanalytic processes using the principles of lean production (Toyota Production System). American journal of clinical pathology, 125(1), 16-25.

[24] Knowles, S., & Barnes, I. (2013). Lean laboratories: laboratory medicine needs to learn from other industries how to deliver more for less. Journal of clinical pathology, jclinpath-2013.

[25] Yerian, L. M., Seestadt, J. A., Gomez, E. R., & Marchant, K. K. (2012). A collaborative approach to lean laboratory workstation design reduces wasted technologist travel. American journal of clinical pathology, 138(2), 273-280.

[26] L.H. Morón-Castañeda, A. Useche-Bernal, O.L. Morales-Reyes, I.L. Mojica-Figueroa, A. Palacios-Carlos, C.E. Ardila-Gómez, M.V. Parra-Ardila, O. Martínez-Nieto, N. Sarmiento-Echeverri, C.A. Rodríguez, C. Alvarado-Heine, M.A. Isaza-Ruget. Impact of Lean methodology to improve care processes and levels of satisfaction in patient care in a clinical laboratory, Revista de Calidad Asistencial, Vol. 30 (6), November–December 2015, pp. 289–296

[27] HY Chan, SM Lo, LLY Lee, WYL Lo, WC Yu, YF Wu, ST Ho, RSD Yeung, JTS Chan. Lean techniques for the improvement of patients' flow in emergency department, World Journal Emergency Medicine. 2014; 5(1): 24–28

[28] Sugianto, J. Z., Stewart, B., Ambruzs, J. M., Arista, A., Park, J. Y., Cope-Yokoyama, S., & Luu, H. S. (2015). Applying the principles of lean production to gastrointestinal biopsy handling: from the factory floor to the anatomic pathology laboratory. Laboratory medicine, 46(3), 259-264.

[29] Umut, B., Sarvari, P.A., Applaying lean tools in the clinical laboratory to reduce turnaraund time for blood test resutls, Proceedings of The IRES International Conference, San Francisco, USA, 13th, 2016

[30] Jason A. Coons, Techsolve, Beginning the Lean improvement journey in the Clinical Laboratory, white paper 2007

[31] Melanson, S. E., Goonan, E. M., Lobo, M. M., Baum, J. M., Paredes, J. D., Santos, K. S., ... & Tanasijevic, M. J. (2009). Applying Lean/Toyota production system principles to improve phlebotomy patient satisfaction and workflow. American journal of clinical pathology, 132(6), 914-919.

[32] Amirahmadi, F., Dalbello, A., Gronseth, D., McCarthy, J. Innovations in the Clinical Laboratory - An Overview of Lean Principles in the Laboratory, Mayo Medical Laboratories (2007)

[33] Litchfield, I., Bentham, L., Hill, A., McManus, R. J., Lilford, R., & Greenfield, S. (2015). Routine failures in the process for blood testing and the communication of results to patients in primary care in the UK: a qualitative exploration of patient and provider perspectives. BMJ quality & safety, bmjqs-2014.

[34] Stanković, A. (2008). Developing a Lean consciousness for the clinical laboratory. Journal of Medical Biochemistry, 27(3), 354-359.
[35] White, B. A., Baron, J. M., Dighe, A. S., Camargo, C. A., & Brown, D. F. (2015). Applying Lean methodologies reduces ED laboratory turnaround times. The American journal of emergency medicine, 33(11), 1572-1576.
[36] Sirvent, J. M., Gil, M., Alvarez, T., Martin, S., Vila, N., Colomer, M., ... & Metje, T. (2016). Lean techniques to improve flow of critically ill patients in a health region with its epicenter in the intensive care unit of a reference hospital. Medicina Intensiva (English Edition), 40(5), 266-272.
[37] Novis, D. A. (2008). Reducing errors in the clinical laboratory: A Lean production system approach. Lab Med, 39(9), 521-529.
[38] Dickson EW, Singh S, Cheung DS, Wyatt CC, Nugent AS. Application of Lean Manufacturing Techniques in the Emergency Department. Journal of Emergency Medicine. 2008;37(2):177-182.
[39] René J. Buesa. (2009). Adapting lean to histology laboratories. Annals of Diagnostic Pathology, Volume 13, Issue 5, October 2009, Pages 322-333
[40] Michael, C. W., Naik, K., & McVicker, M. (2013). Value stream mapping of the Pap test processing procedure. American journal of clinical pathology, 139(5), 574-583
[41] [28] Agarwal, S., Gallo, J. J., Parashar, A., Agarwal, K. K., Ellis, S. G., Khot, U. N., ... & Kapadia, S. R. (2016). Impact of lean six sigma process improvement methodology on cardiac catheterization laboratory efficiency. Cardiovascular Revascularization Medicine, 17(2), 95-101