Optimization of Lean Surgical Route through POCT Acquisition

Carlotta Patrone, Lucia Cassettari, Lorenzo Damiani, Roberto Mosca, Roberto Revetria

***Abstract*— A Business Process Reengineering analysis has been performed on the ambulatory process based on the evaluation of Oncologic and Haematological patients. Through the Value Stream Mapping a significant waiting time to obtain the reports and results of blood tests has been observed.**
The Health Technology Assessment to evaluate the potential acquisition of one or more Point Of Care Testing (POCT) has been carried out through Discrete Events Simulation, followed by a detailed economic analysis. Considering the results, a significant reduction of waiting time and global decrease of health costs have been detected. Two POCT (nowadays operating) have been successfully installed.

***Index Terms*— BPR, Lean, Response Surface Methodology, Stochastic Simulation.**

I. Introduction

Process Reengineering and Response Surface Methodology techniques have gained increasing success in the manufacturing field and Lean demonstrated positive efficiency in the healthcare setting.
Business Process Re-engineering (BPR) provides a deep revision of processes analysing the initial mapping of routes, focused on the exclusion of all unnecessary activities and duplications.
Through the Value Stream Mapping Lean gained a primary role in this phase because of its value to highlight all the unnecessary activities in the patient health-process. The waiting time for the results of blood tests before the chemotherapy infusion and the blood transfusion have been analysed.

The BPR underlined different solutions to reduce the waiting time (i.e. deviation of pneumatic mail) but unfortunately some of that were unsuitable.
The acquisition of a Point Of Care Testing (POCT) representing a small size device to obtain blood test result in few minutes was considered in the setting of the present study. Two hospital department, have been analysed and the prospect of acquisition of one or two POCT has been assessed. A simulation model, validated by the Montecarlo technique, has been implemented and the economic analysis has been carried out to obtain the more suitable solution.

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II. Materials and Methods

The Value Stream Mapping was applied to the process of Oncological and Haematological patients needing chemotherapy infusion or blood transfusion.
The decision to focus the attention on the timing of blood test results was given by the Direction of the Hospital to improve the health assistance.
Analysing the healthcare process the first step was represented by the patient acceptance, the blood collection and than by the manual delivery of the sample to the lab. The Figure 1 shows the main steps of Complete Blood Count (CBC) given by informatics tracing: T0 (patient acceptance) T1 (laboratory tube check-in), T2 (lab technician validation), T3 (biologist validation) T4 (report validation, not always coinciding with T3 because the reports are often composed by results with different execution time).
The evaluation of timing for sample transport from the department to the lab (Ttrasp) was carried out with contribution of the nurses to obtain accurate data.
Table I shows the results of the process from blood collection to the medical report showed in Figure 1 for years 2013 and 2014.

Table I: Data analysis

Year	T4-T0	T1-T0	T TRASP-T0	T1-T TRASP	T4-T1	T2-T1	T3-T2	T4-T3
2013	01:45	00:38	\	\	01:07	00:15	00:34	00:18
2014	01:56	00:41	\	\	01:15	00:16	00:33	00:26

The Table I shows the main CBC waiting values respectively 1:45 [h:min] in 2013 and 1:56 [h:min] in 2014.
In this phase the promptness of the blood test results is critical because in case of anaemia or kidney insufficiency the chemotherapy infusion is not allowed and the waiting time for the patients would be worthless.
Table I shows how the waiting time, from the patient acceptance to the blood tubes arrival to the lab was 38 minutes in 2013 and 41 minutes in 2014 respectively. In this time interval, the blood tubes were stocked on the desk and were transported with batch logics by the operator.
Once in the lab, blood tubes waited 1:07 [h:min] in 2013 and 1:15 [h:min] in 2014 respectively.
The lab process for these tubes, treated as urgent, provides the blood test execution (lasting about 2 minutes), the technician validation represented by T2 – T1, the biologist validation (T3 – T2) who needs an average of 2 minutes, and finally the digital report signature (T4 – T3).

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As already pointed out, (T4 – T3) does not coincide with (T3 – T2) as in the report signature converge different results often requiring different timings.
As showed in Table I, there is a bottleneck given by the biologist signature. The analysis on site showed the batch processing. In these case was possible to improve results and timing by proposing the one-piece-one-flow process. This solution resulted applicable since the biologist was completely dedicated to urgencies. Nevertheless the waiting (T4 – T3) was not adjustable.

The analysis of details that caused the increase of waiting times with global worsening of performance on 2014 was conducted (mean increasing time of 12 % and increasing of 4.53 % of the number of urgent CBCs – 76.791 urgent CBCs on 2014 vs 73.463 on 2013) (see Table I). The overall capacity of the Analysis Laboratory unit was calculated and than reported in Figure 2, (referred to May 2014).

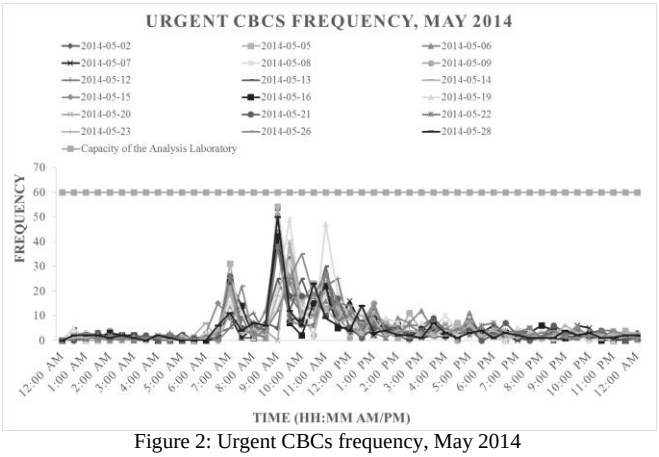

Figure 2: Urgent CBCs frequency, May 2014

The capacity of 120 tubes/hour was calculated and reported in Figure 2 (60 blood tubes/30 minutes). Figure 2 shows the two peaks that are related to physical examination in the ward (typically at 9 a.m. and at 11 a.m.). In the future we could focus the analysis on the urgent test prescription that forces the lab to work in that "two peaks" modality in order to rationalize and level of production.

The next step is the analysis of the department process (see Table II). Table II shows an evident decrease of test response time (T4-T1) for the haematology unit (26 minutes, versus 47 minutes in the period before the observation (1/01-12/09 2014).

Table II: Analysis of the data

Period of observation	T4-T0	T1-T0	T TRASP-T0	T1-T TRASP	T4-T1	T2-T1	T3-T2	T4-T3
Oncology	01:46	00:29	00:14	00:15	01:17	00:11	00:35	00:31
Haematology	01:14	00:47	00:28	00:19	00:27	00:07	00:14	00:06

We measured the decrease of performance time (T4-T1) because the data collection of this project started in the haematology unit and was performed by an industrial engineer. The results demonstrate that data collection influenced the performance. Table III shows the data before the beginning of the project.

Table III: Data before the observation period

Period	T4-T0	T1-T0	T TRASP-T0	T1-T TRASP	T4-T1	T2-T1	T3-T2	T4-T3
Haematology before the observation period	01:48	00:55	\	\	00:53	00:22	00:18	00:13

Table II shows the two bottlenecks: the first one was located in the wards (transport) and the second one in the laboratory (validation exam by the biologist).

In the department the time between the patient acceptance (T0) and the transport to the lab (Ttrasp) was 14 minutes for Oncology and 28 minutes for Haematology respectively. The mean number of tube transport for day realized by the operator was 6.7 for Oncology and 3.3 for Haematology respectively. Moreover, the mean time between the operator departure with the tubes from the ward (Ttrasp) and the laboratory tube check-in (T1) was 15 minutes for Oncology and 19 minutes for Haematology respectively.

Statistical analysis to test the robustness of the results was performed.

Figure 3 shows the distribution of time between the patient acceptance (T0) and the availability of the report (T4).

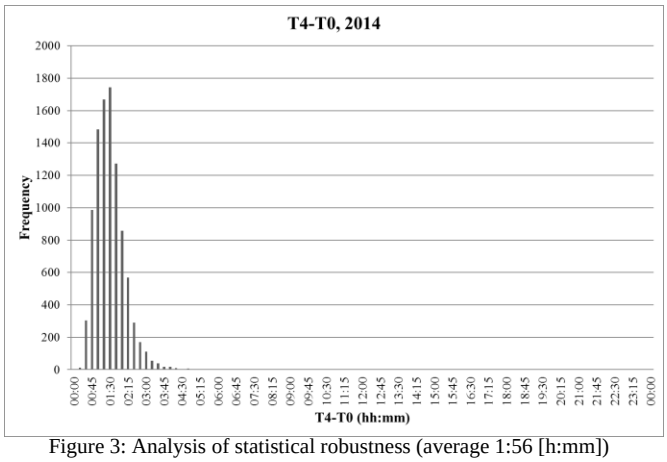

Figure 3: Analysis of statistical robustness (average 1:56 [h:mm])

Summarizing, bottlenecks were the following:

- Transport
- Exam validation by the biologist

Moreover in the setting of the present study the analysis to remove the bottlenecks was conducted.
Results showed how the transport bottleneck could not be eliminated because of the inability to modify the pre-existing pneumatic tube, nor to increase the number of tube transport from the ward to the lab. Concerning the exam validation by the biologist, the solution could be the one-piece-flow working, as already pointed out.
The bottleneck of the transport could not be eliminated. For this reason the assessment on the purchasing of a POCT shared by the two different structures was conducted. The two wards were located logistically far apart. Figure 4 shows the hypothetical area set for the location of the POCT. This area was the blood samples centre and it was 83.7 m far from the Oncology and 56 m far from Haematology respectively.

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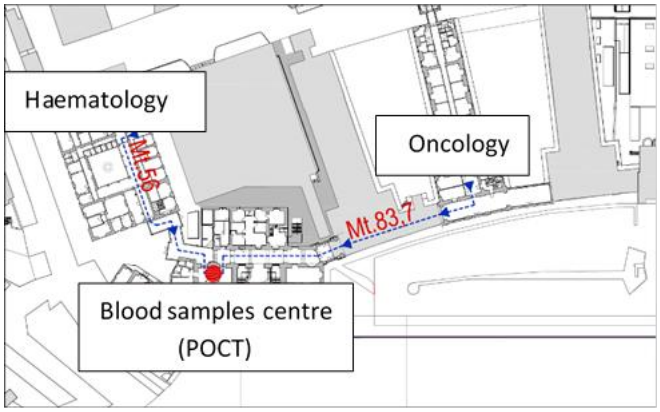

Figure 4: Hypothetical area set for the location of the POCT

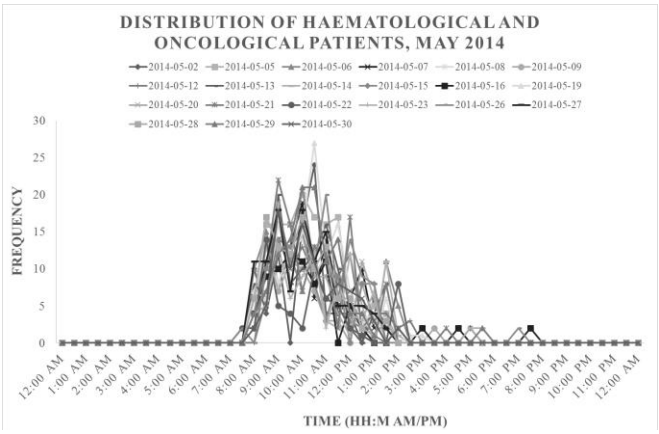

Figure 5: Distribution of haematological and oncological patients, May 2014

To assess this possibility, a discrete event simulator was implemented through Flexsim Healthcare, by Flexsim Software Products Inc. This was a simulation software of the Visual Object Oriented type, i.e. providing 3D objects libraries appositely created to replicate the physical behaviour object of the study. The software can be used to model entire wards and to analyse the main parameters. In this case the sustainability of sharing of a POCT and in a further phase the coefficient of utilization of the POCT.

First, the patient's access distribution has been analysed in order to assess the statistical distribution fitting with the data but no statistical distribution matched with the data. For this reason, the frequency histogram was insert into the simulation model. Then, the distribution of haematological and oncological patients was analysed (see Figure 5) in order to individuate the time slot for the simulation and to size correctly the POCT capacity. Figure 5 shows the time slot 8 a.m. – 2 p.m. as the period of maximum afflux and this time slot was selected for the simulation.

The Health Technology Assessment (HTA) department identified different types of POCT on the market with the main difference of the capacity.

The different capacity were the following:

- 100 tubes/hour
- 80 tubes/hour
- 60 tubes/hour.

The POCT with the worst capacity (60 tubes/hour) was used in the simulation in order to analyse the worst scenario.

A fundamental step is the right detection of the simulation run period that is strictly linked to the degree of stochasticity implemented in the model. Using as input of the model the frequency distributions derived from the data collection is one of the most qualifying points of the modelling.

However, the essential distinction between model and reality is that, whereas the real system is conditioned only by the background noise of the stochastic sources, the model is afflicted, in the output results, by a double uncertainty source, represented by the overlapping of the stochasticity naturally present in the real system and the stochasticity connected to the employ of the Montecarlo method. It means that the number of random extractions of each frequency distribution must be sufficiently high to provide non-unbiased estimates of the statistical parameters of each single starting distribution. This methodology allows to obtain results in line with those provided by the real system. In fact in this way the extra-noise that affects the model is eliminate by the period of the simulation.

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The size of the experimenter lack of knowledge is carried out through a quantitative value called Experimental Error commonly expressed through a statistical quantity the Mean Square Pure Error (MSPE).

The MSPE study can be conducted, according to the type of the analysed system, through two methods:

- MSPE for systems evolving in time;
- MSPE for systems evolving in runs.

The substantial difference between the two methodologies lies in the nature of the analysed objective function. The first technique is applied for the objective function that evolves in time in which is necessary to minimize the experimental error directly in the length of the run. In the opposite case, for reasons connected to the intrinsic nature of the analysed system, is impossible or nonsense to extend the run length over a certain limit and experimental error should be studied acting on the number of run replications. The case study reported use the first methodology. In fact, as input of the model the patient arrival frequency distribution split in time band is used.

The length of the simulation run reduces the experimental error and it is been detected by a first pool of simulations with a one year length run (see Figure 6).

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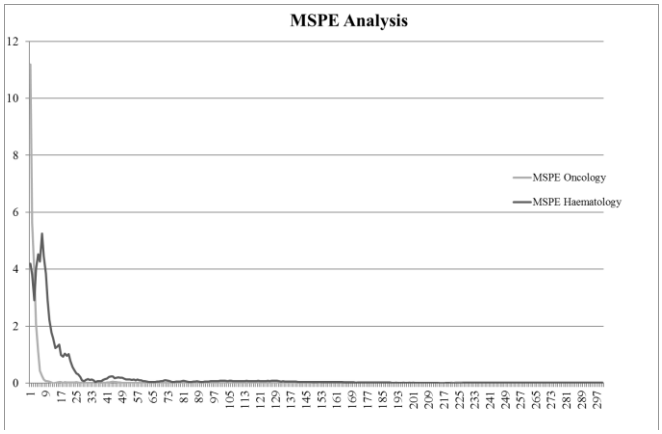

Figure 6: MSPE analysis

Figure 6 shows that the experimental error became negligible at 150 run hours of simulation.
The POCT with 60 tubes/hour capacity is more than suitable to fulfil the test of the two departments.

The simulation demonstrated the following data:

- Utilization coefficient between 26 and 28%;
- Lead time about 2 minutes with negligible waiting time at the POCT.

Finally a cost analysis has been conducted through the data provided by the HTA department. Data showed how the POCT cost was very limited, so the analysis of the scenario with two different POCT was performed (see Figure 7).
Figure 7 shows the economic convenience of executing a CBC by POCT instead by lab. Standard lab results provide very complex reports that unfortunately are useless for the chemotherapy infusion.

The also called "superfluous works" are one of the eight wastes pointed out by Lean and were also represented by all the information no value added or useless for the process.
Figure 7 shows that the best solution, in terms of economic convenience and clinical risk, was the purchase of two POCT.
The configuration with two POCT allows to achieve different results:

- Eliminate the waiting time to the POCT (each department has its POCT);
- Remove the possibility of exchanging haematological and oncological tubes diminishing the clinical risks;
- Re-allocate the operator dedicated to the transport to another department;
- Avoid to purchase the expensive informatics interface that was essential to reduce the clinic risk in case of sharing a single POCT by two structures.

III. Conclusions

By the analysis reported in the present study, it was possible to purchase two POCT allowing a saving for the hospital of more than 30.000 €/year from the first year, to reach over 47.000 €/year from the second year. This analysis main result was the reduction of the patients waiting, passing from 1:46 [h:min] in Oncology and 1:14 [h:min] in Haematology, to an "instantaneous" answer. POCT are presently in use and the focus is now to implement an informatics interface allowing to optimize the operators work.

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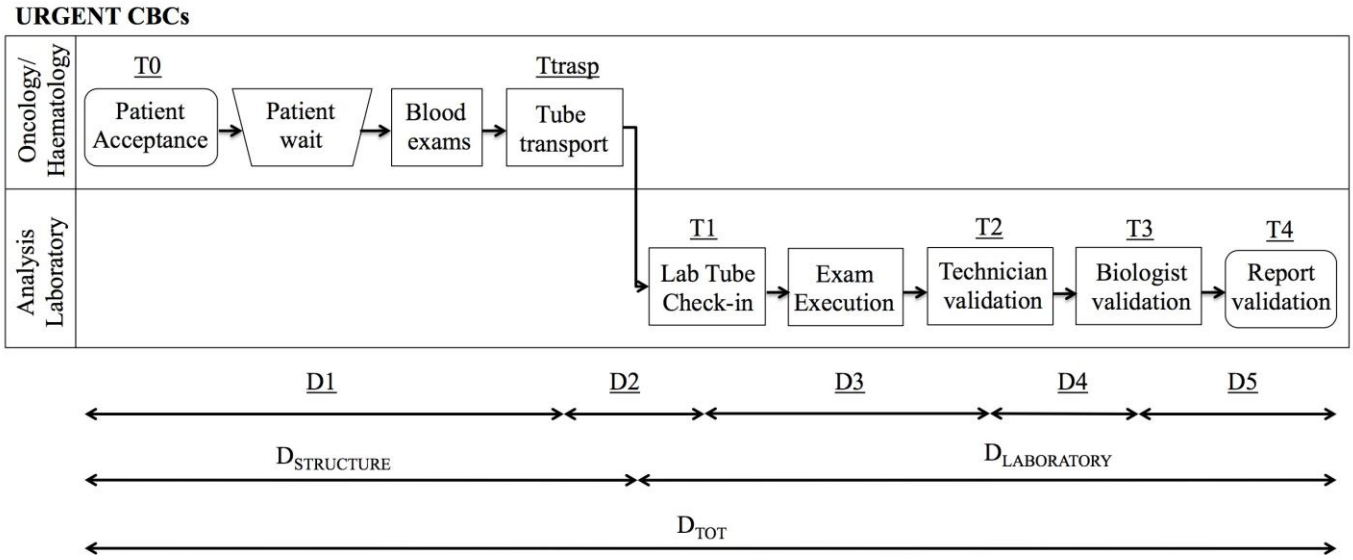

Figure 1: Swimlane diagram of the process

Economic analysis for the purchase of 1 POCT vs 2 POCT

SCENARIO of 1 POCT WITHOUT the re-allocation of the operator dedicated to the transport to another department and WITH the purchase of an informatic interface						
ENTERING COST (€)	**$YEAR_1$**	**$YEARi_{i=2,...,n}$**	**CEASING COST (€)**	**$YEARi_{i=1,...,n}$**	**$DELTA\_YEAR_1$**	**$DELTA\_YEARi_{i=2,..,n}$**
POCT COST (+VAT)	8540					
VEC COST of 1 POCT(+VAT)	2440	2440				
SOFTWARE INTERFACE COST (+VAT)	6100					
POCT EXAM COST	10080,7	10080,7	LAB EXAM COST	44643,1		
TOT	27160,7	12520,7	TOT	44643,1	-17482,4	-32122,4

SCENARIO of 2 POCT WITH the re-allocation of the operator dedicated to the transport to another department and WITHOUT the purchase of an informatic interface						
ENTERING COST (€)	**$YEAR_1$**	**$YEARi_{i=2,...,n}$**	**CEASING COST (€)**	**$YEARi_{i=1,...,n}$**	**$DELTA\_YEAR_1$**	**$DELTA\_YEARi_{i=2,..,n}$**
2 POCT COST (+VAT)	17080		TRANSPORT OPERATOR	18000		
VEC COST of 2 POCT (+VAT)	4880	4880				
POCT EXAM COST	10080,7	10080,7	LAB EXAM COST	44643,1		
TOT	32040,7	14960,7	TOT	62643,1	-30602,4	-47682,4

Figure 7: Economic analysis for the purchase of 1 POCT vs 2 POCT

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