ECONOMIC ASSESSMENT FOR A RFID APPLICATION IN TRANSFUSION MEDICINE

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ABSTRACT

Aim of the study is to evaluate economical feasibility of a Transfusion Medicine RFId application, which was studied in order to enhance patient safety and in order to improve blood inventory management processes.

A reverse engineering of processes was performed through Flow Charts and Activity Forms and a RFId-based processes re-engineering has been designed in order to reduce criticalities. Then a Return on Safety assessment was performed through a RFId-enabled processes FMECA and through Key Performance Indexes (KPI) design.

Finally a cost-revenues analysis was performed in order to verify the investment economic sustainability. Using HF and UHF RFID technology was considered, and a multi-scenario economic analysis was performed.

This pointed out that Payback Periods, related to the two technology choices, are comparable only if project implementation allows a waste reduction higher than 3.5%. The study also showed that economic benefits are maximized if project application is pervasive.

Keywords: RFID, economic assessment, transfusion medicine, risk management

1. INTRODUCTION

The health care industry is currently growing very fast and it is also facing many challenges from the increasingly competitive and globalized business environment.

In order to stay competitive, businesses in the health care industry have applied new technologies to manage patients, personnel, and inventory to streamline the efficiencies and effectiveness of business functions (Chong and Chan 2012). The potential of Radio Frequency IDentification (RFID) technology within health care environments has been assessed by several studies, showing positive effects on patient safety and logistics concerning patients and medical products (Van der Togt et al. 2011).

Improving operational efficiency through RFID technology, allows Heath care facilities to gain a competitive advantage over their competitors (Chong and Chan 2012).

Nevertheless, prior experiences show that RFID systems have not been designed and tested in response to the particular needs of health care settings might introduce new risks. Although the high employment flexibility of RFID technology, each application has to be carefully studied in order to achieve estimated project results and investment economic justification.

Even though the main goal of health care investments is to increase the quality of service provided to patients, economic analysis is necessary to provide an economic justification of proposed investment. Particularly, a RFID application project has a specific complexity because of variety of components which can be chosen for the system design. RFID systems differ in operative frequencies, transponder energy supply, complexity of chips mounted on tags, presence of additional components such as sensors, memory capacity ecc.

These characteristics are related to technical specifications (reading distances, volume of multiple read etc..), and to considerable cost differences for the systems implementation (Talone and Russo 2006).

The present work is allocated in this context. Its aim is to assess the economical feasibility of a RFID application in Transfusion Medicine, which was studied in order to enhance patient safety (Borelli et al. 2010) and in order to improve blood inventory management processes (Orrù et al. 2010).

Transfusion Service is one of the healthcare areas with high intervention potential. As a matter of fact clinical risk related to transfusion medicine is still a very important topic within Healthcare systems. ABO incompatible transfusions data frequency is considerable: Germany 1:36000; USA (New York) 1:38000; France 1:135207; Ireland 1:71428 (Ahrens et al. 2005), in case of Acute Haemolitic reaction, deadly consequences for patients may occur in 10% of cases (De Sanctis, Lucentini et al. 2004). Post transfusion viral transmission probability is about 1:1900000 for HIV and 1:1600000 for HCV (Goodnough 2003).

It's important to note that about 50% of United Kingdom SHOT (Serious Hazards of Transfusion) 2011 reports are caused by human error, RFId systems aim to delete them by introducing safer identification devices and procedures.

Transfusion medicine is one of the most important intervention areas because blood components are high added value assets, so a more efficient management of them may generate important economic advantages.

Furthermore, the specific blood need of Sardinia Island people are outstanding: in view of the very high proportion of thalassemic patients, it is the most High-level in Italy (64 packed red blood cells units/1000 inhabitants, while the national average is 42) (Istituto Superiore della Sanità 2008).

2. RFID PROJECT

The project has been developed at Blood Transfusion Centre (BTC) of AOB Hospital in Cagliari (Sardinia Island, Italy). The Blood Transfusion Center and two of the most important operative units of the Hospital, Transplant Unit and Brain surgery unit, were involved. The main study steps are summarized below.

2.1 Analysis step

In the first part of the study, a reverse engineering of present processes (As-is) was performed, by means of visits and operator interviews in order to map processes, to define information and material flows and to analyze infrastructure and technology status. As-Is analysis was performed through two tools : Flow Charts and Activity Forms.

Criticalities and process error sources were put in evidence through a Failure Mode Effects and Criticalities Analysis (FMECA) in order to suggest suitable actions for process refinement. Through Risk Priority Index (RPI) definition and through a bar chart set and a variable threshold ABC analysis, possible failure modes were studied and classified.

FMECA showed that most critical activities are carried out inside Unit Wards; particularly highest RPI values were measured in case of human errors.

2.2 Synthesis Step

In the second part of the study, an RFId-based processes re-engineering (To-Be Model) has been designed in order to reduce criticalities and to improve Transfusion Medicine service performances. Synthesis stage was divided in two different parts which are mutually complementary.

The first part regarded "Transfusion Loop" processes (Borelli et al. 2010), while the second one regarded all processes from Blood Donation to final storage (Orrù et al. 2010). Their implementation would be a new system model for whole Blood Chain process management. (Borelli et al. 2011).

Process re-engineering stage was formalized by creating more than 20 new flow charts and the related Activity Forms.

2.3 Return on Safety (ROS) assessment

A Return on Safety (ROS) assessment was performed through a RFId-enabled processes FMECA and through Key Performance Indexes (KPI) design.

FMECA pointed out that human errors in manual operations are still the most important. Particularly clinical activities (including patient treatment, manual blood testing etc.) are fewer, than other general activities (writing, material handling etc.).

Three KPI were used in order to evaluate "ex ante" the RFId project main goal achievement i.e. clinical risk reduction in Blood Chain Processes.

ROS assessment pointed out an appreciable clinical risk reduction within the whole Blood Chain (figure 1) and a not considerable variation of activities amount.

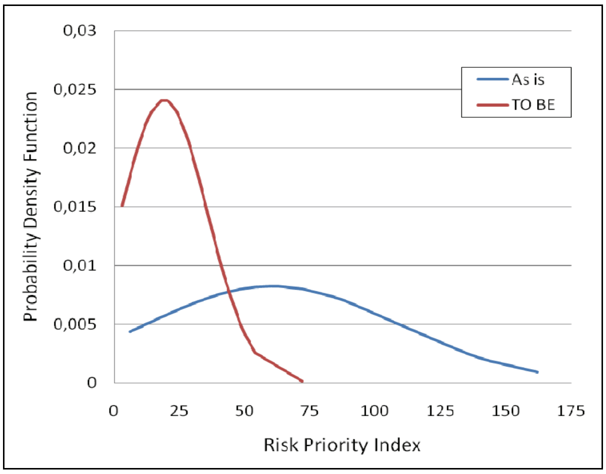

Figure 1. Comparison between AS-IS and TO-BE Normal Distribution of RPI values

3. ECONOMIC ASSESSMENT

After ROS assessment a cost-revenues analysis was performed in order to check the investment economic sustainability.

Cost-revenues type economic analysis was chosen, because it considers cash revenues only, ignoring other kinds of benefit such as image return, legal disputes missed costs ecc. These benefits, even though generate revenue, require strong hypotheses to perform their monetization, so it was decided to consider them in a next study step i.e. the cost-benefits analysis.

The economic analysis was carried out through 6 spreadsheets development. One of them is a general data and information collecting about the case study Hospital, one is related to project development costs and process management costs, two are related to revenues setting out, and finally, the last two are used to process data and to show the analysis results.

3.1. General Data collection

As a first step, general data about the whole hospital and Operative Units were collected in a worksheet called "Context Data", in order to have a detailed frame of the case study. This kind of data were set as variable parameters in order to check the analysis results trend and to have the possibility to apply the computing model to other healthcare facility contexts. For instance receptive capacity data, medical and non-medical personnel amount, all blood components transfusion statistics, wastes statistics (due to over date and other general causes) were collected. Part of this data were directly provided by AOB Healthcare facility, while remaining data were obtained by "Regione Sardegna" official documents (Regione Autonoma della Sardegna 2008). Available Blood donation and blood components assignation statistical data were related to Cagliari large area, so they were treated and scaled in order to estimate AOB Healthcare facility only data.

Furthermore, macro-process cycle times were collected in the Context Data worksheet. They had been extracted by a time and methods analysis which had involved all Blood Transfusion center processes, and all unit ward transfusion processes. All activities, regarding both human actions and automatized processes (automatic screenings, blood units or samples centrifugation etc.) were timed; recorded times which referred to simultaneous performing of multiple cycles or requests, were set out in unit time form.

3.2. Cost Computing

The second step consisted in cost computing, which was carried out splitting plant costs and operating costs.

As for cost computing a market analysis was made, and advice was sought from two of the most important Italian suppliers and developers of RFID systems, which also provided purchasing official estimates.

Costs computing was carried out referring to eight distinct design scenarios. The use of two types of RFID technology, HF 13.56 MHz and UHF 865-868 MHz, was hypothesized. Furthermore, since the research project should be developed in the Hospital following several steps, partial applicative scenarios were considered. According to the "To Be Model", First level application and Second level application were separately analyzed because they can be developed independently and they have different and complementary goals.

Each technology option was indeed studied both in case of Transfusion Loop only (processes ranging from patient accommodation to blood component transfusion) and all blood chain processes (acceptance, testing, treatment and storage of donated blood) application.

The last distinction was related to the type of tracked items: packed red blood cells (RBC) only (the most used blood component in transfusion medicine), and all blood components tracking were separately studied.

Considering partial applicative scenarios will be useful because, during experimental development phase of the project, it provides economic framework by showing minimum project expansion level that are sufficient to achieve a positive return of the investment.

3.2.1. Plant Costs

Main plant costs were hardware and software purchasing, network infrastructure adaptation or realization, and personnel training about the new system and new procedures. Plant costing was carried out referring to two design scenarios: the use of two types of RFID technology, i.e. HF 13.56 MHz and UHF 865-868 MHz, was hypothesized. Total plant costs are quite similar: UHF costs are about 1.5% higher than HF costs; particularly Hardware costs are the only element that differ, while software development and infrastructure costs (for instance Wi-Fi network deployment) were considered the same for the two technologies.

3.3. Operating Costs

Main operating costs were related to tag purchasing. The difference between the plant cost installation was almost limited, while UHF tags average cost is about 30-40% lower than HF tag cost. This difference greatly affects the technology choice.

In addition, maintenance costs related to hardware, network infrastructure technology and software were computed as operating costs. Maintenance costs were calculated as a fraction (1% - 2%) of each item cost.

3.4. Revenues

Revenues directly obtained by plant using were all intended as missed disbursement. They derive from two main kind of improvements: productivity improvement due to cycle time reduction, and quality improvement due to wastes reduction and more efficient blood inventory management.

3.4.1. Productivity

Economic benefits obtained by Transfusion Service productivity improving were quantified as follow.

For each macro-process, project-status cycle times were estimated basing on the related flow chart and activity forms. Then, differences between present-status and project-status cycle times were computed. Both positive and negative differences were obtained, because re-engineering caused streamlining of some process while integration of some others through additional activities that aim to improve safety level. Hospital staff pay scale were considered, and medium salaries were converted in €/min; then economic benefits for cycle (for instance a single blood unit treated, or a single request treated etc.) were evaluated and, considering the number of cycles per year, annual economic benefits were computed. This analysis was performed considering both Transfusion loop only application and all blood chain process application, and considering separately RBC units only and all blood components traceability. These scenarios differ in cycle number.

Table1. Economic benefits due to productivity improving of Blood components assignation process.

Blood Assignation			
	Cycle Time Gain [min]	Benefits [€/Cycle]	Benefits [€/year]
Physician	0.05	0.02	940.60
Nurses	0.25	0.06	2939.40
Lab Technicians	0.20	0.05	2351.50
Auxiliaries	0.00	0.00	0.00

3.4.2. Quality

Then missed disbursement due to the expected decreasing of discarded blood units were quantified. This analysis step was carried out by distinguishing two scenarios: packed red cells only tracking and all blood components tracking.

Each blood component unit cost was obtained by official documents (Regione Sicilia 2006) and they were updated to year 2011 through appreciation coefficient equal to 1.0974, according to the National Institute for Statistics (ISTAT) official tables. Each "saved" blood unit was also associated to a consumables and disposable medical devices saving.

Due to the difficulty in precisely estimating waste reduction, this was set as a parameter, and the range between 3% and 4% was identified as possible variation range.

4. DATA ELABORATION

The economic analysis main parameters were summarized in both analytical and graphical form for each technological and operational scenario, and they were reported in two specific worksheets, the first one related to first level application only, and the second related to all blood chain processes application.

Partial cash flows were computed for each cost and revenue worksheet, while total cash flows were reported in data elaboration worksheets, considering a 25 year investment horizon. The cash flows were updated assuming a 5% discount rate, because using of pubblic funds for project development was assumed.

Traditional financial indicators for investment evaluation, such as Net Present Value (NPV) and Pay Back Period (PBP) were then calculated and reported both in analytic and graphic form.

Furthermore a differential analysis was performed for each studied scenario, in order to compare HF and UHF technology investments. UHF technology is marked by plant cost higher than HF while operating costs lower than HF, so differential analysis aims to point out minimum periods for which UHF investment would be more cost-effective than HF investment.

5. SENSITIVITY ANALYSIS

First study steps showed that process re-engineering causes an overall slightly reduction of process amount and process cycle times, caused by the balance between process streamlining and integration (Borelli et al. 2011). The influence of productivity enhancement on positive cash flows is quite low: about 4.3% of total estimated annual revenues. Due to the high unit cost of blood components, waste reduction is the key parameter which substantially conditions positive cash flows trend.

Due to the difficulty in precisely estimating annual waste reduction related to project development, a sensitivity analysis was carried out in order to monitor the PBP trend to waste reduction variation within the range limits (3-4%) (Figure 2).

Exact quantification of this parameter can be obtained during the pilot plant testing phase in the healthcare facility, through the process data collection during a window period (at least six months). This data may be screened and compared to the present economic analysis, in order to provide an important decision support in suitable technology choice.

The sensitivity analysis was performed referring to the global extension scenario i.e. all blood chain processes application and all blood components tracking.

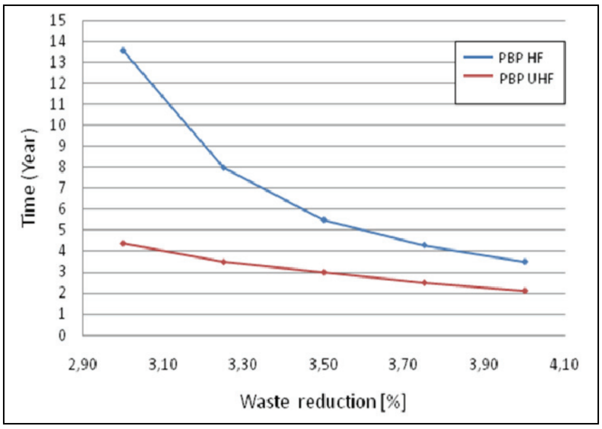

Figure 2. Sensitivity Analysis.

6. RESULTS

6.1. Global Application Scenario

Analysis results was performed by assuming waste reduction parameter equal to 3%, i.e. the variation range lower limit.

Analysis results show clearly that the investment is economically sustainable in case of project global application, i.e. including all blood components traceability and all blood transfusion chain processes.

Furthermore analysis points out that among operating costs, tag purchasing is still the most important aspect for the project development. Cost difference between UHF and HF technology, cause significant PBP difference (about 13.8 years using HF tags, about 4.5 using UHF tags). This is also highlighted by differential analysis.

6.2. Partial Application Scenario

As for partial application scenarios which were analyzed, main results are the following.

In case of Transfusion loop only application, that is a possible pilot plant opening configuration, cash flows are always negative, so the investment is not justified from a strictly financial point of view. Anyway, the almost complete elimination of clinical risk related to ABO incompatible transfusions, and the consequent patients and staff safety increase, may generate benefits that could be sufficient for the implementation.

The only partial application scenario where the investment PBP is within time horizon (PBP=8.5 years), is the case of all blood chain processes application for RBC only traceability, using UHF technology.

6.3. Sensitivity Analysis

Sensitivity analysis pointed out that the two PBP, related to the different technology choices, are comparable only if project implementation allows a waste reduction higher than 3.5%. Assuming a 3.5% waste reduction, PBP related to UHF system is about 3 years while PBP related to HF is slightly higher than 5 years.

In the optimistic case of 4% reduction, the two measured PBP further approach, till they arrive at about 18 months mutual difference.

On the contrary assuming waste reduction values below the 3.5% threshold, the payback time difference between the two technologies increases dramatically: UHF technology is rather more convenient.

Assuming a waste reduction equal to 3%, the PBP relative difference is about 9 years (PBP related to UHF is 4.5 years while PBP related to HF is 13.8 years).

7. CONCLUSIONS

In this paper, a cost-revenue economic analysis for investment evaluation related to a RFID project in Transfusion Medicine was performed.

Two main technology alternatives and several applicative scenarios which range from a pilot plant configuration to a project global development were considered.

The study showed that economic benefits are maximized if the project application is pervasive. Therefore RFID system in the healthcare should not be limited to transfusion traceability, but that should be a start-up step, which should lead to platform development in order to solve many hospital logistic problems. In this way return on investment economic parameters would be optimized, and the whole Healthcare facility performances would be enhanced.

Economic and sensitivity analysis results pointed out that UHF technology employment would ensure profitable pay back periods, even if waste reduction parameter, measured during experimental phase, would be below the 3.5% critical threshold.

Currently only the use of ISO/IEC 18000-3 mode 1 13.56 MHz RFID tags has been accepted by the United States FDA as supplemental data carriers on blood products (Hohberger et al. 2011), so experimental tests have to be performed in order to verify the possibility to use also UHF systems in transfusion medicine, and eventually to outline application guidelines.

Tests should verify two fundamental conditions. First, the absence of acute adverse in-vitro effects on blood components following prolonged exposure to UHF radio energy; second, UHF systems reliability in operative conditions.

The research team is currently also improving the economic analysis by taking into account, in addition to the current analysis revenues, benefits that are not immediately cash convertible, anyway attributable as project results. An economic conversion of non-economic benefits analyzed within the Return on Safety assessment, will allow new global financial indicators defining; a new cost-benefits analysis based on these indexes could provide a complete framework for project evaluation.

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