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Application of a business process model (BPM) method for a warehouse RFId system implementation

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Abstract. In recent years, the importance of the RFId technology within the operations management environment has become more evident. In particular, the RFId technology is recognised as an accelerator of the change towards a more efficient way to manage operations in an industrial context. The aim of this paper is to present a case study for the application of a pre-existing model (based on the Business Process Modelling method) for the technical, economic and financial evaluation of an RFId technology application in the area of industrial logistics for a bike manufacturer. The paper will face this issue preliminarily analysing the RFId utilization in the industrial context, afterwards analysing the existing literature on the BPM use for the evaluation of the applicability of RFId to the industrial context and lastly illustrating the case study and the results of the application of the BPM to the specific firm. The results demonstrate the improvement that it is possible to achieve in terms of financial returns and in terms of bikes worked in the warehouse per year.

Keywords: Business process modelling, Radio Frequency Identification, warehouse management, process optimisation

1. Introduction

The Radio Frequency Identification (RFID) technology has its first origins in the period just before the Second World War, when transponders were widely used by the Allies in 1939 to identify an aircraft and therefore, their nature, i.e. allies or enemies. This baptism led to various studies in the years that followed the Second World War which theorized and hoped for a research study to develop equipments that could transmit information by reflecting a power signal. After this baptism in the following years the RFId started to be used in different fields with different application in the industrial field of application (Cardullo, 1973; Landt, 2001; Walton, 1983).

RFID technology can be defined as a general purpose technology owing to its many uses that are all characterised by pervasive technological innovation; in fact, when this technology is introduced at a point in an economic chain, it easily spreads downstream and upstream from the insertion point and offers benefits of increased efficiency for

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the processes of all parties in the supply chain, thereby making it possible to face the uncertainties and the complexities of these systems more effectively (Fera, Fruggiero, Lambiase, Macchiaroli, & Miranda, 2017; Iannone, Lambiase, Miranda, Riemma, & Sarno, 2014).

Radio frequency systems have significant advantages when compared to other identification and tracking technologies such as bar codes and magnetic stripes. These advantages are summarised in aspects related to data management (both in terms of addition, deletion or substitution), to the different reading technology of data and so on. Indeed, these technologies are widely used in the field of logistics management of industrial plants, particularly those operating at 13.56 MHz with up to 1 m (standardized by ISO 15693) and the UHF up to 10 m (ISO 18000 norm). The RFId technology has already found many applications in sectors as diverse as food and beverage, automotive, health care and other areas of manufacturing and in all these industries the application results improved significantly the financial and technical performances; what this paper wants to demonstrate is about the applicability of this kind of solution to a small firm's logistics department (small in terms of financial incomes and work-force).

This paper is organised as follows in (i) a first paragraph they will be reported all the research papers that applied the BPM or other re-engineering methods to demonstrate the usefulness of the RFId application, after that (ii) it will be presented briefly the BPM method, after (iii) it will be illustrated the case-study to assess the effectiveness and the efficiency of the implementation of this kind of solution for the improvement of the warehouse operations and finally it will be illustrated a paragraph of conclusions.

2. Literature review

Since the nineties, the Radio Frequency Identification (RFId) technology has found widespread industrial applications as demonstrated by Lim et al. in their literature review (Lim, Bahr, & leung, 2013). At the beginning of there was a strong element of innovation, especially in relation to the control of the industrial processes; however, their wider use faced obstacles owing to their high cost. Even today, the economic feasibility regarding the use of this technology as a fundamental part of traceability and process control in industrial applications is still debatable (Busato, Fera, Iannone, Mancini, & Schiraldi, 2013; Fera, Iannone, Mancini, Schiraldi, & Scotti, 2013).

As reported by Zhu and others in 2012 (Zhu, Mukhopadhyay, & Kurata, 2012), the RFID technology now finds wide applications in many fields, specifically in industrial areas characterised by the presence of a well defined supply chain. The supply chain with its actors (distributors, manufacturers, suppliers and sub-suppliers) has the possibility, thanks to this technology, to know in detail and in real-time location the use of any object connected to the product or service offered. In particular, the authors report that the use of these technologies enables a significant reduction in labour costs and simplification of work processes and consequently an increase in the supply chain system efficiency. This increased efficiency will bring an increase in production capacity of the companies that decide to embark on a journey for the innovation process that includes the use of these technologies.

Another important advantage of the introduction of this technology is closely related to the improvement of the information flow management with accurate data collection and real-time sharing. In this context, Lee and others demonstrated the effectiveness of this management in buildings life cycle management can be helped by the RFId on the elements of the buildings (Lee, Jeong, Kun Soo, & Ning, 2013).

Many authors investigated solutions from a technological-scientific point of view including the use of RFId technology in various fields; in fact the industrial areas where this technology found a sensible impact were operations such as warehouses (Alyahya, Wang, & Bennett, 2016), production (Mancini, Pasquali, & Schiraldi, 2012; Busato, Fera, Iannone, Mancini, & Schiraldi, 2013; Cao, Li, & Miller, 2013)and maintenance (Lin, Cheung, & Siao, 2014; Ko, 2009) of the products sold.

A more detailed example of the application of this technology is cited in a paper that appeared in 2011 (Ferrer, Heath, & Dew, 2011) which investigated the advantages that can be obtained by the inclusion of this technology as part of a manufacturing process with a job shop system with reworking. This study through a discrete event simulation approach (method used also by others authors (Packianther, et al., 2014)) showed that the introduction of RFId technology has brought a possible increase in value added during reworking which is achieved through an increased efficiency of the reworking department. This increase of efficiency is achieved mainly through the ability to continuously track the position of the item that has to be reprocessed through the active radio frequency technologies and monitor the traceability of the part on the machines through those passive reflections, thereby 'writing' the story of the piece on the tag itself.

In 2012, some authors presented a paper (Zhu, Mukhopadhyay, & Kurata, 2012), which proves the possibility of using this technology with a positive influence on a large part of all business sectors of the fashion industry which is widely recognized as one of the main users of this technology (Martino, Fera, Iannone, Sarno, & Miranda, 2015). This study highlights how this technology can provide crucial help to those who are responsible for the management of this type of companies. In this article, the RFID technology is presented as a solution that can offer real-time support for the collection of data regarding the position of logistics and semi-finished products, as well as other data related to the advancement of production and saturation of production.

In 2015, a very interesting study showed that the integration of RFID technology with other detection systems and decision support systems is feasible (Guo, Ngai, Yang, & Liang, 2015), thereby confirming the aforementioned 2012 study. In this paper, the authors suggest the integration of RFID technology, which provides a real-time service about production data offering the real-time advancement of the scheduling of internal production, with the production department of another company. This integration, already made in the fashion industry, is then extended to the various production sites of the company, thereby offering the ability to control the progress of production across multiple sites and have an aggregate control over it. These controls are possible only with this type of technology, which corresponds to their introduction in the normal industrial production processes of software tools that enhance the analysis capacity of the production departments made by them. In addition, it is important to note that the authors report the ability to scale and change the size of their implementation.

Nevertheless, it is possible to identify through this paper the future steps offered by these kind of technologies that offer a real way to achieve the internet of things and more in general the named factory 4.0 (Meyer, Magerkurth, & Ruppen, 2013).

Some authors have recently published some interesting work just about the use of the RFId technology in the field of logistics management and the analysis of demand forecasting and chasing (Thiesse & Buckel, 2015; Ballestín, Pérez, Lino, Quintanilla, & Valls, 2013). The results of these studies conclude that the introduction of this technology also brings significant benefits for decisions making process for the management policies of the finished product inventory and shelf replenishment policies for retailers. The RFID technology has also been used very successfully within the warehouse management domain to reduce poor accuracy or inaccuracy of management within the warehouse while managing multiple items (Fan, Chang, Gu, Yi, & Deng, 2014; Fan, Tao, Deng, & Li, 2015).

Moreover, in the past few years, the feasibility and effectiveness of the integration of RFId with lean management techniques has been demonstrated (Chen, Cheng, & Huang, 2013) to produce a drastic reduction in waiting and transport times as well as optimise warehouse operations.

Significant advancements have been made in the field of maintenance by using the ability of RFId to monitor and track technological maintenance and control processes. Some examples of this ability are presented in the following papers: (i) application of RFId for the in-bound operations for air-cargo management systems (Chang, Son, & Oh, 2011); (ii) application of RFID for the management of maintenance for replacement of aircraft parts (Ngai, Cheung, Lam, & Ng, 2014). This last paper and many others focus on pertinent themes such as the aircraft maintenance issues, thereby highlighting the potential use of RFId to reduce increased costs due to the incorrect management of spare parts and inaccuracies in the management of the multiple-item parts subject to usage and technological obsolescence (Fan, Tao, Deng, & Li, 2015).

After the analyse of the literature about the use of the RFId in the industrial context, let us to briefly present some papers about the method that it is possible to use to assess the RFID implementation. One of the more used method is the business process modelling and re-engineering; infact several papers are available in the international literature about these methods since the 2009 so far. In 2009 in the Journal of Food Engineering appeared a paper about the application of the BPR of the supply chains processes related to a food industry using RFID as a possible technology for the re-engineering (Bevilacqua, Ciarapica, & Giacchetta, 2009). In the following year also another paper used the BPM to assess the goodness of an investment in RFId solutions for a Russian automotive project (Becker, Volkov, Weiß, & Winkelmann, 2010). In 2011 the business process analysis methods were used also to assess the possibility to re-engineer the processes of the supply chain of an engineering procurement and construction company globally distributed using always the RFId technology (Jakkhupan, Arch-int, & Li, 2011). Always in the same year also another scientific contribution appeared that was using the business process methods to assess the implementation of an RFId tracking system in a warehouse (Wamba & Chatfield, 2011). The use of this methodology has a continuity in the years until our nowadays, in fact also 2014, 2016 and 2017 it is possible to find papers about the application of the aforementioned methods to the evaluation of the implementation of the RFId systems to the industrial context (Kumar & Rahman, 2014; Ciarapica, Bevilacqua, Mazzuto, & Paciarotti, 2016; Reyes, Li, & Visich, 2016; Cui, Deng, Liu, Zhang, & Xu, 2017).

This brief literature review highlights the growing use and importance of RFId as a technological tool to help with production, logistics and other services related to these two important business areas. The aim of this paper is to present a business process modelling (BPM) method to assess the possibility of implementing an RFId system through a pilot project in the bike warehouse of a small firm, demonstrating the applicability of this kind of methods and technology also to a small firm, not referring them to the big supply chains problems or to the big companies needs.

3. The BPM method

The problems associated with the implementation of an RFId system not only involve the problem of buying these kind of systems but also the problems of operations and economic feasibility (Tzeng, Chen, & Pai, 2008; Fera, Iannone, Mancini, Schiraldi, & Scotti, 2013). The feasibility study is often conducted by comparing the as-is with the to-be of the process involved in the RFId introduction; this comparison can be performed using the business process re-engineering (BPR) approach (Hammer & Champy, 1993; Bevilacqua, Ciarapica, & Marchetti, 2011). The BPR, in general and especially when applied to the RFId implementation problems, is performed through three main steps (Bottani, 2008):

1. documenting the current process
2. defining its future state based on RFID implementation
3. estimating productivity and value performance of processes modified with the RFId

Therefore, it is possible to state that the feasibility assessment can be performed in three main steps: one dedicated to the analysis of the as-is process, one dedicated to the to-be process and one dedicated to the costs and time savings produced by the passage from the as-is to the to-be process. The as-is analysis is generally performed by collecting data about the processes involved in the re-engineering approach; in particular, for our purpose, the main focus was about the time lapsed in the execution of the single steps of the process. The possibility to draw and to measure the time for the execution of the single steps of a more general process is very important because it offers the possibility to better assess the profitability of implementing a new process that can change the 'how' of the process execution. This is followed by collecting the process data and associating with the single process steps, thereby making it possible to start to define new process scenarios that also consider also the presence of the RFId technology and enables changing the process through new procedures, activities and so on (Bottani, Ferretti, Montanari, & Rizzi, 2009). The introduction of the RFId technology can lead to a reduction of the number activities in a process or at least a reduction of the instances where they are still needed. It is also worth noting that the RFId introduction can not only initiate savings but also create new activities that are time-consuming. It would be possible to understand how technology introduction can lead to a significant process change by comparing the new and the old processes, thereby implying the possibility to define a relevant economic change in the execution of the process; this point is assessed in the last part of the method.

For every user or business stakeholders to be able to use the result of a BPM, it is important to clarify all the activities of the process and use standard notations (Business Process Model and Notation, BPMN (OGM, 2011) and a defined performance measurement metrics (Han, Kang, & Song, 2009) where possible, thereby making the choice of the appropriate detail level in representing the process diagram critical. For the purpose of this paper the notations of OGM and the performance metrics defined in Han et al., 2009 (Han, Kang, & Song, 2009) are used.

4. Case study: The warehouse operations for a bike assembly firm

The case study analysed is a company that sells bikes. The bike market is a seasonal market; hence the demand is concentrated over certain months when all the demand needs to be satisfied. In particular, the case study analysed here attempts to answer client requests about making a decision to build or to buy by comparing its production capacity with the external demand. If the demand exceeds its capacity, the buying process starts in parallel with the purchasing process for the components to be assembled directly in the factory. Once the products (produced in house or by a supplier) are ready, they arrive in pallets at a warehouse that is tasked with receiving the pallets, allocating them in the warehouse, loading them in the enterprise resource planning (ERP) software and then prepare the pallets several days later to realize customer orders. The order is generally composed of many kind of bikes. The operators have to sort the different kind of bikes from several pallets to the appropriate one. After the client pallet is prepared, it is ready for the shipment and delivery. In some cases, the products are returned to the company because they contain defects or they are not what the client had ordered.

Now let us to introduce the method used to apply the BPM and to calculate the advantage/disadvantage come from the RFId application. The BPM was applied analysing, preliminarily, the actual status of the warehouse operations and analysing the new processes after a re-design activity. To understand if the operations change could be useful for each activity of the as-is processes, it was measured with the chronometer the total time needed to execute each activity; this time was considered for each part directly where the imputation of time was direct, while where the imputation was indirect, due to the fact that the time for the activity was devoted to more than one part, the time measured was divided by the number of bikes object of attention in the specific activity. For the time calculation, after the re-design, it was considered the original time minus the time of the operations “no more needed” (so cancelled from the process) and minus an estimated time saving that was assessed, applying a conservative coefficient of reduction of 30%, with the help of the management responsible of the warehouse. Considering these variations it was possible to estimate a new cycle time for the logistics operations for each bike and it was possible to consider an improvement of the warehouse capacity and goods rotation.

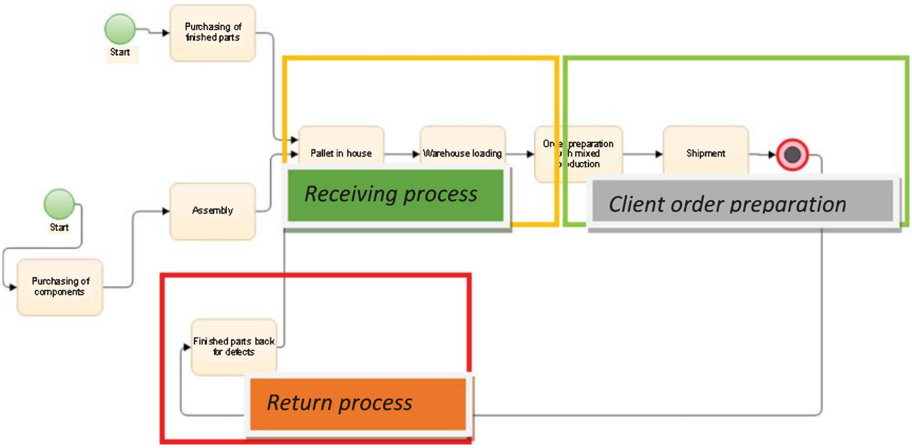

Fig. 1. General process of the case study.

Therefore, except for the production issues, it is possible to distinguish three main phases (represented in Fig. 1) in the general process: (i) the receiving process, (ii) the client order preparation and (iii) the return of defective products.

It is quite easy to imagine that the traceability offered by the RFId can help a system such as this one in sorting the defective product base on whether it is produced in house or not, however, the possible improvements are not limited to this but also to the possibility of tracing and automating the receiving activities in terms of physical controls (number of bikes for pallet, per kind, etc.), the handling activities and the order preparation activities. As mentioned previously, it is possible just from the BPM of the as-is to feel what improvements could be needed; in fact, this feeling is proved to exist.

After that the general process is drawn; the as-is phase continues with the drawing of the detailed process. This paper exclusively considers the activities from the ‘pallet in house’ process as they are recognised to be more sensitive to the implementation of the RFId technology.

Firstly, it describes the process of storing the identical goods received from the assembly shop and from the suppliers. Figure 2 describes the detailed activities that are needed to execute the receiving operations in the warehouse as it is now. First, it assigns an operator to the truck for pallet unloading operations, receives a task and simultaneously prints an unloading list note through the tracking number of the received pallet or by referring to the pallet tracking number. Second, there is the effective unloading of the pallet and this activity is followed by pallet controlling in terms of the number of bikes received and their visual quality check after which there is a formal control of correspondence between the unloading list note executed and the purchasing order. If this check is not ok, it leads to three types of actions (not represented in the chart for space reasons): (i) a return to the supplier for an integration of the quantity when the bikes are less than ordered, (ii) a return of goods if the bikes are more than ordered and, last, (iii) a return of goods to the supplier if the products contain fabrication defects. However, if this check is ok, the bikes are approved so that they

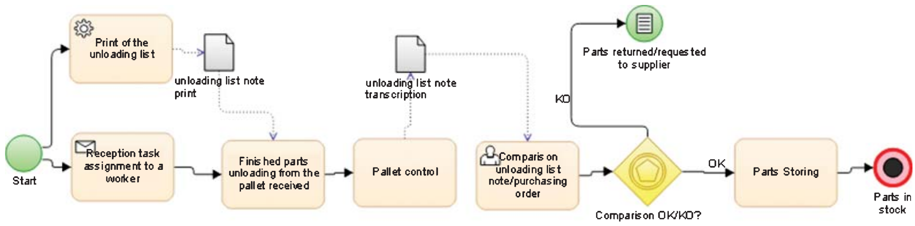

Fig. 2. The goods receiving process.

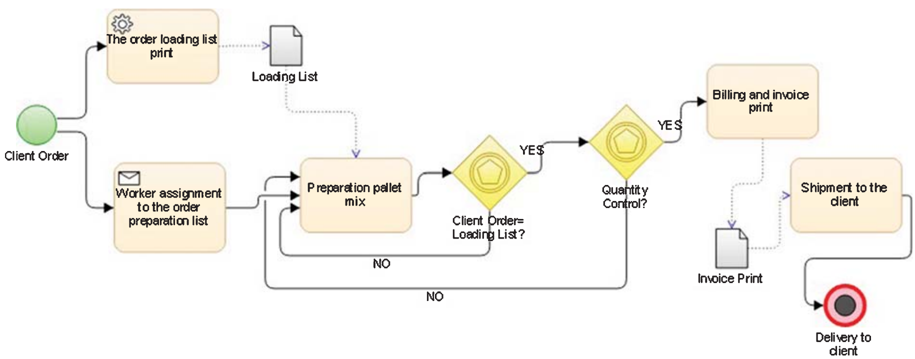

Fig. 3. Client order preparation process.

can enter the warehouse where they are loaded physically. They are also entered into the ERP.

After the part is stored in the warehouse, it is possible to satisfy a client order by following the activities illustrated in Fig. 3. The process starts with a client order that generates the involvement of a worker who is assigned the loading list picking activity and simultaneously also receives a printed document of the loading list details for the client. After the tasks are assigned, the worker begins preparing the pallet for the client; after this is done, the worker checks whether the loading list matches with the client order, and then controls whether the number of bikes loaded on the pallet is equal to the number of bikes reported in the order. The worker then approves the billing and invoice printing to the administrative office so that the order can be shipped. Delivery to the client concludes this process.

When the client receives the shipment of the goods, the goods are checked for quality; if any problems arise, the pallet or some of the bikes contained in the pallets (depending on the quality assurance in the receiving goods policy of the clients) can be returned to the seller. This initiates a return back process (see Fig. 4).

So, let us to explain in detail what happens in the processes as they are. If the goods received from the client are not compliant with the issued order, the goods are returned back to the supplier. A return goods note is printed and given to the worker who receives the task to analyse the non-compliance. The control begins and it can lead to three kind of exits: (i) the possibility to resell the product or substitute it with another similar or

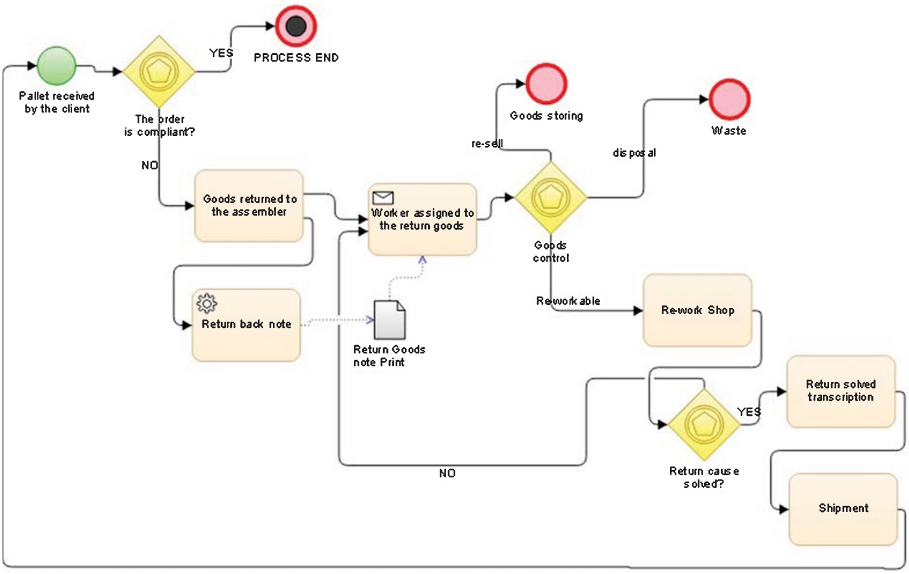

Fig. 4. The return back process.

identical product, but only at the outlet; (ii) dispose off the product as waste; (iii) the part is re-workable, so it is passed on to the re-work shop and if the problem is solved, the worker assigned at the beginning of this process will fill in the return solved note so that the shipment to the client can be initiated. The process is closed in loop with the goods received once again received by the client.

The as-is analysis is completed with the time description of the single activities of the sub-processes shown in Figs. 2, 3 and 4. The completion time for each activity is recorded and reported, as shown in Table 1.

At this point, an activity of re-designing the process was executed; some activities of the processes detailed before were signed off as ‘no longer needed’ and some others experienced an improvement in terms of time savings. In Table 2 the activities no longer needed are reported and indicated with an ‘X’. The new processes are drawn and compared to the old ones to understand better where the improvements were done.

The basic RFId architecture to be implemented in the firm warehouse is constituted by the application of active RFId to each product and each pallet (to create a bi-univocal relation between the parts transferred and the pallet) and the presence of two portals for the incoming and out coming goods in two separate locations of the warehouse.

A quick analysis of the contents of Table 2 shows that the activities that are deleted are the ones connected with the ‘bureaucratic attitude’ of the process execution, i.e. the printings, the transcription, the quantity controls and so on. In fact, the introduction of this kind of technology is strongly connected with the elimination of the muda activities, i.e. the activities that do not add any significant value to the final product or service.

Table 1
The execution time of the activities

Process	Activity	Time [minutes]
Goods Receiving Process	Reception task assignment to a worker	8
	Print of the unloading list	2
	Finished bikes unloading from the pallet received	120
	Pallet Control	5
	Comparison of the unloading list with the purchasing order	8
	Bikes storing	32
	Total	175
Client order preparation	Order Preparation task assignment to a worker	8
	Print of the loading list	2
	Preparation pallet mix	80
	Comparison of the loading list with the client order	18
	Quantity Check	12
	Billing - Invoice Print	3
	Shipment to the client	2
	Total	125
Return back for defects	Return back task assignment to a worker	8
	Print of the return note	2
	Goods control	13
	Rework shop	17
	Return solved control	6
	Return solved transcription	2
	Shipment to the client	2
	Total	50

Table 2
The activities no longer needed

Process	Activity	Activity no more needed
Goods Receiving Process	Reception task assignment to a worker	
	Print of the unloading list	X
	Finished bikes unloading from the pallet received	
	Pallet Control	X
	Comparison of the unloading list with the purchasing order	X
	Bikes storing	
Client order preparation	Order Preparation task assignment to a worker	
	Print of the loading list	X
	Preparation pallet mix	
	Comparison of the loading list with the client order	X
	Quantity Check	X
	Billing - Invoice Print	X
	Shipment to the client	
Return back for defects	Return back task assignment to a worker	
	Print of the return note	X
	Goods control	
	Rework shop	
	Return solved control	
	Return solved transcription	X
	Shipment to the client	

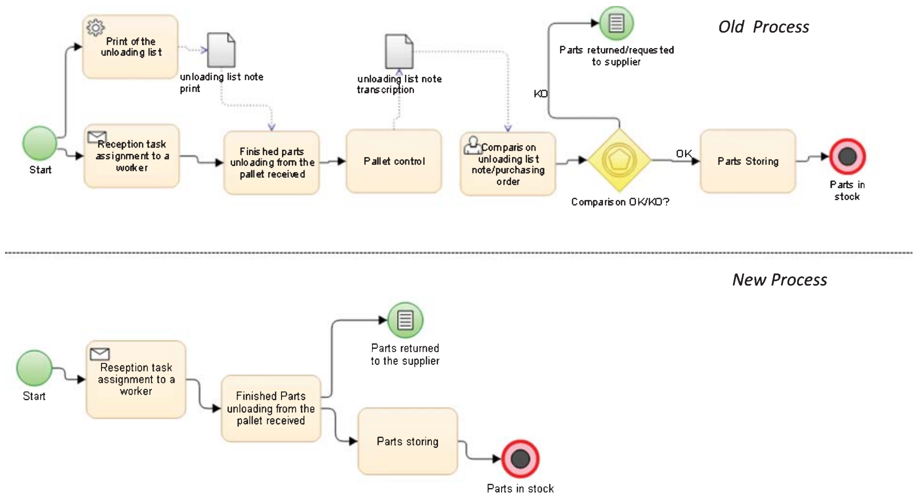

Fig. 5. The old and the new processes for receiving bikes.

Table 3
Time savings for the receiving process

Process	Activity	Time [minutes]	New Time [minutes]
Bikes Receiving Process	Reception task assignment to a worker	8	1
	Print of the unloading list	2	0
	Finished bikes unloading from the pallet received	120	87
	Pallet Control	5	0
	Comparison of the unloading list with the purchasing order	8	0
	Bikes storing	32	17
	Total	175	105

The first process to be analysed is the receiving one. All the activities associated with the name ‘bureaucratic’ are cancelled and the activities related to the handling of the bikes are reduced in time because the operations will be helped by the possibility of considering implementing innovations also for the reading system infrastructure to avoid time wasting during identification, control and errors in these last two tasks. These improvements make it possible to derive an improvement in terms of lean shape of the process, as shown in Fig. 5, and a significant reduction in the execution time of the first process. It is worth noting that the time saved is estimated by calculating the trivial operations no longer needed in the activities. This task was performed for this study for each activity where it is possible to identify a way to save time.

Table 3 reports the time savings of up to 40% that are derived from implementing this technology.

Now we analyse the second process (Fig. 6), i.e. pallet preparation in response to the client demand. In this process, the impact of the introduction of RFId technology is more evident than in the previous process. This is attributed to the fact that the formal

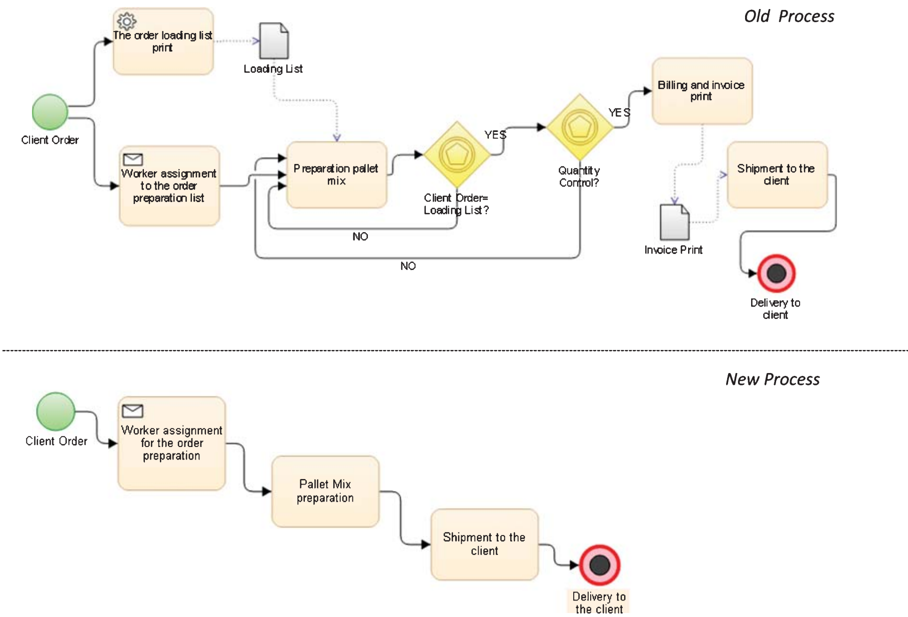

Fig. 6. The old and new processes for order preparation.

Table 4
Time savings for the order preparation process

	Activity	Time [minutes]	New Time [minutes]
Client order preparation	Order Preparation task assignment to a worker	8	1
	Print of the loading list	2	0
	Preparation pallet mix	80	50
	Comparison of the loading list with the client order	18	0
	Quantity Check	12	0
	Billing - Invoice Print	3	0
	Shipment to the client	2	2
	Total	125	53

and quantity control activities are performed by the RFId portal reader and no longer executed by a human; the same can be said for the operations related to the billing and invoice preparation.

As for the previous process, it is possible to realise a significant reduction in the complexity of the processes to make the overall process leaner. An analysis of the possible time savings shows a process improvement of 57% (see Table 4) since all the activities connected to the control of the pallet to be sent to the client are no longer present and the pallet preparation operations are reduced in duration due to the possibility of integration of the automatic identification technology with readers onboard the trolleys and other helping elements of the operations too helping achieve this reduction such as the direct assignment of a worker on receiving a client order.

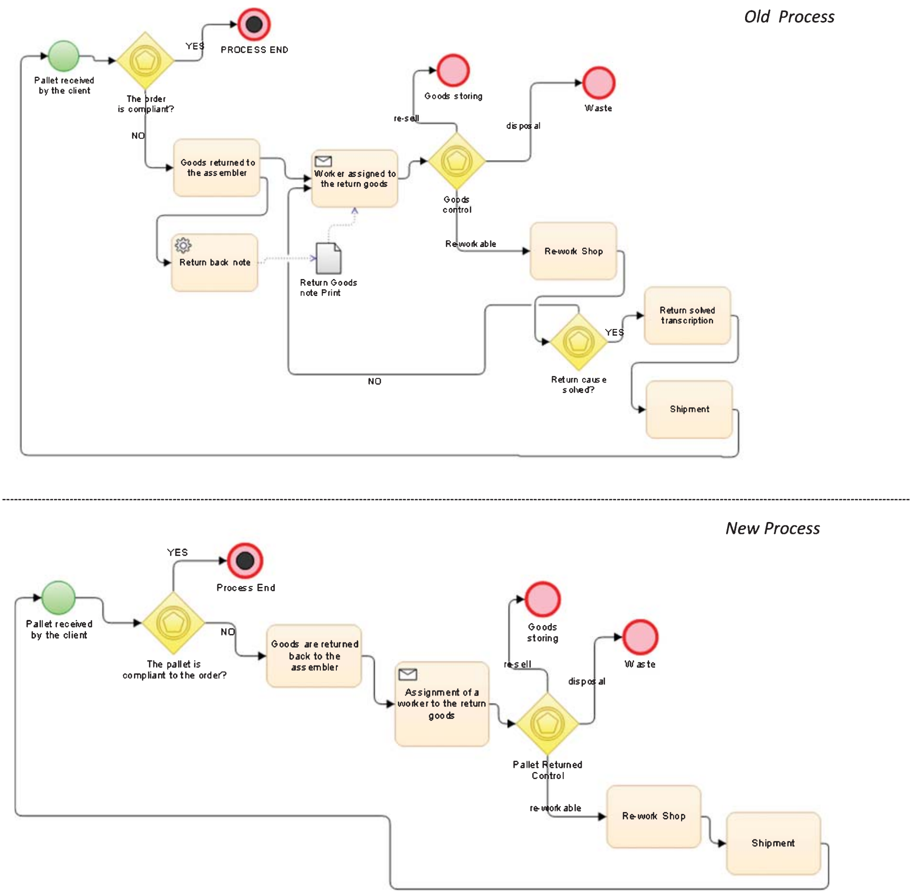

Fig. 7. The Old and new return back processes.

For the last sub-process (Fig. 7), i.e. the return of the defective bikes from the client, activity reduction is observed at the beginning and at the end of the process, thanks to the elimination of the ‘bureaucratic’ activities, thereby achieving a very lean process.

The time savings derived from implementing the RFId technology are because of the possibility to eliminate the preliminary and the end ‘bureaucratic’ activities and the possibility of reducing the time needed for the control of the returned part. This reduction is because of the possibility of the complete part history being available to the worker by simply reading the information contained in the RFId tag of the part. The total time saved, of about 38%, is once again significant.

Once the time savings generated by implementing the RFId systems have been presented, the assessment related to the productivity and economic return of the RFId implementation will be presented.

Because a general reduction of the time for executing the logistic operations was observed due to the introduction of RFId, it would also be possible to increase the han-

Table 5
Time savings for the return back process

	Activity	Time [minutes]	New Time [minutes]
Return back for defects	Return back task assignment to a worker	8	1
	Print of the return note	2	0
	Goods control	13	5
	Rework shop	17	17
	Return solved control	6	6
	Return solved transcription	2	0
	Shipment to the client	2	2
	Total	50	31

Table 6
Productivity improvements

Parameter	Before RFId	After RFId
Cycle time [min/bike]	0.75	0.57
Handling capacity [bikes/yr]	140000	180000

dling capacity of the warehouse. Although this step involves only a rough calculation about the variation of the warehouse capacity, nevertheless, it is important because it gives us the scope of improvement that can be achieved.

For a system capacity of 140000 bikes/yr and taking into account a 5-day working week with 8-hour shifts, the cycle time for handling a part is 0.75 min/bike. RFId implementation allows time saving of 48%, that it is the mean value between the time savings of the first two sub-processes, even if no defected part will be present. Being conservative in our assessment led us to consider a safety coefficient of 2 for calculating the convenience (this coefficient will give remarkable robustness to the assessment); therefore, the actual time saving will be half of the calculated saving, i.e. 24%. This would imply a part handling time of 0.57 min/bike, i.e. 180000 bikes/yr; a safety coefficient of 2 will allow for 40000 bikes more to be handled per year.

Moreover, it is worth noting that the application of these new systems makes it possible to achieve an interesting number of rotations of the warehouse that assure the company a safer financial behaviour. The warehouse rotations (calculated as the ratio between the handling capacity and the maximum volume that is possible to stock in the warehouse, i.e. 45000 bikes) will pass from 3 rot/yr to almost 4 rot/yr, thereby significantly reducing the financial needs of the company and making it possible to satisfy more demand.

Once the productivity improvement was demonstrated with a very conservative approach, this was be followed by the demonstration of the economic convenience of this solution. This was done by collecting the data about the composition of the current demand and the cost structure of the company being analysed. Investment data too was collected.

The implementation of the RFId technology requires both an investment and an increase in the production cost; the first due to the implementation of the tag reading

Table 7
Unit costs for the investment

Item to be bought	Cost
RFId tag [€/tag]	0.08–0.12
Portal for RFId reading [€/piece]	1700–2500
Antennas and controller [€/piece]	500–600
RFId reader for trolleys [€/piece]	1200–1500

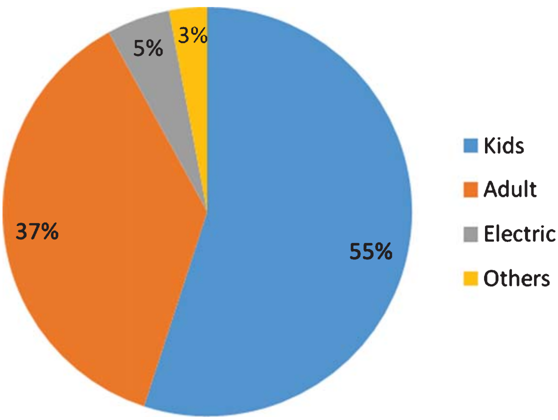

Fig. 8. Contribution of products to the total demand.

system in the production area and the second due to the fact that the cost for the RFId tag too needs to be considered for each bike produced. The unit values for purchasing these of technologies are referred to the market for buying the volumes declared earlier (see Table 7).

In the as-is situation, the demand of the company is constituted by four main kinds of bikes, i.e. the ‘kids’, the ‘adult’, the ‘electric’ and the ‘others’ which refer to many kinds of products. Figure 8 represents the percentage of the contribution of each type of bike to the total demand.

This product distribution will be considered for the next calculation to redistribute the amount of revenues with the new capacity level.

Table 8 reports the as-is economic data as follows: the revenues for each type of bikes are 42 €/bike (kids), 53 €/bike (adult), 126 €/bike (electric), 260 €/bike (others); the direct workforce cost (14 full time and 2 part time) is 440000 €/yr; the raw-materials per piece are 25.71 €/bike; the logistic costs are 4.57 €/bike; the fixed cost of production (machines and instruments mortgage and excluding workforce) is €989000; the overheads are 450000 €/yr; and the errors in the delivery of products to the client have a weight of 0.23 €/part. Therefore, it is possible to calculate a company profit of 150000 €/yr as analysed in the actual situation.

Implementing the RFId systems could result in an increase in the fixed cost for production by the increasing the reading systems mortgages and by increasing the

Table 8
Economic parameters of the case study

Economic parameter	Value
Revenue for ‘kids’ [€/bike]	35
Revenue for ‘adult’ [€/bike]	45
Revenue for ‘electric’ [€/bike]	65
Revenue for ‘others’ [€/bike]	110
Direct workforce cost [€]	440000
Raw Material cost [€/bike]	25.71
Logistic cost [€/bike]	4.57
Production fixed cost [€]	989000
Overheads cost [€]	450000
Delivery errors cost [€/bike]	0.23

Table 9
Economic comparison between the as-is and to-be solution

Economic parameter	Total values [€]	New Total values [€]
Revenue for ‘kids’	3‘ 272‘ 500	4‘ 042‘ 500
Revenue for ‘adult’	2‘ 830‘ 500	3‘ 496‘ 500
Revenue for ‘electric’	552‘ 500	682‘ 500
Revenue for ‘others’	561‘ 000	693‘ 000
Total Revenues	7‘ 216‘ 500	8‘ 914‘ 500
Direct workforce cost	440‘ 000	440‘ 000
Raw Material cost and tag	4‘ 370‘ 700	5‘ 422‘ 200
Logistic cost	776‘ 900	959‘ 700
Production fixed cost	989‘ 000	996‘ 000
Overheads cost	450‘ 000	450‘ 000
Delivery errors cost	39‘ 100	0
Total Cost	7‘ 065’ 700	8‘ 267’ 900
Profits	150‘ 800	646‘ 600

variable cost of production due to purchase of the tags; nevertheless, this will result in an increased handling and selling capacities. For our study, we considered the increase of the sales to 180000 bikes/yr; the 40000 additional bikes will be divided between the different bikes categories as per the increased contribution to the total demand from a revenue of 7.2 million Euro to almost 9 million Euro as reported in Fig. 8, while the line of the raw materials will have an increase equal to the cost of tag per bike (=0.11 €/bike), the fixed costs of production will increase by 7000 €/yr due to the 5-year mortgage for the RFId investment of €35000 in the reading system, while the direct workforce cost will remain the same since the number of workers will remain the same, giving sense to the efficiency benefit come from the RFId implementation. All these modifications and analysis are clearly stated Table 9.

A financial analysis was performed to complete the assessment of the proposed technical solution by keeping the same number of direct workers, eliminating the errors by 30% (constant throughout the project development time span) and increasing the capacity by 200000 units per year. Other relevant hypotheses are made about the following economic items:

Table 10
Cash flow analysis

Year	1	2	3	4	5
Number of products handled	140000	160000	180000	200000	200000
Systems acquisition	–€30.000,00	0	0	0	0
Tags buying	–€21.000,00	–€24.000,00	–€25.200,00	–€28.000,00	–€26.000,00
Maintenance of the system	–€1.500,00	–€1.500,00	–€1.800,00	–€1.800,00	–€2.100,00
Errors avoided	€9.600,00	€10.971,43	€12.342,86	€13.714,29	€13.714,29
Profits Increase	€–	€21.428,57	€42.857,14	€64.285,71	€64.285,71
Year cash flow	–€42.900,00	€6.900,00	€28.200,00	€48.200,00	€49.900,00
Cumulated cash flow	–€42.900,00	–€36.000,00	–€7.800,00	€40.400,00	€90.300,00

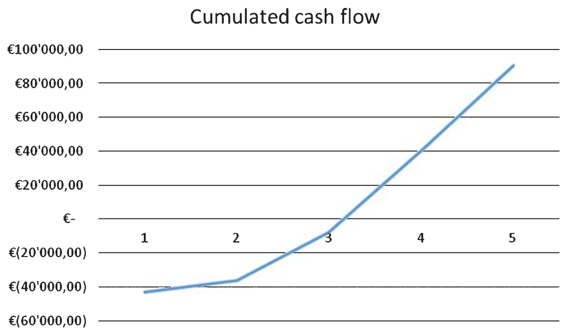

Fig. 9. Payback period.

- the cost of tags during the project development time span will be decreased by 0.01 €/tag every 2 years;
- the maintenance cost, calculated at the beginning as the 5% of the equity invested, will be increased by 1% every two years;
- Profits will be calculated in a conservative way by maintaining a constant profit per unit of 1.07 €/bike.

If these hypotheses were applied, it is possible to calculate the cash flow for five years with no other investment towards warehouse expansion or buying; in fact, the increased capacity is realised thanks to the increased stock rotation (i.e. from 2.8 to 4.0 rotations per year).

As shown in the last row of Table 10 and as illustrated in Fig. 9, the payback period (PBP) is equal to 3.1 years.

Other interesting financial results related to the investment pertain to the internal return rate (IRR) of 14%, the net present value greater than €22000 and a 147% return on the equity in five years. The main financial results are tabulated in Table 11.

Therefore, understanding the application of the BPM method allows for the demonstration of the managerial, economic and the financial convenience.

Table 11
Financial indices of the investment

PBP	3,1 years
IRR	14%
NPV	€22.052,81
ROE	147%

5. Conclusions

In recent years, more attention has been paid to improving the existing processes with new technologies, thereby realizing a sensible advancement of the performances.

This objective can be achieved using many managerial techniques such as business process modelling. This paper presents an application of the well-known BPM method to an implementation of the RFId technology to a warehouse system that handles products produced by a bike assembly shop, part of these bikes are assembled in the shop and a significant part of the total number are bought by external assemblers.

Through the BPM method, it was possible to demonstrate the feasibility of the project in terms of managerial facets first and then from an economic and financial point of view.

The BPM method demonstrates itself to be an incredible tool to validate and analyse management change and IT technology implementation that also have impacts on the process management.

The use of BPM allows to assess the effectiveness of any technical or managerial solution, so this paper demonstrates one more time that is a very useful way to assess any organizational improvement project. Moreover this paper helps the practitioner and researchers of the industrial context for the implementation of this method in the logistics of the bikes that could come from a mixed source, i.e. from internal assembly shop or from the suppliers, and especially for a small firm. In particular the practitioner could have a good help in the method to re-design the process when the RFId is used and in the individuation of the index to be analysed to assess the effectiveness of the solution proposed. Comparing this work to the previous ones on this topic, i.e. on the application of the BPM to an RFId solution for a small firm's warehouse, it is possible to recognize the possibility to enlarge the field of knowledge about the kind of the processes that is possible to analyse and assess using the BPM.

The RFId system revealed a significant increase of the bikes handling, as observed by the number of bikes to be handled increasing from 140000 bikes/yr to 200000 bikes/yr and by the increased stock rotation index from 2.8 to 5.0.

The introduction of these systems could lead to the improvement of management systems, especially if the possibility of making the processes leaner is considered (sensible reduction of the logistic lead-time for the main phases of the general process) and errors in dispatching the products to the client are avoided. In particular, thanks to the BPM application a possible reduction of 46% in the logistics lead-time and a very easily achievable reduction of the 30% for the dispatching errors was demonstrated.

The proposed solution was also tested to evaluate the economic and financial convenience in accordance with the BPM general method presented. The results are very encouraging, revealing a PBP of 3 years, an IRR of 14%, an NPV of €22000 and an ROE of more than 140% in five years. It is worth noting that these results were obtained by considering a safety coefficient of 2 in the calculation of time improvement due to RFId implementation, i.e. all the possible time reductions were divided by 2.

It is possible, therefore, to conclude that the BPM has demonstrated its effectiveness in process analysis and in the specific case analysed, it also demonstrated the effectiveness and the efficiency that can be achieved by applying the RFId system in a bike warehouse that handles products produced and assembled internally or received from external sub-contractors.

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