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A financial viability analysis of a RFID system in the microcomputer supply chain

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RESUMO O propósito deste artigo é descrever uma metodologia para a avaliação da viabilidade econômica de aplicações de identificação por rádio frequência (RFID) e identificar as contribuições de tal tecnologia. O impacto da tecnologia RFID foi avaliado utilizando-se de uma análise de retorno de investimento. Uma pesquisa extensa de 6 meses foi realizada na empresa estudada, obtendo-se dados com gerentes de logística e da cadeia de suprimentos, para validar os processos e coletar os dados necessários. A tecnologia FRID possibilita controle de estoques, rastreamento de peças e satisfação dos clientes. A viabilidade do uso da tecnologia foi confirmada. Dentre os benefícios obtidos incluem-se redução de um trabalhador no time de estoque, redução no custo de substituir um componente, e redução no custo com componentes defeituosos. Este é um dos poucos artigos que visa quantificar a contribuição da tecnologia RFID.

Palavras-chave Engenharia Econômica. RFID. Identificação Por Rádio Frequência. Análise De Viabilidade Financeira. Taxa Interna De Retorno. Automação De Processos.

ABSTRACT *The purpose of this study is to describe a methodology to assess the financial viability of radio frequency identification (RFID) applications and the main contributions of this technology. The impact of RFID technology on supply chain processes was assessed using an Internal Rate of Return analysis. An extensive, six-month discussion and refinement process with the logistics and supply chain managers of the company under study was conducted to validate the procedure and to collect the necessary data. Such technology enables inventory control, tracking of parts/products and customer satisfaction. The viability of using RFID technology for inventory control and product tracking was confirmed. Among the benefits obtained: the reduction of one worker from the inventory team, reduction in the costs for replacing a component and reduction in the costs incurred with defective components were found. This is one of the few attempts to quantify RFDI technology's contribution.*

Keywords *Economic Engineering. RFID. Radio Frequency Identification. Financial Viability Analysis. Internal Rate Of Return. Process Automation.*

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1. INTRODUCTION

RFID systems are rapidly replacing Universal Product Codes (barcodes) (STAMBAUGH; CARPENTER, 2009). According to Soares *et al*. (2008), inventories are the sectors that can potentially benefit the most with RFID technology. The benefits with its implementation go far beyond the mere change of the technology of automation of data capture. Its main objective is to increase the integration of the entire logistics chain, providing tools that enable tracking and control of the products that circulate in the chain (WAMBA; CHATFIELD, 2009).

The literature on financial analysis of RFID systems is very scarce. Some exceptions are Miragliotta *et al*. (2009) which focuses on activity based cost and on benefits for both the manufacturer and retailer in the fast moving consumer goods industry, and Kinley (2004), which reviews the RFID Return On Investment (ROI) for a specific application in a semiconductor environment. Balocco *et al*. (2011) developed an analytical profitability assessment model to evaluate the barriers preventing RFID technology diffusion in the fast moving consumer goods industry. Jones *et al*. (2007) demonstrated the cost effectiveness of using a RFID system to track calibrated tools throughout a production facility. Other studies in different environments are therefore needed.

This case study initiates in 2008, motivated by research carried out in many microcomputer assembly companies of the Polo de Informática de Ilhéus/BA. This group of companies is comprised of 20 assemblers of microcomputers. The raw materials are practically all imported from Asian suppliers (China, South Korea and Thailand, among others) and the companies supply the Brazilian market, specially the north and northeast regions of the country.

The difficulties faced by these companies in managing their inventories of raw materials and finished products, even using barcodes for quick identification during production, were the motivational factor behind this study.

This study has the objective of evaluating the financial viability of adoption of an RFID system in a microcomputer assembly company, situated in the Polo de Informática de Ilhéus/BA. The system aims an adequate return on investment to modernize the company with an up-to-date solution. It is noteworthy that no other company in the region possesses this technology.

This is an empirical study based on non-structured interviews with the company´s managers and workers from the inventory team. Other sources of data include company documents and reports, which were the source of almost all the financial data used in the study. All the necessary data for the analysis were selected, and the internal rate of return and net present value of the project were then calculated, following the methodology presented in Abreu *et al*. (2005). The results of the implementation of the new technology were positive; among the benefits obtained were reduction of one worker from the inventory team, reduction in the costs of substituting a component, and reduction in the costs incurred with defective components.

The paper is organized as follows: Section 2 presents the literature review. Section 3 presents the financial viability analysis, which includes the calculation of the Internal Rate of Return (IRR) and Net Present Value (NPV) for the RFID investment. Section 4 presents the results, and section 5 presents the conclusions.

2. LITERATURE REVIEW

2.1. RFID Technology and Process Improvement

RFID solutions enable you to advance your business to a new level of efficiency by providing greater visibility into your inventory as it moves across the supply chain. With real-time tracking information, you'll always know where your critical business assets are. RFID systems can be used just about anywhere, from clothing tags to missiles to pet tags to food -- anywhere that a unique identification system is needed.

According to Whang (2010), Radio Frequency Identification (RFID) has been hailed as a major innovation to enhance the efficiency of inventory management (GAUKLER *et al*., 2004) and supply chain management (HEINRICH, 2005). The basic premise of RFID is that a radio frequency reader can read as many as 200 tags in a second without the line-of-sight requirement. Near-real--time tracking and tracing capabilities, together with item-level identification through EPC (Electronic Product Code) standard, would allow a host of new chances of improvements in inventory management (WHANG, 2010). Among these improvements is the increased efficiency by making products available at the right time and in the right place, with lower operational cost. As a result, numerous manufacturing plants are adopting RFID technology for product tracking purposes, especially within sectors that move multiple parts through their facilities each day (CHOW *et al*., 2006; KACH; BORZABAD, 2011).

To be worldwide competitive, factory systems must be flexible, collaborative, and responsive to meet the changing needs of customers so that quality products and services can be delivered in a timely manner. System flexibility and responsiveness are mainly characterized through the capability of quick system adaptation to the fluctuations in product demand and manufacturing functionality. The delivery of the right data to the right user at the right time through integrated factory systems is the key to entail system flexibility and responsiveness. However, there is a lack of well-established standard approach to the design and development of factory integration projects (QIU; XU, 2004; QIU, 2007). As manufacturing systems are full of concurrent, asynchronous, and interactive control issues, pertinent information on parts should be available to the users (e.g., machine controllers, operators, inspectors, etc.) at the point-of-need to ensure that parts are properly processed across the shop floors of the company.

No matter where parts are on the supply chain or within a factory, all the parts should have their identities. The current approaches typically use different proprietary mechanisms implemented by individual players on the supply chain. As a result, significant efforts will be required for integrating the information systems throughout the supply chain (factories) due to the lack of a standard approach to exchanging pertinent information on a given part. Therefore, there is a need for an open-system mechanism to identify all the parts on the supply chain (QIU, 2007). To have individual parts identifiable, an identity is needed for each part. A typical standard identification scheme for types of products is the Universal Product Code (UPC) or so-called "barcode". A barcode is created using a 12-digit numeric sequence scheme. Barcodes require "line-of-sight";

they can be scanned only when a scanner can "see" them. If one barcode is ripped, soiled or falls off, the barcode cannot be scanned (QIU, 2007; MIT, 2003). With the advances of semiconductor technologies, radio frequency identification (RFID) as a promising identification technology has advanced substantially recently. An RFID tag can hold much richer information compared to a barcode. More importantly, an RFID tag can be read-only (i.e., passive tags) or read–write (i.e., active tags). The data capability in light of volume is unceasingly increasing, while the cost of an RFID tag continues to drop (QIU, 2007; MCFARLANE, 2003). It is the data capacity of an RFID tag that creates an opportunity of identifying any single item in the physical world, which makes possible a tagged product uniquely identifiable throughout the supply chain (QIU, 2007).

The RFID technology has its origins in the Second World War, with the IFF (Identification Friend-or-Foe) identification system, which allowed Allied units to distinguish between Allied and enemy aircrafts (HUNT *et al*., 2007). The RFID technology works on the same basic principle. A signal is sent to a tag, which is activated and reflects back the signal (passive system) or transmits its own signal (active system).

RFID technologies offer several contributions to supply chain and inventory management through their advanced properties such as unique identification of products, easiness of communication and real-time information (SARAC *et al*., 2010; SAYGIN *et al*., 2007; MICHAEL; MCCATHIE, 2005). The progress through RFID can be observed in different types of supply chains such as warehouse management, transportation management, production scheduling, order management, inventory management and asset management systems (BANKS *et al*., 2007). RFID can improve the traceability of products and the visibility throughout the entire supply chain, and also can make reliable and speed up operational processes such as tracking, shipping, checkout and counting processes, which leads to improved inventory flows and more accurate information (CHOW *et al*., 2006; TAJIMA, 2007; SARAC *et al*., 2010). Companies integrate and store the more accurate data obtained through RFID technologies in their information technology systems for better supply chain planning and management (WHITAKER *et al*., 2007). There is thus a strong link between IT applications and RFID technologies. Through these numerous benefits, RFID technologies can provide cost reduction, increased revenue, process improvement, service quality, etc. Banks *et al*. (2007) show a list of general quantitative and qualitative key factors for RFID implementations. However, the objective of RFID implementation is not just to improve current systems. Reorganizing processes using this new technology can also lead to large gains in the overall supply chain effectiveness (AGARWAL, 2001; LANGER *et al*., 2007; MCFARLANE *et al*., 2003; SARAC *et al*., 2010). Bottani and Rizzi (2008) indicate that reengineering models increase possible benefits gained through RFID for all processes of distribution centers and retailers. Dutta *et al*. (2007) conclude that RFID integration through new business architectures provides more benefits than technology integration in current business processes.

According to Pinheiro (2006), the considerable advances of RFID technology are undeniable. However, many challenges remain in order to enable its widespread use. These challenges can be perceived by the analysis of applications for the RFID gadgets. For some applications, the technology is reasonably consolidated, while for others there is still a need of new gadgets, security protocols and reductions in the price of tags.

In this section, a literature review is presented with a list of advantages and disadvantages of RFID technology. Such factors were taken into consideration when the company decided to implement the RFID technology.

2.2. Advantages of the use of RFID technology

In a multitude of industrial contexts, implementing RFID technology has shown to improve operations, supply chain and logistical systems by reducing forecasting errors and increasing delivery times (DUTTA *et al*., 2007, KACH; BORZABAD, 2011). The use of RFID technology seems particularly useful within fast moving consumer goods markets, since it allows for real-time visibility of the supply chain (BOTTANI *et al*., 2010). Higher material transparency within organizational systems allows for more accurate forecasting, effectively reducing any inefficiencies that may exist within the supply chain (DELEN *et al*., 2007, KACH; BORZABAD, 2011).

RFID can also be beneficial in managing supply chains. Relying on an increasingly large number of suppliers can make the information flow across all parties difficult. RFID tags and the technology behind them allow for rapid automated item identification without the need of a physical operator, increasing inventory allocation efficiencies. Through the provision of real-time data, RFID technology helps in systematically reducing information gaps across the supply chain (ATTARAN, 2007; GAUKLER *et al*., 2007, KACH; BORZABAD, 2011).

2.3. Disadvantages of the use of RFID technology

RFID technology does not guarantee improved processes across all functions of the supply chain (WU *et al*., 2006). Just like any technology, RFID has downsides and risks (KHARIF, 2005; TAGHABONI-DUTTA; VELTHOUSE, 2006). To begin with, there are costs and capital requirements for implementing the physical technology and software needed for RFID (USTUNDAG; TANYAS, 2009). Justifying the startup costs may be a prohibitive barrier for implementing RFID technology (KACH; BORZABAD, 2011). Second, there are cases that suggest how RFID may not be so effective and other cases where the implementation of the system was not successful (KHARIF, 2005). Additionally, lack of timing and technology coordination between suppliers when implementing RFID practices can create problems across the supply streams (WHANG, 2010). When to implement RFID technology is an important question facing many practitioners and researchers alike (KACH; BORZABAD, 2011).

2.4. Internal rate of return

According to Woiler and Mathias (2008), the study on financial viability of projects, in any area, is of vital importance to enable the decision-making process. This occurs not only while analyzing and selecting the opportunities that are more convenient, but also while avoiding improper or badly dimensioned investments. The decisions taken in the phase of financial viability analysis will influence the entire lifetime of the project and, depending on its size, will also influence the financial health of the company.

According to Buarque (1984), the most frequently used methods for financial viability analysis are the analysis of cost/benefit (with financial restatement), the Net Present Value (NPV) and the Internal Rate of Return (IRR), all of these based on Discounted Cash Flow (DCF). This study has the objective of bringing the invested values to their present values, and to evaluate the financial viability analysis of the RFID system, calculating the NPV and IRR.

We present below a short summary of the methodology used to calculate the Internal Rate of Return (Abreu *et al*., 2005).

Given a collection of pairs (time, cash flow) involved in a project, the internal rate of return follows from the net present value as a function of the rate of return. A rate of return for which this function is zero is an internal rate of return.

Given the (period, cash flow) pairs (n, C_n) where n is a positive integer, the total number of periods N, and the net present value NPV, the internal rate of return is given by r in the equation (1).

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n} = 0 \quad (1)$$

The period is usually given in years, but the calculation may be made simpler if r is calculated using the period in which the majority of the problem is defined (e.g., using months if most of the cash flows occur at monthly intervals) and converted to a yearly period thereafter.

Any fixed time can be used in place of the present (e.g., the end of one interval of an annuity); the value obtained is zero if and only if the NPV is zero.

In the case that the cash flows are random variables, such as in the case of a life annuity, the expected values are put into the above formula.

It is not possible to solve the equation with the usual method, because often the value cannot be found analytically. In this case, numerical methods or graphical methods must be used.

According to Abreu *et al*. (2005), Return Rate (r) is given by the equation (2).

$$r = (P/a)*Kd + (Pl/a)*Ke \quad (2)$$

Where: P – Money Lended; Pl – Personal Investment; Kd – Financing Rate; Ke – Cost of Capital; and a – Total Investment, Asset.

The asset will be the sum of investment and necessity of working capital for the initial year. At the end of the period of utilization of the equipments, they have a residual value. The Market Residual Value (MRV) is the value obtained with the equipments in the market. The Residual Accounting Value (RAV) is the value left to be depreciated or that can still be accounted for. A tax is levied over the MRV value (CAVALCANTE, 2008).

According to Abreu *et al*. (2005), the Cash Flow is the sum of the Operational Cash Flow, the Net Capital Expenses and the Working Capital Variation. Then the Return Rate (r) brings the Cash Flow to its present value, resulting in the Discounted Cash Flow.

By summing up the discounted Cash Flows, the Net Present Value is obtained. With these values it is easy to calculate the IRR (Microsoft Excel software was used).

3. METHODOLOGY

This study presents a financial viability analysis of the use of a RFID system in a single company, located at the Polo de Informática de Ilhéus/BA in Brazil. This company was chosen because it had the same limitations and characteristics of other companies of the region. Due to a confidentiality agreement, we are not allowed to divulge detailed information about the company, such as number of employees, revenue, exact location and name. We can affirm that the company is similar in those dimensions to the other companies in the Polo de Informática/BA.

This is an empirical study, based on data collected in interviews during the implementation of the RFID project, in a period of six months. The purpose of the study is to describe a methodology to assess the financial viability of radio frequency identification (RFID) applications and the main contributions of this technology. The impact of RFID technology on supply chain processes has been assessed using an Internal Rate of Return approach (Abreu *et al*., 2005)

The data collection was carried out during non-structured interviews with the company´s managers and workers from the inventory team, for a period of 6 months in 2011, while the system was being installed. Other sources of data include company documents and reports, which were the source of almost all the financial data used in the study. All the necessary data for the analysis were selected, and the internal rate of return and net present value of the project were then calculated, following the methodology presented in Abreu *et al*. (2005). The software Microsoft Excel was used for this purpose. The data collected during interviews consisted mostly of the description of the operations of the company, the list of components used in the assembly of products, information about return rates of computers, number of workers at each stage of production, technical and workforce-related problems faced by the company, equipment used in the assembly of computers, workflow of production, etc.

The motivating factor behind this study lies in real problems faced by the companies in the Polo de Informática. Based on our interviews, the most relevant difficulties found in companies of the region are described below:

Sales of products that did not have all the necessary components as ordered by the client. In such cases, the company frequently substituted components of higher value for the missing components. This might create a discrepancy between the inventory control system (database) and the actual inventory.

Traceability of components during the phases of assembly – when one component was damaged and was substituted – The control of this activity is performed, in most companies, manually by filling a spreadsheet in the end of the working hours, and then releasing the information into the inventory control system (database).

Problems while reading the barcodes during the phases of data insertion into the ERP (Enterprise Resource Planning) system of the companies;

Manual control of the raw materials inventory.

4. ANALYSIS AND DISCUSSION OF RESULTS

This section will present the financial viability study performed to evaluate the financial advantage to implement the RFID system in the company, here called XYZ due to confidentiality purposes.

4.1. Financial Study

For the financial study, all the values in dollars (U$) were converted to Reais (R$) using a rate of 1.55 (U$1.00 = R$1.55). Therefore, the working unit is Reais. Considering that we are studying the implementation of an automatic identification system, neither the depreciation of equipments nor the residual value at the end of the system´s lifespan was considered.

4.2. Investments

Table 1 describes the necessary investments for all equipments and resources of the RFID system. However, the costs related to software development, integration of the software with the ERP system and the training of workers will be subsidized by the Brazilian Informatics Law. Therefore, at year 0 the necessary investments, considering the subsidies, will be of R$ 45,194.31, according to Table 2.

Table 1 – Investment.

Investment	Cost (R$)
Symbol XR450 Reader	4,771.42
2 Motorola AN400 Antennas	2,489.13
RFID Portal made of aluminum	1,500.00
2 Symbol MC9090-G Collectors	23,414.81
Zebra 110Xi4Thermal Printer	13,018.95
Software Development	8,000.00
Integration with the Company´s ERP System	3,000.00
Training for workers	6,000.00
Total	**62,194.31**

Source: Author.

Table 2 – Investment with subsidies.

Investment With Subsidies	Cost (R$)
Symbol XR450 Reader	4,771.42
2 Motorola AN400 Antennas	2,489.13
RFID Portal made of aluminum	1,500.00
2 Symbol MC9090-G Collectors	23,414.81
Zebra 110Xi4Thermal Printer	13,018.95
Software Development	0.00
Integration with the Company´s ERP System	0.00
Training for workers	0.00
Total	**45,194.31**

Source: Author.

4.3. Fixed Costs

While using the RFID system, the workers of XYZ will not have additional tasks compared to the ones they already performed before. The tasks involved in using a RFID system are very similar to the ones involved in using barcodes.

The fixed costs will be the technical support service of the RFID system and the electrical energy to make the equipments work.

In order to calculate the fixed cost of the technical support service, it was considered a minimum wage of R$ 545.00 (Law 12.382/2011 – 01.03.2011), since it is the average cost charged by companies that develop ERP systems to medium-sized microcomputer assemblers at the Polo de Informática de Ilhéus/BA at the time the study was done. Considering that the RFID system will be installed in three stations, the annual fixed cost will be R$19,620.00.

The fixed monthly cost of electrical energy for RFID equipments will be of R$ 312.84, according to Table 3. The annual cost will be of R$ 3,754.08.

Table 3 – Monthly cost of energy per equipment.

Equipment	Quantity	Power (kW)	Days	Monthly Cost (R$)
Nest with Single Slot for Collector	2	0.19	30	150.48
XR450 Reader	1	0.21	30	83.16
Zebra 110Xi4 Thermal Printer	1	0.2	30	79.20
			Total	**312.84**

Source: Author.

The total annual fixed cost will be R$ 23,376.00, where R$ 19,620.00 is from technical support services and R$ 3,756.00 is from energy for equipments.

4.4. Variable Costs

The variable cost comes from the acquisition of RFID SteelWave Micro tags that will be attached to the machines´ components (mother-board, hard-disk, DVD reader, RAM memory, power supply and case) and from the acquisition of the RFID ALN-9640 tag, which will be attached to the packaging box.

According to Carrender (2009), the price of a RFID UHF tag was reduced from one dollar in 2000 to around ten cents of dollar in 2009. This amounts to a reduction in cost of around 10% a year. This reduction fraction will be used in the present study, even though we do not have hard evidence that the reduction in cost will continue at this rate. However, we consider this estimate as conservative, since there are more optimistic forecasts (MOSCATIELLO, 2003).

It is worth noticing that half of the costs of the RFID SteelWave Micro tags were transferred to the other links of the XYZ supply chain.

Table 4 presents the forecast of variable cost for each machine over the years.

Table 4 – Forecast of variable cost.

		2012		2013		2014		2015		2016	
Variable cost per machine	Qtty	Unit Cost (R$)	Cost (R$)	Unit Cost (R$)	Cost (R$)	Unit Cost (R$)	Cost (R$)	Unit Cost (R$)	Cost (R$)	Unit Cost (R$)	Cost (R$)
RFID ALN-9640 Tag	1	0.43	0.43	0.39	0.39	0.35	0.35	0.31	0.31	0.28	0.28
RFID SteelWave MicroTag	6	1.91	11.46	1.72	10.31	1.55	9.28	1.39	8.35	1.25	7.52
Total			11.89		10.70		9.63		8.67		7.80

Source: Author.

4.5. Production Estimates

The company estimates the monthly production of 12,100 machines on year 1 (2012). Therefore the annual production will be of 145,200 machines. Taking into consideration the forecasts of IDC (2011), that world sales of computers will have increase rates of 10.0%, 11.3%, 11.0% and 10.8% respectively in the years 2013, 2014, 2015 and 2016, the following annual production forecasts can be made, according to Table 5 below.

Table 5 – Annual production forecast.

Year	Sales Increase Forecast	Production Forecast
2013	10.0%	159,720
2014	11.3%	177,769
2015	11.0%	197,324
2016	10.8%	218,570

Source: IDC (2011).

It is worth noticing that IDC forecasted even higher increase rates for emerging markets, but we chose to use the more conservative values.

4.6. Gain Estimates

The monthly cost of an inventory operator is R$ 1,154.30 and the annual cost of such operator is R$ 13,851.60.

The cost of a machine with basic configuration is around R$ 300.00, with the following costs per component, as shown on Table 6.

Table 6 – Costs per component.

Items	Unit Cost (R$)	Percentual
Case	40.96	13.65%
Mother-Board	74.72	24.91%
Processor	60.33	20.11%
RAM Memory	27.68	9.23%
Hard Disk	40.96	13.65%
DVD Reader	22.14	7.38%
Power Supply Unit	22.14	7.38%
I/O products*	11.07	3.69%
Total	**300.00**	**100.00%**

Source: Author.

*Loudspeakers, mouse and keyboard.

One of the difficulties faced by the company, evidenced in a FMEA (Failure Mode and Effects Analysis) form, is that components are frequently missing in the inventory. In order to deal with this problem, the company substitutes components of higher grade or value for the missing components. Such situation results in an increase of 3% on the cost of each machine, on average. This problem happens only in 30% of the batches, on average. The RFID system eliminates this problem, since the supplier is informed of the exact composition of the client´s inventory in real time. Detailing these costs and distributing the values over the years, the following values are found, as shown on Table 7.

Table 7 – Cost of substituting components.

Year	Items	Quantity	Unit Cost (R$)	Total Cost (R$)
2012	Cost of Production*	145,200	300.00	43,560,000.00
	Cost of Production w/ substitution**		309.00	43,952,040.00
			Diference	**392,040.00**
2013	Cost of Production*	159,720	300.00	47,916,000.00
	Cost of Production w/ substitution**		309.00	48,347,244.00
			Diference	**431,244.00**
2014	Cost of Production*	177,769	300.00	53,330,700.00
	Cost of Production w/ substitution**		309.00	53,810,676.30
			Diference	**479,976.30**
2015	Cost of Production*	197,324	300.00	59,197,200.00
	Cost of Production w/ substitution**		309.00	59,729,974.80
			Diference	**532,774.80**
2016	Cost of Production*	218,570	300.00	65,571,000.00
	Cost of Production w/ substitution**		309.00	66,161,139.00
			Diference	**590,139.00**

Source: Author.

*Cost of Production, following specifications

**Cost of Production, with the substitution of a component

Another important point, the most significant one, is the MRA (Material Return Authorization). The company has internal MRA costs (by substituting defective components in the phases of assembly) and external MRA costs (by substituting defective components in the clients´ machines during the warranty period).

The internal MRA costs are paid by the company, since it does not have an efficient control system to trace the defective component to its origin during the assembly process (a worker manually fills a spreadsheet at the end of working hours). This makes it very difficult to identify the batch and supplier of the defective component, in order to contact the supplier and obtain warranty rights. The present system does not allow control over the manufacturer of defective components. The defective parts are scattered in the batch. An effective control by a RFID system allows to identify problematic batches with efficacy, and a prompt return of the batch to the supplier. The company would therefore stop incurring costs due to defective components.

The average internal MRA index is around 15%. The components that have higher indexes of defect during the assembly are: mother-board, processor and RAM memory. These components correspond to 18.08% of the cost of a basic configuration machine, on average. The cost of this percentual average corresponds to R$ 54.24, as shown on Table 8.

The average external MRA index is around 10%. The components that have higher indexes of defect are: mother-board, processor, RAM memory and power supply unit. These components correspond to 15.41% of the cost of a basic configuration machine, on average. The cost of this fractional average corresponds to R$ 46.22, as shown on Table 8.

During interviews with managers of the five largest companies in the Polo, it was estimated that with the RFID system there would be a dramatic reduction in the MRA indexes. The internal RMA would be reduced to 3%, and the external, to 1%. These were structured interviews with the sole purpose of obtaining an estimate of MRA reductions from the senior managers of the aforementioned companies. The CEOs were informed of the characteristics and functionalities of the RFID system, and estimated the MRA numbers based on their personal experience. The final numbers of 3% and 1% represent an average of the values estimated by the CEOs.

By detailing the internal and external MRA costs and distributing these values over the 5-year period, the following values are obtained, as can be seen on Table 8.

Table 8 – Cost of Internal and External MRA.

Year	Items	Annual Production	MRA Index	Quantity for MRA	Unit Cost (R$)	Total Cost (R$)
2012	Internal MRA	145,200	15%	21,780	54.24	1,181,424.35
	External MRA		10%	14,520	46.22	671,081.18
2013	Internal MRA	159,720	15%	23,958	54.24	1,299,566.79
	External MRA		10%	15,972	46.22	738,189.30
2014	Internal MRA	177,769	15%	26,666	54.24	1,446,458.30
	External MRA		10%	17,777	46.22	821,612.27
2015	Internal MRA	197,324	15%	29,599	54.24	1,605,554.61
	External MRA		10%	19,733	46.22	912,014.11
2016	Internal MRA	218,570	15%	32,786	54.24	1,778,428.78
	External MRA		10%	21,857	46.22	1,010,180.54

Source: Author.

With the new RFID system the company estimates to reduce or eliminate:

1) The annual cost of one inventory operator (due to automation);
2) The annual cost of substituting a component of higher grade or cost for a missing one;
3) The annual costs of internal MRA from 15% to 3% and of external MRA from 10% to 1%.

Distributing these values over the five years of production, the following estimated gains are calculated, as shown on Table 9.

Table 9 – Estimated gains.

Year	Items	Annual Production	RMA Index	Quantity	Unit Cost (R$)	Total Cost (R$)
2012	Operator	145,200		12	1,154.30	13,851.60
	Costs of Substitution					392,040.00
	Internal MRA		12%	17,424	54.24	945,139.48
	External MRA		9%	13,068	46.22	603,973.06
					Total	**1,955,004.15**
2013	Operator	159,720		12	1,154.30	13,851.60
	Costs of Substitution					431,244.00
	Internal MRA		12%	19,167	54.24	1,039,685.98
	External MRA		9%	14,375	46.22	664,379.61
					Total	**2,149,161.19**
2014	Operator	177,769		12	1,154.30	13,851.60
	Costs of Substitution					479,976.30
	Internal MRA		12%	21,333	54.24	1,157,177.49
	External MRA		9%	16,000	46.22	739,483.39
					Total	**2,390,488.79**
2015	Operator	197,324		12	1,154.30	13,851.60
	Costs of Substitution					532,774.80
	Internal MRA		12%	23,679	54.24	1,284,432.84
	External MRA		9%	17,760	46.22	820,826.57
					Total	2,651,885.81
2016	Operator	218,570		12	1,154.30	13,851.60
	Costs of Substitution					590,139.00
	Internal MRA		12%	26,229	54.24	1,422,753.87
	External MRA		9%	19,672	46.22	909,194.83
					Total	**2,935,939.31**

Source: Author.

4.7. Operational Cash Flow

In order to calculate the NPV, it is necessary to calculate the Operational Cash Flow. In order to do this, the revenues, total costs, depreciation, profits before interest and taxes, interest (which is zero in this case, since no loans or investments were made), taxable profits, taxes and profits are calculated. The profits represent the economy achieved with the use of the RFID system.

The revenues are the gain estimates for every year. Total costs are the variable costs multiplied by the yearly production, added to the fixed costs. Profits before interest and taxes are the revenue minus total costs and depreciation (which is zero). The taxable profits are equal to the profits before interest and taxes, since there is no interest. There are no taxes in the implementation of the system, since it is a profit-free activity. The profits will then be the taxable income minus taxes. The cash flow will then be the depreciation, added to the profits before interest and taxes, minus the taxes, which are also zero. Since production changes over the years, different values are obtained, as shown on Table 10.

Table 10 – Operational Cash Flow.

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Revenues		1,955,004.15	2,149,161.19	2,390,488.79	2,651,885.81	2,935,939.31
Total Costs		1,749,804.00	1,922,446.80	2,137,049.41	2,369,558.36	2,622,173.30
Depreciation		0.00	0.00	0.00	0.00	0.00
Profit before interest & taxes		205,200.15	226,714.39	253,439.38	282,327.45	313,766.01
Interest		0.00	0.00	0.00	0.00	0.00
Taxable Profits		205,200.15	226,714.39	253,439.38	282,327.45	313,766.01
Taxes		0.00	0.00	0.00	0.00	0.00
Profits		205,200.15	226,714.39	253,439.38	282,327.45	313,766.01
Operational Cash Flow		**205,200.15**	**226,714.39**	**253,439.38**	**282,327.45**	**313,766.01**

Source: Author.

4.8. Necessity of Working Capital and Working Capital Variation

According to Abreu *et al.* (2005), the necessity of working capital is a function of the activities performed and varies according to revenues and the financial cycle. The necessity of working capital will just be the amount of money necessary to buy and pay whatever is necessary for the implementation of the system. As all the equipments are already part of the initial investment, the only working capital that is needed is for the acquisition of the RFID tags, which are the only variable cost as shown on Table 5. The difference between the working capital of one year and the next is called Working Capital Variation.

The sum of the variations of working capital is zero, since at the end of the accounting period, all differences are remedied. Therefore, in the last year, the value is equal to the one that enables a zero-sum over the period.

The values of necessity of working capital and working capital variation are presented on Table 11.

Table 11 – Necessity of working capital.

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Necessity of Working Capital	1,726,428.00	1,899,070.80	2,113,673.41	2,346,182.36	2,598,797.30	2,598,797.30
Working Capital Variation	-1,726,428.00	-172,642.80	-214,602.61	-232,508.95	-252,614.94	2,598,797.30

Source: Author.

Since the acquisition of RFID tags has to be made one year before they will be used, year zero starts with necessity for capital. Since it is expected that the company will continue to use the system after the first 5 years, at year five the necessity of working capital is still present.

4.9. Residual Value

We followed the method described previously, when calculating the residual value. Since we will not contemplate the selling of equipments, after their life span, the MRV and RAV values are zeroed.

4.10. Return Rate

In this viability study it was considered that Money lended will be 100% of the assets. The financing rate will be considered as 10%, according to the limit for financing the acquisition of raw materials and inventory goods for a large company (BNB, 2011). The cost of capital was set at a conservative value of 20%. The Return Rate is indicated in Table 12 below.

Table 12 – Return Rate.

P – Money Lended	1,944,265.11
PI – Personal Investment	0.00
Kd – Financing Rate	6.00%
Ke – Cost of Capital	20.00%
a – Asset	1,944,265.11
r – Return Rate	10.00%

Source: Author.

4.11. Discounted Cash Flow, NPV and IRR

On year zero there is a withdrawal of capital for the payment of the investment in the RFID system. On year five, there is the input of capital for the sale of assets (here considered zero, as explained before). These values are Net Capital Expenses. Table 13 presents the calculation of NPV and IRR.

Table 13 – Cash Flow, Discounted Cash Flow, NPV and IRR.

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Operational Cash Flow		205,200.15	416,621.47	655,037.32	918,142.87	1,207,492.40
Net Capital Expenses	-45,194.31					0.00
Working Capital Variation	-1,726,428.00	-172,642.80	-214,602.61	-232,508.95	-252,614.94	2,598,797.30
Cash Flow	-1,771,622.31	32,557.35	202,018.86	422,528.37	665,527.93	3,806,289.70
Discounted Cash Flow	-1,771,622.31	29,597.59	166,957.74	317,451.82	454,564.53	2,363,406.44
NPV	1,560,355.80					
IRR	15%					

Source: Author.

According to Abreu *et al.* (2005), the IRR has a definite criteria for acceptance. Its value should be larger than the Minimum Attractive Rate of Return (MARR). Considering that the MARR is equal to the rate of return (r), the RFID project is viable, since the IRR (15%) was larger than the MARR (10%). Besides, with the estimated production for the period, a NPV of R$1,560,355.80 is achieved.

4.12. Results

In this study it was evidenced that the RFID Project at the XYZ Company is viable. The main numerical outcomes of the methodology have been addressed in the previous sections. All the results and methods have been extensively discussed with the company´s managers involved in the research project both to verify the accuracy, i.e. compliance with the real processes, and the robustness of the numerical outcomes.

It can be observed that the larger financial gain comes from the reduction of the external and internal MRA costs. It is worth mentioning that one of the reasons for the high MRA indexes is that the company does not control and in many cases can´t identify the batches and the manufacturers of damaged components. This results in a significant cost for the company. The RFID technology was selected as the best tool to enable a quick solution to this problem, since it enables traceability and real time control of inventories. The company will be able to rank its best suppliers and pass the costs of MRA of damaged components to the manufacturers, since the components are under warranty.

For the case study, the prices of tags were obtained from a European wholesaler. Until the end of this study, negotiations were under way with the tag manufacturer, aiming a significant cost reduction, since the products will be bought directly from the manufacturer.

It is worth noticing that there are other significant gains inherent to the use of RFID technology, which are however difficult to measure. Such gains are shared by the entire productive chain, because with real time inventory control the suppliers of this company will be able to monitor the flow of parts and ensure that their customer (the company) will have its needs fulfilled. This real time monitoring between supplier and company is replicated in the remaining links of the chain, which ensures better service quality to the end consumer, and reduction of logistical and operational costs. In such condition, the component can be tracked from the first supplier to the end consumer (WAMBA; CHATFIELD, 2009). Miragliotta *et al*. (2009) focused on the benefits for both the retailer and manufacturer, and found that when the tags were attached to both cases and pallets, the benefit for the retailer was much larger that the benefit for the manufacturer. The retailer had a reduction of 10.26 cents of euro per case and the manufacturer had a reduction of 2.18 cents of euro. Considering that similar results might be obtained in the microcomputer supply chain, the benefits for the other players must be very significant, especially considering the relatively low complexity of the system.

5. CONCLUSIONS

This study presented a methodology for the calculation of the internal rate of return for a RFID project. The validation of this methodology was based on a case study, in a microcomputer assembly company located at the Polo de Informática de Ilhéus/BA-Brazil.

The financial viability analysis covered a period of five years. A Net Present Value of R$ 1,560,355.80 (equivalent to U$ 768,647.00 on 09/20/2012) and an IRR of 15% were obtained. Considering that the IRR was larger than the MARR (10%), the project to implement the RFID system in the company is viable.

It is worth noticing that half of the costs of the RFID SteelWave Micro were transferred to the other links of the XYZ supply chain.

It is easy to observe that the largest gain was the reduction of external and internal MRA costs; With the RFID technology this problem can be drastically mitigated, resulting in significant benefits for the company.

The results presented here indicate that the project is financially viable even with higher tag costs. With the evolution of the technology, and with the widespread use of RFID tags, such costs will be reduced and the use of RFID technology will be viable in many other industries/sectors.

One key limitation of this research is the case study approach based on a single case. This paper, however, provides direction for practitioners on how to assess RFID's potential impact in the microcomputer assembly process. The literature on financial analysis of RFID systems is very scarce. This research contributes to our understanding of RFID's potential in intra-organizational supply chain management processes. Hopefully, the experience and lessons learned from this case study can be shared with the readers, and they will be beneficial to those organizations that are contemplating the implementation of RFID systems.

As a suggestion for future studies, the methodology presented here could be used to evaluate the financial viability of RFID technology to other segments of flexible manufacturing, such as electronics, cars, and white line (refrigerators, washing machines, freezers, etc.)

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