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Measuring RFId Benefits in Supply Chains

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ABSTRACT

RFId systems hold great potentials in enhancing supply chain performances. Some of the major retailers in the World (Wall Mart, Metro Group, Tesco) made sounding campaigns promoting the benefits they were able to attain. Despite the growing number of researches concerning RFId benefits, a study investigating their measurement in the supply chain context is still lacking. This paper proposes to associate qualitative RFId benefits identified in literature with corresponding measures by designing three tools: (1) an RFId oriented Performance Measurement System for the identification of all RFId related supply chain performance indicators on the base of the SCOR Model. (2) A benefits-processes-measures matrix linking the benefits identified in literature with SCOR model process to identify supply chain measures impacted by the RFId system implementation. (3) A reference framework summarizing benefits measures.

Keywords

RFId, benefits, SCOR, measures.

INTRODUCTION

Since their early adoption in retailing RFId systems have shown great potentials for supply chain and warehouse management. The first studies in this field contributed to the exploration of both hardware and functional requirements of the technology and the expected impacts on logistics and operations "inside the four walls of the facilities" (Laubacher, Kothari, Malone, & Subirana, 2006). It's only when the MIT Auto-ID Center developed the idea of disposable and standardized, low cost, high volume tags that RFId interorganizational applications moved "from obscurity to mainstream" (Hunt, Puglia, & Puglia, 2007; Want, 2006): the related development of the EPC architecture (Leong, Ng, & Engels, 2004) made its first appearance in the retailing market. The well known example of Wall-Mart and Gillette (Smith, 2005) collaboration, showed the real potential of the technology producing significant impacts on the performance of the supply chain reducing the stock outs and over stocks, increasing collaboration and coordination between supply chain partners, and generally providing a higher service level to the final customer. The claimed success of the Wall-Mart initiative raised the question of the replicability of the results both in the same and in different contexts. The need for a reliable assessment of the return on investments in RFId technology has then become compelling. In literature, several models have been proposed to support the development of RFId projects feasibility studies (Chuang & Shaw, 2005; Hodges & McFarlane, 2005; Hou & Huang, 2006; Jeong & Lu, 2008; Veeramani, Tang, & Gutierrez, 2008), however, despite the relevance of the matter, the estimation of benefits is still more approximate and qualitatively based than the costs one (Laubacher, et al., 2006). This issue relates both to RFId benefits characteristics and to the lack of a reference framework for their evaluation. The studies published to date mainly assess the qualitative impacts of RFId on both the activities of the single firm or of the entire supply chain (Chopra & Sodhi, 2007; Chuang & Shaw, 2005; Laubacher, et al., 2006) or focus their attention on a specific supply chain, e.g. the printing industry (Hou & Huang, 2006), and neglect to generalize their findings.

With this paper we aim at proposing a general framework for the measurement of RFId benefits within the context of a supply chain, supporting supply chain managers in translating each operative impact of this technology into "hard dollar return". The idea at the base of the methodology adopted in this study is straightforward: to associate the predicted qualitative impact of the technology to a supply chain performance measure/indicator through the development of an RFId oriented Performance Measurement System (PMS).

The paper is arranged in three sections. The next paragraphs present the research model and, after a brief discussion on the general issue of measuring, describe the assumption at the base of the methodology. In section two we detail the approach and the attained results.

FROM QUALITATIVE BENEFITS TO MEASURES

The published literature on RFId benefits measurement within supply chains mainly consists of papers suggesting or testing general qualitative "lists" of impacts expected or consequence of RFId systems implementation (like the increased speed of order preparation or the improvement of quality management). These analyses adopt a qualitative approach without exploring the development of methodologies or procedures for a quantitative assessment of the impacts identified. This reflects the wider problem of measuring benefits in the IS context (Seddon, Greaser, & Willcocks, 2002), eventually worsened by the lack of business cases on RFId technology (Curtin, Kauffman, & Riggings, 2007). But what measuring a benefit means? First of all, a measure can be defined as the quantitative result of a measurement process, and consists in a symbol used to evaluate an attribute (Mari, Lazzarotti, & Manzini, 2008). Thus, a measure provides the quantitative dimension to a benefit, and has to be associated to a proper indicator. In order to develop our framework we relate these indicators (numbers or ratios) to the efficiency and effectiveness of a particular business process. In a supply chain, then, these indicators refer to the environment of analysis. Thus, we decided to adopt the SCOR model as the reference supply chain process framework.

METHODOLOGY

The methodology used to develop the research framework is built around three main research questions:

1. Which benefits are generated from RFId adoption?
2. How performance is measured in the supply chain context?
3. How the impacts of RFId on supply chain performance can be measured?

The identification of RFId benefits (1) is based on a literature review and is functional to the identification of the possible process impacted by the adoption of this technology. By establishing a link between a benefits and the impacted supply chain process on the base of the widely adopted SCOR model (2), it is then possible to associate an impact to a process performance measure (3). The next sections detail the research steps to develop the proposed RFId benefits reference framework.

Identifying the benefits of RFId adoption: a literature review

We reviewed 30 paper published between 2004 and 2008 describing the different approaches used in assessing RFId impacts and emerging benefits. We categorized these papers according to their focus and contribution in four categories: methodologies, real implementations, qualitative benefits, and literature review (Pigni, Astuti, & Buonanno, 2004). We summarized our findings in Table 1, and the details can be found in the Appendix.

	Category	**Authors**
1	Methodology	(Bertelè, 2006; Laubacher, et al., 2006; van de Wijngaert & Versendaal, 2008)
2	Case studies and real implementations	(Bertelè, 2006; Loebbecke & Huyskens, 2008; Pigni, Ravarini, Astuti, Buonanno, & Mari, 2006; Xiao, et al., 2007; Zhang, Ouyang, & He, 2008)
3	Quantitative	(Hou & Huang, 2006; Jeong & Lu, 2008; Koh, Kim, & Kim, 2006; Munoz & Clements, 2008; Spivey Overby, 2004; Tellkamp, 2006)
4	Qualitative	(Chuang & Shaw, 2005; Coltman, Gadh, & Michael, 2008; Fosso Wamba & Harold Boeck, 2008; A. Hilger, Ghijsen, & Semeijn, 2007; A. M. Hilger, Ghijsen, & Janjaap Semeijn, 2007; Hou & Huang, 2006; Laubacher, et al., 2006; McFarlane & Sheffi, 2003; Michael & McCathie, 2005; Niederman, Mathieu, Roger Morley, & Kwon, 2007; Pigni, et al., 2004; Smith, 2005; Soon & Gutiérrez, 2008).
5	Review	(Pigni, et al., 2004)

Table 1. The categorization of the papers reviewed

In particular, only three studies (Ref. 1 – Table 1) provided an assessment of a *Methodology* to discover and classify the RFId impacts on firm operations, whereas several *Real implementations* (Ref. 2 – Table 1) accounted for the experiences of cross-section application in heterogeneous contexts including air baggage handling and fashion retailing. Other works effectively approached the problem of the measurement of RFId benefits (Ref, 3 –Table 1), but their scope was generally limited. Hou and Huang (2006), for example, identify the possible supply chain performance indicators influenced by the introduction of a RFId system within the Taiwanese print and paper supply chain and they gathered "quantitative values" of performance. Nevertheless this work shows some limits in terms of generalizability: the model is concentrated only on the Taiwanese print and paper industry, and the methodology adopted for identifying the indicators is not detailed or explained. Tellkamp (2006), presents a mathematical model to show how RFId systems are able to reduce stock out, and level of overstocks but disregards other possible effects different from the control of stock levels. The studies concentrating on *Qualitative Benefits* (Ref. 4 – Table 1) generally provide the description of the impact without providing any associated measure (i.e. reducing stock out, increase speed and accuracy in sku/pallet preparation, fast item/sku/pallet identification, safety stock reduction, stock turnover improvement). We summarized and categorized these findings and we identified 41 different classes of impacts resulting from RFId adoption. By associating the benefits produced by RFId adoption with supply chain process as defined in the SCOR model we developed a Performance Management System (PMS) oriented at the assessment of RFId applications.

Measuring supply chain performance

A PMS is a "..set of metrics used to quantify both the efficiency and effectiveness of actions" and its metrics/indicators are linked each other by several internal relationships (Neely, 2005). In particular, concerning the development of PMS in supply chains, literature offers contribution both regarding the structure of the PMS, and the development of suitable indicators. Shepherd (2006) provides a taxonomy of metrics specifically in the supply chain context and develops a PMS structure categorizing "the indicators according to their applicability to the five supply chain processes defined in the supply chain operations reference (SCOR) model (plan, source, make, deliver and return or customer satisfaction)". Accordingly, we designed the PMS RFId identifying and analyzing SCOR model process and performance indicators (Model settling).

Dimension of Analysis	Authors
Definition and Framework	(Neely, 2005; Neely, Gregory, & Platts, 1995; Rouse & Putterill, 2003)
Features Required	(Moullin, 2004; Tangen, 2005a)
Single Indicators	(Gosselin, 2005; Tangen, 2005b)
Application	(Bourne, Kennerley, & Franco-Santos, 2005; Najmi, Rigas, & Fan, 2005)

Table 2 The references used to base the development of the PMS

Identification and analysis of SCOR process

The SCOR model is one of the most common, reliable and fast tool to explore and analyze every supply chains. By describing supply chains using these process building blocks, the model can be used to describe supply chains that are very simple or very complex using a common set of definitions (SCOR version 6.0). We define the structure of the PMS framework and the indicators on the base of the SCOR model process. The SCOR model subdivides the supply chain into five primary management processes: Plan, Source, Make, Deliver and Return each composed of three levels of process detail, describing the supply chain till its activities. Moreover, the SCOR model contains a list of metrics for each process that can then be matched with Shepherd's review on supply chain PMS (this review lists and classifies performance indicators from 44 previous articles). In this way we eliminated indicators that were duplicated and retained only the ones functional to RFId impacts evaluation. Following the model structure, for each level we listed the processes with their descriptions and highlighted those directly affected by RFId system implementation. The SCOR model features two interesting aspects functional to the design a generalizable performance system and capable of considering supply chain operative aspects. First of all, the second detail level of source, make, and deliver presents alternative process that represent the different types of supply chain. Moreover, it considers a general enable processes that ".. prepare, maintain, or manage information or relationships on which planning and execution processes rely"(Quick Reference SCOR 8.0). For our scope the enable processes, belonging to the management information domain, are essential because RFId systems dramatically increase the ability of suppliers to acquire and share a vast array of data regarding the location and properties of any entity that can be physically tagged. The supply chain map obtained by the SCOR model can be completed with the performance indicators associating to each sub-process the relative metrics.

Identification of process performance indicators (Model settling)

Performance indicators functional to the proposed RFId oriented PMS are based on the SCOR Model Version 6.0 (containing the list of metrics for each process), and Shepherd et al.'s (2006) review of supply chain metrics. Both these works present a set of indicators associated to supply chain process. After matching them we identified 42 indicators for the "plan" processes, 27 for "source", 49 for "make", 51 for "deliver", 33 for "return". This result allows to consider the features of each indicator (Tangen, 2005a) and the framework of the RFId oriented PMS. In this way it is possible to create a table listing the main indicators of supply chain performance relevant for the analysis of RFId impacts. In particular, for each first level SCOR process we identified:

- ID Sub-process: the process of second and third level the indicator refers to. Some indicators are considered Inter-processes, because they evaluate the entire supply chain as: total supply chain cycle time, order fulfillment lead time, order lead time, total supply chain inventory, customer response time, total supply chain response time;
- Name of indicator;
- Definition: describes the indicator meaning and main feature;
- Formula: is the mathematical representation of the referenced definition of the indicator and its constituents. It highlights the hierarchical linking of different measures;
- Category: Type of performance indicator: *time*, *quality*, *costs*, *flexibility*, *innovativeness;*

- Type: the performance can be measurable through a quantitative value (Quantitative measure - QN) or not (Qualitative measure - Q);
- Hierarchical process relationship: shows the possible linking between indicators belonging to different processes.

The table generated identifies both the features of the indicators (Tangen, 2005a) and the framework of the PMS.

Measuring RFId impacts on supply chain performance

RFId benefits can be associated to supply chain metrics defining a link between performance indicators and the SCOR processes. The association is possible selecting all PMS processes impacted by an RFId system and the benefits previously identified in the review of PMS supply chain processes (a middle-intermediate association). We consider that a modification in a process is reflected in a change of its performance metrics, so the middle-intermediate association process-benefits enable the association of benefits to metrics. In detail for each benefit identified in the review we associate one or more affected SCOR process. This association is made, at first, by linking the benefit with the corresponding first and second level SCOR model process and then by identifying the third level process eventually affected. This association is required as the SCOR model provides performance indicators only at this level of analysis, thus the association between a benefits and the process indicators can be evaluated only considering such a detail. Thus, the PMS model developed, presents all performance indicators for each associated processes. The PMS allows to link process performance indicators to the associated qualitative benefit enabling the effective measurement of process performance.

Id	L1 process	Id associated process	Name	Formula	Category	Type
t1	PLAN	Inter-process	Total Supply Chain Inventory	= Total level of inventories for each supply chain stage	Cost	QN
t2	PLAN	Inter-process	Total supply chain response time	=Forecast Cycle Time+ Total supply chain cycle time	Flexibility	QN
p10	PLAN	P2,P3,P4	Order flexibility	=Mix flexibility; Volume flexibility	Quality	QN
s1	SOURCE	S1,S2,S3	Material Acquisition Costs	=Materials Management + Effective material cost + Receiving costs + material storage costs	Cost	QN
s2	SOURCE	S1.1/S2.1/3.1	Materials Management as a % of Materials Acquisitions Costs		Cost	QN
s3	SOURCE	S1.2/S2.2/S3.2	Receiving costs as a % of Material Acquisition Costs		Cost	QN
m1	MAKE	M1,M2,M3	Total cost of resources	=Inventory level; personnel requirements; equipment utilization, energy usage and cost	Cost	QN
m2	MAKE	M1.3/M2.3/M3.3	Value-added productivity	= Total Product Revenue-External Direct Material	Cost	QN
m3	MAKE	M1.3/M2.3/M3.3	Number of items produced	=Number of items produced /day	Cost	QN
d1	DELIVER	D1/D2/D3	Total logistics costs	=Distribution costs + Warehouse cost + Scheduling	Cost	QN
d2	DELIVER	D1/D2/D3 from picking to receiving and testing	Distribution costs	=Fulfillment order cost + Delivery cost	Cost	QN
d3	DELIVER	D1.8/D1.9/D2.8/D 2.9/D3.7/D3.8	Fulfillment order cost	=Labour cost of picking and loading activities	Cost	QN

Table 3. Supply chain metrics, associated process, formula and classification

For instance, the qualitative benefit “Fast item/sku/pallet identification” (benefit number 5 – see Appendix) is linked to the SCOR model sub-processes “Receiving and verifying material inbound and outbound” (third level) belonging to source, make, deliver and return first level SCOR model process. The associated indicator can be measured as a decrease of source cycle time, according to the supply chain PMS designed (Table 3). The associated measure is "the days elapsed between order release and the receipt of goods at manufacturing or distribution center".

It should be highlighted that SCOR models indicators are generally presented as descriptions of a composite performance measure, itself associated to activities not comprised in the SCOR model because considered specific to each business. Thus a further association can be made between the composite performance measure and its determinants. As shown in Table 4, the mathematical representation of the performance indicator cited above, is composed of "total supply lead time" and "accepting to transferring products time" (expressed as the sum of all activities dealt with receive where identification product is one of the main activities in receiving products and the identification activities can be measured by identification time that represents the time necessary to identify a product).

Adopting a bottom up perspective, we can then observe that an increase in the performance of identification activities impacts the accepting metric: a component of source cycle time.

Similarly, the qualitative benefit "Reduction of the difference between physical inventory and virtual inventory" (benefit number 14) can be associated to the "make" and "deliver" first level SCOR processes, linked with the sub-processes "issue material" (the third level of make category) and "pick product" (the third level of deliver category), thus affecting picking activities, too. This benefit can then be measured as an increase of inventory availability that can be defined as the difference between the logical and physical inventories.

We followed a slightly different method when dealing with benefits impacting information flows. For instance, the qualitative benefits "standardization of data" (number 24) had to be associated to a SCOR model enabling process. This benefit is linked with the sub processes of third level "Maintain data" for each enable category (enable plan, enable source, enable make, enable deliver). Among the indicators of enable processes, "standardization of data" can be translated into an improvement of "information availability". In fact standard data aid the inquire-query on/trough the information system.

This approach allows the translation of the qualitative benefits identified in the literature review into process performance measures. This association represents the final output of our research.

PLAN			
Level	**Id**	**Name**	**Definition**
...	...	....	.....
...	...	....	.....

SOURCE			
Level	**Id**	**Name**	**Definition**
...	...	....	.....
3	S1.2	Receive and verify material	The receipt and acceptance of material deliveries. This includes all of the activities associated with receiving, verifying and accepting material deliveries.
3	S2.2	Receive and verify material	The receipt and acceptance of material deliveries against the contract requirements. This includes all of the activities associated with receiving, qualifying, verifying, and accepting material deliveries.
3	S3.2	Receive and verify material	The receipt and acceptance of material deliveries against the contract requirements. This includes all of the activities associated with receiving, qualifying, verifying, and accepting material deliveries.
...	...	....	.....

Number	Benefits	Definition	Author
.....	....	....	...
5	*Fast item/sku/pallet identification (Accen2)*	*Speed up in the identification of item/sku/pallet using a anti-collision protocols.*	(McFarlane-Sheffi); (Hou-Huang); (Laubacher- Kothari); (Michael-McCathie); (MIT-Orange) (Pigni, et al.)
.....	....	....	...

MAKE			
Level	**Id**	**Name**	**Definition**
...	...	....	.....
...	...	....	.....

DELIVER			
Level	**Id**	**Name**	**Definition**
...	...	....	.....

DELIVER RETURN			
Level	**Id**	**Name**	**Definition**
...	...	....	.....

SOURCE RETURN			
Level	**Id**	**Name**	**Definition**
...	...	....	.....

Id	L1 process	Id associated process	Name	Formula	Category	Type	Reason for association benefit-performance indicator
....	....	....	....	....	....	....	....
s13	SOURCE	*S1.1,S1.2/ S2.1,S2.2/ S3.1,S3.2*	*Purchase order cycle time (Source Cycle Time)*	*=Total Supply Lead Time+Accepting to transferring products time*	T	QN	Purchase order cycle time includes also identification activities for inbound goods. As consequence an authomatic identification allows to reduce the overall value of this indicator.
s17	SOURCE	*S1.2/S2.2/S3.2*	*Accept to transfer time*	*=SUM of all activities dealt with receive (in particular identification of products)*	T	QN	Identification is one of the main activities controlled by this indicator.
s18	SOURCE	*S1.2/S2.2/S3.2*	*Idetification time*	*= Time to identify a product*number of order products*	T	QN	Identification time measure the time necessary to accept inbound goods. RFId system immediatly reduce this time.
....	....	....	....	....	....	....	....

Figure 1. Illustration of the proposed association process of a qualitative benefit to its measure

Limits Of The SCOR Model in Measuring RFId Benefits

The proposed association of benefits and metrics, despite being extensive, is still limited. We identified four main categories of benefits impacting the supply chain hardly referable to a SCOR process.

1. Point of sales benefits: Shoplifting control and theft reduction, for example, are typical RFId benefits arising at the point of sale but the SCOR model doesn't cover this part of the supply chain.

2. Non operative benefits: The SCOR model identifies only operative process whereas RFId impacts other competitive dimensions like:

- *Image improvement*: a company image is an intangible asset and the marketing function can use the introduction of RFId system in order to increase visibility and brand value of the firm.
- *Parallel distribution control and reduction*: its nature is not immediate measurable, nevertheless can be similar to SCOR process "Order Tracking and Genealogy" because the tracking of goods allows to have update information on its state and the parallel distribution can be more limited.

3. Tracking and traceability benefits are among the most reported impacts of RFId adoption because they affect the entire supply chain. In order to measure it we advance two possible solutions. The first limits the analysis to a single family of SCOR operative process. The availability of information about position and state of item in real time allows scheduling the activities of all chain actors with greater efficiency, thus impacting the effectiveness of planning that can be measured. The second to consider them related to the "enable" processes linked to information management.

4. Information flows benefits RFId technologies effectively create a lean information flow easy to share with supply chain partners. The SCOR model and consequently the PMS designed on its base, consider this aspect by identifying some enabling process. In fact the second detail level of plan, source, make, deliver and return comprises Manage Plan Data Collection, Maintain Source Data, Manage Make Information, Manage Deliver Information, and Manage Return Data Collection. We associated to these process three main indicators: accuracy, timeliness, and availability. RFId systems allow supporting every operative activity with data always accurate, available and updated. All these benefits are measured by indicators created ad hoc, because the SCOR model lacks this dimension. The RFId oriented PMS highlights all the measures designed in order to quantify the impacts on the supply chain.

CONCLUSIONS AND DISCUSSION

RFId is considered a revolutionary technology for improving the supply chain performance. However, the measurement of its impacts has not yet explored enough in literature. This study proposes a framework to help supply chain managers to measure the RFId benefits within the supply chain context. The framework is designed to define supply chain performance measures and associate them to the benefits stemming from RFId systems adoption. It is focused on specific operative processes of a generic supply chain that represents the span of the SCOR Model. Thus it inherits its scope: sales and marketing (demand generation), product development, research and development, and some elements of post-delivery customer support are disregarded. Despite we aimed at generalizing our findings, the RFId oriented PMS doesn't provide a measure of the strategic benefits of RFId adoption. Their evident unpredictable nature and context related nature make general measurement activities practically futile. In order to consider this aspect we suggests to add specific Balance Scorecards designed by each supply chain manager to understand which measure should be checked with particular attention.

Despite its limits, this research represents a starting point for defining the quantitative measures of RFId benefits offering a simple and modular tool able to report the measure of RFId impacts. At the same time, it represents a first attempt to frame RFId value generation in the supply chain and in the inter-organizational context. On its basis researcher could deepen the understanding of business cases for RFId and support the finding of patterns or dynamics of adoption. The process approach at the base of the framework effectively enable its generalizability and allows its application in every supply chain supporting the "measurement process" of the changes brought by this new technology to supply chains. Further research could empirically test the framework surveying a significant sample of supply chains verifying the effective reliability of the measures identified. The operationalization of the model could be functional to the development of software supporting managers in the development of RFId systems feasibility studies (ex-ante) and performance management (in itinere and ex post).

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Appendix

Benefit		Description	Authors
1	Improvement in performance measuring systems and activity based costing	Visibility and real time availability of information on company performance and improvement of activity based costing evaluation.	(Pigni, et al.)
2	Facilitation of statistical process control	Increase of the reliability and timeliness of information on business process.	(Pigni, et al.)
3	Improvement in the quality, the acquisition, and the quantity of data	The availability of data allows the improvement of planning and control processes and simplify the management of changes in processes	(Bertelè, 2006)
4	Increase speed and accuracy in sku/pallet preparation	Speed up and fault risk reduction during sku/pallet preparation procedures.	(Hou-Huang); (Pigni, et al.)
5	Fast item/sku/pallet identification	Speed up in the identification of item/sku/pallet.	(McFarlane-Sheffi); (Hou-Huang); (Laubacher- Kothari); (Michael-McCathie); (Fosso Wamba & Harold Boeck);(Pigni, et al.)
6	Accuracy in the control of inbound shippings.	RFId readers placed at the entry (and exit) gates of yards allows the automatic identification of inbound and outbound products in real time.	(McFarlane-Sheffi); (Michael-McCathie); (Fosso Wamba & Harold Boeck); (Pigni, et al.)
7	Better utilization of inventory capacity	Better utilization of inventory capacity due to the increased availability of information about the products to be stored (product sizes, capacities, and delivery schedules).	(Michael-McCathie)
8	Reusable asset (i.e., pallet) monitoring and tracking	Monitoring and tracking of reusable asset, improving their reverse logistics.	(McFarlane-Sheffi); (Michael-McCathie)

9	Automated dispatching	Tagged products can be automatically associated to the carrier, and information on the transportation be promptly available.	(McFarlane-Sheffi)
10	Best practice for Advanced Shipping Notice	Real time and automatic identification of cargo shipments and delivery.	(Pigni, et al.); (Fosso Wamba & Harold Boeck);
11	Stock turnover improvement	Improvement in stock level management and stock turnover impacting directly inventory management.	(Pigni, et al.) (McFarlane-Sheffi); (Michael-McCathie)
12	Safety stock reduction of both item, raw materials, WIP	Safety stock reduction of item, raw materials and WIP through increased supply chain visibility and demand forecasting.	(Laubacher- Kothari);
13	Obsolescence cost reduction	Reduction of the risk linked to inventory obsolescence and to resulting fee.	(Pigni, et al.) (Laubacher- Kothari)
14	Stock Shrinkage reduction	Reduction of the difference between physical inventory and logical inventory.	(Pigni, et al.); (Smith)
15	Real time stock level control	Auto ID information provided by "virtual inventory networks" can be stored and accessed anywhere that is convenient - in storage, on the move, in stock rooms, etc.	(McFarlane-Sheffi); (Hou-Huang); (Michael-McCathie); (Soon & Gutiérrez); (Chuang & Shaw);
16	Improved Handling	Reducing the differences between physical inventory position and logical inventory position. In this way it is possible to reduce the picking time: workers can find immediately the items and improve their productivity.	(Michael-McCathie); (Soon & Gutiérrez);
17	Tracking of shipment	Transportation carriers are able not only to track individual shipments but the components of the individual shipments.	(McFarlane-Sheffi)
18	Increasing labor productivity (logistics)	Time reductions in operations material handling and process optimization.	(Pigni, et al.) (McFarlane-Sheffi); (Michael-McCathie); (Soon & Gutiérrez);
19	Increased reliability of production and scheduling systems	Increase of reliability and timeliness of data availability for production and scheduling systems.	(Pigni, et al.)
20	Tracking and localization of defective products	Easy localization of defective item/component to simplify rework's process.	(Pigni, et al.) (Michael-McCathie)
21	Reduction of production lead time	Lead time reduction.	(Pigni, et al.) (Michael-McCathie)
22	Quality Management	Support and improvement of quality management. Quality as the process to deliver the right quantity of the right working product in the right place at the right time.	(McFarlane-Sheffi); (Michael-McCathie); (Bertelè) (Pigni, et al.)
23	Timeliness and readiness of order management and billing procedures	General speed up of physical and bureaucratic procedures of order management.	(Hou-Huang); (Pigni, et al.)
24	Standardization of data	The EPC vision of products/items data residing on shared data bases which can be accessed by all supply chain partners	(McFarlane-Sheffi); (Niederman, et al.); (Hilger et al.)
25	Item/sku/pallet Tracking and Origin ("Genealogy")	Enabling item/sku/pallet tracking and tracing across the supply chain.	(Pigni, et al.) (Michael-McCathie); (Fosso Wamba & Harold Boeck)
26	Order Tracking	Enabling order tracking and tracing across supply chain.	(Pigni, et al.) (Michael-McCathie);

27	Improvement in customers' behavior analysis	Increased reliability and timeliness of consumers' behavior at the POS.	(Pigni, et al.)
28	Recall campaign management	Through the EPC manufacturers can obtain instant access to information for managing targeted recalls of defected products.	(McFarlane-Sheffi); (Michael-McCathie)
29	Demand Forecasting accuracy and stock-out reduction	Improvement of demand forecasting accuracy and reliability, reduction of stock out and customer dissatisfaction.	(Laubacher- Kothari); (McFarlane-Sheffi); (Pigni, et al.)
30	Increase on final service level	Improvement of correct order fulfillment and delivery lead time	(Bertelè)
31	Product transparency	Customer is guaranteed on product origin through monitoring and tracking	(Pigni, et al.)
32	Purchasing price reduction	Pervasive reduction of purchasing price connected to the improvement of supply chain efficiency	(Pigni, et al.)
33	Process management improvement of Maintenance, Repair and Overhaul	Speed and accuracy of support services.	(Pigni, et al.) (McFarlane-Sheffi)
34	Claim reduction	The improvement in quality control, total delivery time and associated costs allows the reduction of customer's claims regarding the level of service	(Laubacher- Kothari);
35	Reduction of unsellable products	To reduce the loss associated with perishable, damaged or obsolete products. RFId can improve data integrity and supply chain visibility to optimize FIFO stocks management.	(Laubacher- Kothari);
36	Reduction of shrinkage	Reduction of the loss of products between the manufacturer and the point of sale. There are two principles reasons for shrinkage: (1) theft and (2) "paper shrink," when items are mis-directed within the supply chain or errors are introduced in data n inventory levels. RFID can control both theft and real stock level.	(Laubacher- Kothari);
37	Anti -counterfeit	Risk reduction to find fake products on the market.	(McFarlane-Sheffi)
38	Brand consolidation	Possible brand/image consolidation caused by publicity of RFId system implementation (it depends on type of business)	(Bertelè)
39	Parallel distribution control and reduction	Control of the gray market.	(Pigni, et al.)
40	Shoplifting control	Opportunity to use RFId devices for shoplifting control.	(Pigni, et al.)
41	Theft Reduction	Reduction of stolen units, generally not insured.	(McFarlane-Sheffi); (Laubacher- Kothari); (Pigni, et al.)

Table 4 – The identified qualitative benefits