RADIO FREQUENCY IDENTIFICATION AND TIME-DRIVEN ACTIVITY BASED COSTING: RFID-TDABC APPLICATION IN WAREHOUSING

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Abstract

Purpose: This paper extends the use of Radio Frequency Identification (RFID) data for accounting of warehouse costs and services. Time Driven Activity Based Costing (TDABC) methodology is enhanced with the real-time collected RFID data about duration of warehouse activities. This allows warehouse managers to have accurate and instant calculations of costs. The RFID enhanced TDABC (RFID-TDABC) is proposed as a novel application of the RFID technology.

Research Approach: Application of RFID-TDABC in a warehouse is implemented on warehouse processes of a case study company. Implementation covers receiving, put-away, order picking, and despatching.

Findings and Originality: RFID technology is commonly used for the identification and tracking items. The use of the RFID generated information with the TDABC can be successfully extended to the area of costing. This RFID-TDABC costing model will benefit warehouse managers with accurate and instant calculations of costs.

Research Impact: There are still unexplored benefits to RFID technology in its applications in warehousing and the wider supply chain. A multi-disciplinary research approach led to combining RFID technology and TDABC accounting method in order to propose RFID-TDABC. Combining methods and theories from different fields with RFID, may lead researchers to develop new techniques such as RFID-TDABC presented in this paper.

Practical Impact: RFID-TDABC concept will be of value to practitioners by showing how warehouse costs can be accurately measured by using this approach. Providing better understanding of incurred costs may result in a further optimisation of warehousing operations, lowering costs of activities, and thus provide competitive pricing to customers. RFID-TDABC can be applied in a wider supply chain.

Introduction

Radio Frequency Identification (RFID) was said to be a revolutionary technology that captivated academics and practitioners alike because of its potential for efficiencies and operational improvements (Ngai et al., 2008). Although interest in the RFID technology increasingly grew since 2004 (Lim et al., 2013; Ngai et al., 2008) a literature review conducted recently by Lim et al. (2013) noted, the growth in interest in applications of RFID to warehousing was relatively stagnant as compared with other topic subsets related to logistics. An apparent lack of interest in RFID within warehousing has been attributed to a singular focus on its benefits, namely the identification of items. The research problem addressed by this paper is a question of what other benefits of RFID can be provided, and what new applications of RFID can be introduced in warehousing.

Research questions, aims and objectives

This paper research questions (RQ) are directly drawn from calls in the literature to investigate the impact of RFID on costing methods. The research questions this paper aims to answer are as follows:

1. RQ1: Can RFID provide "automatic accounting of the future"? (Varila et al., 2007)
2. RQ2: Can RFID be used in conjunction with a Time-Driven activity-based costing (TDABC) costing model? How can RFID benefit a TDABC costing model? (Everaert et al., 2008)
3. RQ3: What is the impact of measuring time with RFID on a TDABC cost model? (Somapa et al., 2012)

This paper aims to provide a positive answer to the proposed research questions in a warehousing research context. It is envisaged that RFID technology can provide automation to accounting methods when used with the TDABC costing model, when it is used to collect time data about activities. Another aim is to find out the impact of using RFID with the TDABC cost model. Potential benefits of increased time measurement accuracy and operational improvements are also envisaged. In order to achieve the aims and answer the research questions the specific objectives are set out: conduct a case study at a representative warehouse, compare implementation of TDABC and RFID-TDABC, and lastly provide some insights and comparisons based on achieved results.

Methodology

A case study gives the opportunity to present the application of qualitative methodology in research (Hartley, 2004), hence the process of implementing an RFID-TDABC model is explained using a case company. Case study is found to be a suitable method for meeting the research aims and objectives because evaluating the RFID-TDABC model requires an application to the real life context of a warehouse. The case study method is augmented by the simulation, since some elements of the proposed solution do not yet exist. Giordano et al. (2013) suggests that simulation is suitable for "the system for which alternative procedures need to be tested may not even exist yet"(p. 185).

Company selection

The company selected for this case study research is a small-medium enterprise (SME) called Exquisite Bathrooms (disguised name by owner's request). Exquisite Bathrooms is a distributor of bathroom products operating from a warehouse in Birmingham, UK. Choice of an SME for research purposes is supported by the findings from a literature review, which showed that all studies on TDABC and logistics were based on SMEs (Bruggeman et al., 2005; Diaconeasa et al., 2010; Everaert et al., 2008; Somapa et al., 2012). Furthermore, encouraging use of information-computer technologies (ICT) in SMEs logistic companies is a key to building better supply chains of the future (Evangelista et al., 2013). Lastly, using SMEs in research helps in achieving a better research impact.

Data collection

In order to build the TDABC model and further extend it to a RFID-TDABC model, a range of data was required. A TDABC models requires two parameters: the cost per unit for the consumption of resources in the resource pool and time consumed or spent by the activities in the process. Data was collected by a number of methods in order to obtain sufficient details to build accurate models: archival data (information from financial statements, bill of ladings, customer's orders), interviews with management and warehouse staff, and lastly making warehouse activity observations and taking time measurements. In a few cases durations of the activities could not be measured as events did not occurred during the visits and an estimations were provided by the warehouse manager. Confidence in time measurements was increased by taking ten measurements for each activity and using triangulation to validate results.

Data analysis

Data analysis from a case study was conducted using elements of simulation/modelling in a spreadsheet and an TDABC model and a RFID-TDABC model were created and compared.

Literature review

Radio Frequency Identification (RFID)

RFID is an abbreviation for Radio Frequency Identification and as the name implies it is a technology that transmits information through radio waves. Industrial applications of RFID include: retail, logistics, construction, manufacturing, health care, pharmaceutical industry and animal detection (Lim et al., 2013). General benefits of RFID include: reduced material handling, increased data accuracy, faster exception management, improved information sharing and aforementioned reduced shrinkage (Tajima, 2007). A comprehensive analysis of the RFID benefits in warehousing is provided in Lim et al., 2013.

Warehouse

Core warehouse operations focus around the flow of materials in the facility, which are receiving, put-away, storage, order picking and despatching (Gu et al., 2007). Warehousing literature points to numerous problems faced by warehouse managers. These challenges can be categorised into four subsets: operational, inventory, technological, and environmental and in recent years are addressed by use of the RFID technology (Lim et al., 2013). Literature also points out to several challenges of implementing RFID in a warehousing: uncertain return on investment, integration with legacy systems, failing RFID performance, concerns about privacy and security, and standards development (Bahr and Lim, 2009; Lim et al. 2013).

Costing in warehouses

Besides traditional costing methods in warehouses that focus on capital costs and operating costs (Roth and Sims, 1991; Napolitano, 2003; Richards, 2011) there are several alternative approaches and this paper focuses on Time-Driven activity-based costing (TDABC).

Time-Driven activity-based costing (TDABC)

Time-Driven activity-based costing (TDABC) was proposed by Kaplan and Anderson (2007) and its basic premise is that it only requires two parameters to calculate costs: 1. cost per time unit of supplying resource capacity, 2. unit times of consumption of resource capacity by products, services, and customers. Using only two estimates simplifies the model and allows management to directly estimate demand for resources levied by each transaction, product or customer. Breakthrough of the TDABC model is in the time estimation: each activity has its duration time estimated depending on its characteristics called “time drivers”. Time equations model how time required per activity is affected by several drivers. Numerous benefits of the TDABC methodology are summarised by Kaplan and Anderson (2007) book tag line “a simpler and more powerful path to higher profits”.

To date, there are relatively few studies on use of the TDABC in logistics but, existing studies find it well suited to capture inherent complexity of logistic activities (Everaert and Bruggeman, 2007; Varila et al., 2007; Everaert et al., 2008; Zhang and Yi, 2008; Diaconeasa et al., 2010; Somapa et al., 2012).

Limitations of the TDABC model mainly focus on the errors in estimates and especially overestimations in time equations (Barrett, 2005, Cardinaels and Labro, 2009; Gervais et al., 2009). Inaccuracies with time estimates are addressed by the proposition of the RFID-TDABC.

The RFID-TDABC model: a new way to calculate warehouse costs

The RFID-TDABC is an extension of the TDABC methodology with the RFID data. Concept of the RFID-TDABC was firstly proposed by Bahr and Lim (2010), as a way to maximise the benefits of the RFID implementation at the warehouse and opened a new area for application of the RFID technology within the warehouse environment. The RFID-TDABC model is a response to requirement from the wholesalers for an instrument capable of linking ogistics process information and financial data (van Damme and van der Zon, 1999). Integration between the RFID and the TDABC is a directly addressing inaccuracies with time estimates in TDABC and an overestimation bias (Cardinaels and Labro, 2009). In the RFID-TDABC model exact time measurements are collected without a human intervention. The RFID-TDABC combines the RFID data captured during warehouse operation and the TDABC time equations. Figure 1 illustrates typical warehouse operations and the RFID data records that feed into TDABC time equation (t_i is time estimate, X_i is a time driver).

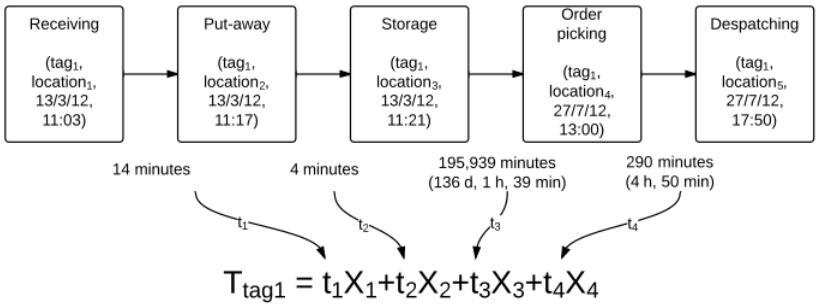

Figure 1: RFID data captured in warehouse and its relation to TDABC time equation.

Benefits of using the RFID-TDABC model

Implementation of the RFID-TDABC model at the warehouse has several benefits that transpire from merging logistical and financial accounting techniques. RFID-TDABC combines advantages and robustness of both techniques. Adding to that ease of implementation at business application level the RFID-TDABC is a solution for organisations that want to make better use of an already installed RFID technology or those who consider introducing either the RFID or the TDABC.

Case study

Case study started with the data collection at the Exquisite Bathrooms company using mixed techniques of: direct observations and mapping of warehouse activities (receiving, put-away, order picking, and despatching), time measurements, interviews with management and staff. Based on the collected data the TDABC implementation was carried out. Then, RFID technology was introduced and equipment necessary for this warehouse was specified (cost, type, etc.). Lastly, the RFID-TDABC implementation was carried out.

Results overview

Comparisons were made between “as is” warehouse activities (without RFID with TDABC) and “to be” warehouse with the implementation of RFID-TDABC presented in Figure 2.

Month	Receiving		Put-away		Order picking		Despatching	
	Time (h)	Cost (£)	Time (h)	Cost (£)	Time (h)	Cost (£)	Time (h)	Cost (£)
Jan	06:42:57	£ 189.39	07:00:44	£ 196.70	15:27:41	£ 433.69	04:02:34	£ 113.40
Jan	06:52:57	£ 194.09	06:39:19	£ 186.68	08:21:53	£ 234.63	01:53:41	£ 53.15
Jan	03:59:49	£ 112.71	06:00:10	£ 168.38	11:10:09	£ 313.30	02:39:55	£ 74.76
Jan	03:45:07	£ 105.80	06:46:00	£ 189.81	16:18:16	£ 457.34	04:02:20	£ 113.29
Feb					14:54:40	£ 418.26	03:42:18	£ 103.93
Feb	06:48:14	£ 191.87	07:55:54	£ 222.48	17:27:43	£ 489.80	03:57:19	£ 110.95
Feb					17:44:06	£ 497.47	04:11:49	£ 117.73
Feb	04:58:25	£ 140.25	04:46:21	£ 133.87	12:47:42	£ 358.90	02:49:11	£ 79.10
Mar	04:50:21	£ 136.46	05:48:59	£ 163.15	15:00:13	£ 420.85	03:28:17	£ 97.38
Mar	05:12:25	£ 146.83	07:03:21	£ 197.92	16:32:56	£ 464.19	04:31:36	£ 126.97
Mar	06:00:31	£ 169.44	06:16:53	£ 176.19	15:01:53	£ 421.63	03:42:13	£ 103.89
Mar	06:06:38	£ 172.32	05:17:40	£ 148.51	14:55:02	£ 418.43	03:52:20	£ 108.62

Results without RFID, TDABC used

Month	Receiving		Put-away		Order picking		Despatching	
	Time (h)	Cost (£)	Time (h)	Cost (£)	Time (h)	Cost (£)	Time (h)	Cost (£)
Jan	03:48:00	£ 107.16	07:00:44	£ 196.70	11:11:49	£ 314.07	02:41:16	£ 75.39
Jan	03:59:53	£ 112.75	06:29:19	£ 182.01	05:49:01	£ 163.16	01:22:10	£ 38.41
Jan	02:15:19	£ 63.60	05:40:10	£ 159.03	07:43:57	£ 216.90	01:51:09	£ 51.96
Jan	02:06:32	£ 59.47	06:06:00	£ 171.11	11:19:44	£ 317.78	02:41:05	£ 75.31
Feb					10:44:08	£ 301.13	02:33:03	£ 71.55
Feb	03:50:14	£ 108.21	07:45:54	£ 217.81	11:57:47	£ 335.56	02:37:04	£ 73.43
Feb					12:21:38	£ 346.71	02:48:40	£ 78.85
Feb	02:49:07	£ 79.49	04:46:21	£ 133.87	08:29:58	£ 238.41	01:50:34	£ 51.69
Mar	02:44:04	£ 77.11	05:48:59	£ 163.15	10:25:53	£ 292.60	02:21:51	£ 66.31
Mar	02:56:36	£ 83.00	06:23:21	£ 179.22	11:34:24	£ 324.63	03:04:30	£ 86.25
Mar	03:23:25	£ 95.60	05:56:53	£ 166.84	10:22:45	£ 291.13	02:33:00	£ 71.52
Mar	03:33:11	£ 100.19	05:17:40	£ 148.51	10:51:50	£ 304.74	02:41:05	£ 75.31

Results with RFID, RFID-TDABC used

Figure 2: Summary of results

Three months data about the cost of activities is combined and presented in a Figure 3a. Column ”No RFID” is a ”as is” state and column ”With RFID” indicates a ”to be” state. In order to give an insight into what an average week may be like in terms of savings, relevant calculations were made and their summary is presented in a Figure 3b.

Activity	No RFID	With RFID	Savings %	Savings £
Receiving	£ 1,559.16	£ 886.58	43.14%	£ 672.58
Put-away	£ 1,783.68	£ 1,718.23	3.67%	£ 65.45
Order picking	£ 4,928.49	£ 3,446.83	30.06%	£ 1,481.66
Despatching	£ 1,203.14	£ 816.00	32.18%	£ 387.14
Total:	**£ 9,474.48**	**£ 6,867.64**	**27.51%**	**£ 2,606.84**

A) Activity costs and savings combined results

Activity	No RFID	With RFID	Savings %	Savings £
Receiving	£ 155.92	£ 88.66	43.14%	£ 67.26
Put-away	£ 178.37	£ 171.82	3.67%	£ 6.54
Order picking	£ 410.71	£ 287.24	30.06%	£ 123.47
Despatching	£ 100.26	£ 68.00	32.18%	£ 32.26
Total:	**£ 845.25**	**£ 615.72**	**27.16%**	**£ 229.54**

B) Activity costs and savings in an average week without/with RFID

Figure 3: Activity costs and savings combined results

The meaning and significance of these results from the case study are provided in the next section.

Discussion of findings

The case study results in an average week with RFID-TDABC include: receiving activity time decreased by 43.14%, activity cost lower by £67.26; put-away activity time decreased by 3.67%, activity cost insignificantly lower by £6.54; eliminating storage issues: location empty, misplaced items, etc.; 100% stock/storage visibility (or nearly 100%); order picking activity time decreased by 30.06%, activity cost lower by £123.47; despatching activity time decreased by 32.18%, activity cost lower by £32.26; manual update of documentation eliminated; and item level insight into cost of activities.

The case study results indicate considerable potential savings of both time and cost. The implementation of RFID-TDABC raises questions about the value of the “minute savings” for the business. There are several reasons why “minute savings” are important. Firstly, there is a compounded effect of workers saving time in doing activities, as they can move to the next tasks increasing the daily warehouse throughput. Secondly, management may come to the conclusion that achieved time savings may indicate that current staffing levels may be adjusted, work hours reduced, or some staff moved to temporary contracts – which gives the business owner additional cost reductions and flexibility. Thirdly, as tasks are executed at higher speeds, it indicates a spare working capacity, which may prompt management to find additional warehousing contracts. The significance of cost savings is more straightforward and focuses on issues like: debt repayment, investing in the business (i.e. new technologies, equipment), expanding its activities etc.

Benchmarking with the literature

Referring these results back to the literature it can be seen that reductions on activity time are similar to those achieved by Lao et al. (2012), Chen et al. (2013), and Vlachos (2014). The increase in stock visibility to 100% corroborates with the findings by Yang et al. (2011). Lastly, overall improvements and shorter activity times are corroborate with results obtained by Wamba and Chatfield (2011).

Research questions: integrated discussion

RQ1: Can RFID provide "automatic accounting of the future"?

The case study showed how RFID system can be set up in a conjunction with the TDABC to provide automated accounting of warehouse activities (RFID-TDABC). RFID provided a time measurement element to the TDABC accounting method thus removing a need for manual time measurements and automating the accounting process. It remains to be seen if RFID-TDABC gains recognition among practitioners in the future, but this paper showed that RFID can provide data for accounting purposes and as such positively answered the RQ1.

RQ2: Can RFID be used in conjunction with a TDABC costing model? How can RFID benefit a TDABC costing model?

The findings from the case study show that RFID can be used successfully with a TDABC costing model. The RFID-TDABC being a combination of the RFID and the TDABC links advantages and robustness of both techniques and provides numerous benefits. Firstly, an intelligent use of the RFID data to track time and feed it to the TDABC model alleviates problems with accuracy of the TDABC time estimates. Organization benefits from easier and faster accounting model building with the RFID-TDABC, its scalability and meaningful results. Additionally, merging of operational and financial data provided by the RFID-TDABC gives management a better understanding of incurred costs. Added robustness of the RFID time measurements model of the TDABC gains more confidence not only of managers, but also it becomes easier to accept by staff as RFID based time measurements are objective. Moreover, it is possible to constantly review the costs, as the the RFID data is continuously being collected during activities. Findings from the case study show that RFID-TDABC may bring significant savings of operational time and money. Summing up, the RQ2 can be answered positively as the RFID-TDABC solution benefits a TDABC costing model.

RQ3: What is the impact of measuring time with RFID on a TDABC cost model?

The case study confirmed that there is a positive impact of using RFID with the TDABC model, as creating cost equations is simplified, the RFID data collection is automated and without a human intervention. RFID-TDABC provides the potential benefits of increased time measurement accuracy as well as a chance for operational improvements. Hence, the RQ3 can also be answered positively.

Research limitations and future work

In reflecting on the validity and reliability of this research, the four qualitative criteria recommended by (Lincoln and Guba, 1985) have been adopted: credibility, transferability, dependability, and confirmability. The credibility criterion involves establishing that the results of research are credible from the perspective of the participants in the research. Whilst there is always room for improvement in this area, this issue was addressed to some extent by inviting warehouse management to comment on summaries of the research findings. Obtaining results from only one

case study is not intended to be definitive and transferability is difficult. However, the process of continuously relating the empirical findings back to the literature helped in this regard. Dependability emphasizes the need for the researcher to account for the changing context within which research occurs. In this regard, the authors fully documented the whole process of implementing RFID-TDABC, from design through to analysis and results discussion. Confirmability refers to the degree to which the results could be confirmed by others. Future work should build on the findings of this research using the proposed methodology and making use of methodological triangulation.

Conclusions

This paper proposed the RFID-TDABC methodology, which merges RFID data with Time-Driven Activity Based Costing and implemented it in a warehouse environment. It is the authors hope that concepts and findings presented in this paper will prompt academics and practitioners to implement them in their own work. Thus further expanding the range of benefits provided by the RFID technology.

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