Association for Information Systems
AIS Electronic Library (AISeL)

2013 International Conference on Mobile Business | International Conference on Mobile Business (ICMB)

2013

The Performance and Reliability of a RFID Cycle-Count – A Quantitative Approach from Fashion Retail

Thomas Buckel
University of Würzburg, thomas.buckel@uni-wuerzburg.de

Frédéric Thiesse
University of Wuerzburg, frederic.thiesse@uni-wuerzburg.de

THE PERFORMANCE AND RELIABILITY OF A RFID CYCLE-COUNT – A QUANTITATIVE APPROACH FROM FASHION RETAIL

Buckel, Thomas, University of Wuerzburg, Chair of IS Engineering, Wuerzburg, Germany, thomas.buckel@uni-wuerzburg.de

Thiesse, Frédéric, University of Wuerzburg, Chair of IS Engineering, Wuerzburg, Germany, frederic.thiesse@uni-wuerzburg.de

Abstract

In recent years, several retailers gained experience with the implementation and use of radio-frequency identification (RFID). Although extensive benefits through the use of RFID have been discussed in academia and practice for many years, strategic approaches to reach the promised targets still are largely unexplored. To support practitioners with using RFID in retailing, the reliability of data generated by RFID in-store processes has to be investigated. As a starting point, we compare in the present study the quality of a RFID cycle-count to a physically conducted count. We collected data from a real-world implementation and completed parallel counts in 9 RFID pilot stores at a global fashion retailer. Our results based on an item-level error investigation show, that the error rate of a RFID cycle-count nearly is as low as the error rate of a physical conducted count. As a consequence for further research, more reliable data collected in a cycle-count lead to a better stock accuracy, more effective in-store replenishment processes and less stock-out situations.

Keywords: RFID, retail, cycle-count, inventory management, stock accuracy

1 Introduction

The rise of radio-frequency identification (RFID) has affected and even redesigned retail operations to a great extent. Especially in a fast forward moving retailing business with a rapid switching range of items, improved product and on-shelf availability is a key factor for a favorable and sustainable market position and in terms of fulfilling customer demands (Kotzab and Teller, 2005). The positive impact of a RFID implementation on these two factors as a consequence of better product monitoring have been analyzed for example by Hardgrave et al. (2009) and Wong et al. (2007). However, various reasons affect the reliability of product monitoring enabled through the RFID readers – theft, misplacements, mis-categorization, or imperfect read rates (Condea et al., 2012; Gaukler et al., 2007). To mitigate this issues in order to get a clean and reliable ‘snapshot’ of all actual product locations and quantities, the RFID cycle-count (an inventory count conducted at frequent intervalls) is a properly measurement.

The overall problem within the use of RFID is what Lee and Ozer (2007) call a "credibility gap". This phenomenon describes the lack of knowledge how the benefits described in academia can sustainably achieved. Transferring these findings to the actual case signify, that the benefit of a RFID cycle-count is evident, but not empirically verified. Only if the captured data during a RFID cycle-count is reliable and at least comparable to the accuracy of a conducted physical count, the results help to sustainably improve stock accuracy and on-shelf availability. Therefore, to address these lacks and to improve the credibility of RFID data, the present study addresses the following research questions:

RQ1. What facts cause most errors for a RFID cycle-count and a physically conducted count?

RQ2. Is the RFID cycle-count data reliable and comparable to the data quality of a physical count?

RQ3. Which count-type has the potential to solve occurring errors during the counting process?

RQ4. Can a physical cycle-count completely be replaced by conducting a RFID cycle-count?

To answer these review questions, we simultaneously conducted physical and RFID cycle-counts in 9 RFID pilot retail stores with an average stock of 6500 items. We compared the two counts and documented all errors, which were caused by the type of count with specific items. We further investigated all differences between both count-types to analyze the reasons for all occurring errors. Our analyses also provide insights into the reliablity of RFID for the use in retail stores.

2 Related Work

The aim of the first contributions in academic journals was to prime the RFID community about potential benefits, opportunities and applications as well as privacy perception (e.g., Angeles, 2005; Bose and Pal, 2005; Kärkkäinen and Holmström, 2002). While these publications can be classified as ‘general review articles’, more research methods were used and additional research areas emerged in the subsequent years. For example, other contributions focus on socio-psychological issues surrounding the adoption and acceptance of RFID (e. g., Bhattacharya et al., 2008; Li et al., 2010; Reyes and Jaska, 2007). Contributions using mathematical analytical modeling or simulation tools focus on issues like inventory inaccuracy or replenishment strategies (e.g., Condea et al., 2012; Gaukler et al., 2007). In addition, case studies from early adopters discuss for example particular RFID concepts (e.g., Bottani and Rizzi, 2007; Tzeng et al., 2008).

The existing literature reveals that RFID represents a wide field of research and emphasizes various aspects on the success of RFID projects. However, an empirical data set is usually missing. Moreover, contributions focusing on the measurement, performance or reliability of RFID process are scarce and usually can only be found in the form of short articles from practitioners with a limited scope. In particular, the literature lacks in case examples of real-world implementations and the issues that measure the performance and reliability of specific RFID processes.

3 RFID Cycle-counting compared to Physically Counting

The infrastructure of the pilot stores allows for performing a cycle-count at frequent intervals. The RFID count is conducted by using a mobile handheld. We prepared every RFID count with giving instructions to the persons, who were supposed to do the respective count. Those instructions included for example (i) searching for and relegating of loose RFID-tags, (ii) scanning instructions for different types of goods (e.g. hanging goods, flat goods, huge amounts of articles in boxes, shoe cartons standing on metal shelves) and (iii) properly handling of the mobile device hardware and software. The target of our instructions was to maximize the reading rate and to minimize reading errors.

The physical count was conducted by a third party (about 5-8 people per store depending on the size) while the parallel RFID count was conducted by one staff-member and monitored by ourselves after the scanning training explained above. After executing the two counts, the gathered data was exported and both files were matched in order to identify and separate the differences between the two count-types. The items, which produced errors, then were physically searched in the store and the type of error investigated. An investigation for example included the following steps: Is the item physically existing or was a loose tag scanned? Is the tag of the item working or is the item even double tagged? Does the amount of an item match the counted number of the external party?

The timeframe for our analysis was limited, because the stores had to be closed during the counts and investigations of all differences and all items must not be moved or removed. If the store had opened during the counts or the investigation phase, it would have been impossible to reveal all types of errors because some of the error producing items could have been sold for example. Even moving of the items would have extended the time required for the analyses to an unsustainable degree. The search function of the RFID handheld hereby decisively helped us to find all specific items during the limited timeframe. We finally aggregated and documented the results of our item-based investigation.

	Store 1		***Store 2***		***Store 3***		***Store 4***		***Store 5***		***Store 6***		***Store 7***		***Store 8***		***Store 9***		***TOTAL***	
	abs.nr	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***abs.nr***	***%***	***tot.nr***	***tot. %***
Summary of counts																				
Total counted RFID	5638		7068		7178		6360		6128		5164		5427		7050		8076		**58089**	
Total counted PC	5679		7081		7183		6358		6159		5142		5434		7070		8101		**58207**	
Real quantity in store	5733		7089		7212		6385		6198		5325		5448		7074		8136		**58600**	
Percent accuracy RFID		98.3%		99.7%		99.5%		99.6%		98.9%		97.0%		99.6%		99.7%		99.3%		**99.1%**
Percent accuracy PC		99.1%		99.9%		99.6%		99.6%		99.4%		96.6%		99.7%		99.9%		99.6%		**99.3%**
Total Difference RFID / PC	41	0.7%	13	0.2%	5	0.1%	2	0.0%	31	0.5%	22	0.4%	7	0.1%	20	0.3%	25	0.3%	**166**	**0.3%**
Item Difference RFID / PC	107	1.9%	236	3.3%	129	1.8%	125	2.0%	147	2.4%	124	2.4%	124	2.3%	146	2.1%	124	1.5%	**1262**	**2.2%**
RFID absulute errors	43	0.8%	88	1.2%	68	0.9%	48	0.8%	73	1.2%	161	3.1%	60	1.1%	80	1.1%	88	1.1%	**709**	**1.22%**
PC absolute errors	67	1.2%	24	0.3%	57	0.8%	68	1.1%	52	0.8%	173	3.4%	71	1.3%	85	1.2%	84	1.0%	**681**	**1.17%**
Reason codes: RFID count issues																				
R-1: Tag defect	8	0.14%	6	0.08%	10	0.14%	8	0.13%	17	0.28%	10	0.19%	8	0.15%	9	0.13%	13	0.16%	**89**	**0.15%**
R-2: Source tag missing	6	0.11%	7	0.10%	28	0.39%	12	0.19%	20	0.33%	15	0.29%	17	0.31%	35	0.50%	48	0.59%	**188**	**0.32%**
R-3: Wrong code	4	0.07%	1	0.01%	2	0.03%	1	0.02%	5	0.08%	0		0		2	0.03%	3	0.04%	**18**	**0.03%**
R-4: Tag missed during scan	13	0.23%	11	0.16%	16	0.22%	9	0.14%	18	0.29%	11	0.21%	21	0.39%	19	0.27%	5	0.06%	**123**	**0.21%**
Unscanned Area	0		0		0		0		0		86	1.67%	0		0		0		**86**	**0.15%**
Unknown difference	2	0.04%	35	0.49%	7	0.10%	0		8	0.13%	39	0.76%	1	0.02%	6	0.08%	0		**98**	**0.17%**
R+1: Loose tag	6	0.11%	16	0.23%	0		17	0.27%	1	0.02%	0		10	0.18%	6	0.08%	8	0.10%	**64**	**0.11%**
R+2: Wrong code	1	0.02%	11	0.16%	3	0.04%	1	0.02%	0		0		1	0.02%	2	0.03%	5	0.06%	**24**	**0.04%**
R+3: Double tag	3	0.05%	1	0.01%	2	0.03%	0		4	0.07%	0		2	0.04%	1	0.01%	6	0.07%	**19**	**0.03%**
Reason codes: Physical count issues																				
S-1: Item missed	19	0.34%	14	0.20%	36	0.50%	43	0.68%	41	0.67%	42	0.82%	30	0.55%	47	0.67%	32	0.40%	**304**	**0.52%**
S-2: Wrong barcode programmed	11	0.19%	1	0.01%	0		0		2	0.03%	2	0.04%	0		0		2	0.02%	**18**	**0.03%**
S-3: Product not shown	3	0.05%	2	0.03%	0		2	0.03%	0		116	2.25%	11	0.20%	11	0.16%	12	0.15%	**157**	**0.27%**
S-4: Unknown item	9	0.16%	0		11	0.15%	5	0.08%	2	0.03%	0		7	0.13%	0		11	0.14%	**45**	**0.08%**
S+1: Counted too many	20	0.35%	7	0.10%	8	0.11%	13	0.20%	3	0.05%	13	0.25%	18	0.33%	21	0.30%	8	0.10%	**111**	**0.19%**
S+2: Empty shoe carton	5	0.09%	0		2	0.03%	5	0.08%	2	0.03%	0		5	0.09%	6	0.08%	18	0.22%	**43**	**0.07%**
S+3: Wrong barcode programmed	0		0		0		0		2	0.03%	0		0		0		1	0.01%	**3**	**0.01%**

Table 1. Results and numbers of the conducted cycle-counts in every pilot store

The results of both counts in every store are given in Table 1. The particular columns show the results for each store whereas the column on the right shows the aggregated numbers. Overall, a total of 58089 items have been picked up during the RFID counts and 58207 items have been physical counted. The *Real quantity in store* shows the number of items, which should be in the store based on sales and replenishment data. The *Percent accuracy* for *RFID* and the *physical count (PC)* is calculated by the relation of the *Total counted* pieces in each case and the *Real quantity in the store*.

The *Total differences RFID/PC* show the absolute differences among the conducted counts by comparing the total scanned and counted numbers. However, the *Item Differences RFID/PC* show the differences between the two conducted counts based on item-level. Hence, this ratio is not influenced by negative and/or positive differences partially cancelling each other out. For example, the RFID count picked up a specific item which was not physically counted whereas another specific item was physically counted, but not RFID-scanned. This situation would cause no *Total Difference* but two *Item Differences*. The next two lines show the *absolute errors* for RFID and the physical count. This number sums up all particular errors for both count types which are listed below. Based on our investigations, we can report 709 total errors (RFID) respective 681 total errors (Physical count).

In the first instance, we documented all identified quantity errors. We then categorized them during several expert discussions and derived a total of 16 *Reason codes* in a second step (see Table 1). A reason code describes the type of an occurring error and can be interpreted as follows:

- A R-code (R+code) indicates, that the specific error – arose out of the RFID count – incorrectly lowers (increases) the stock level.
- A S-code (S+code) indicates, that the specific error – arose out of the physical count – incorrectly lowers (increases) the stock level.

The total distribution on a percentage basis for all shown reason codes, total differences and total errors has been calculated using the average value of the total RFID-scanned items and physically counted items.

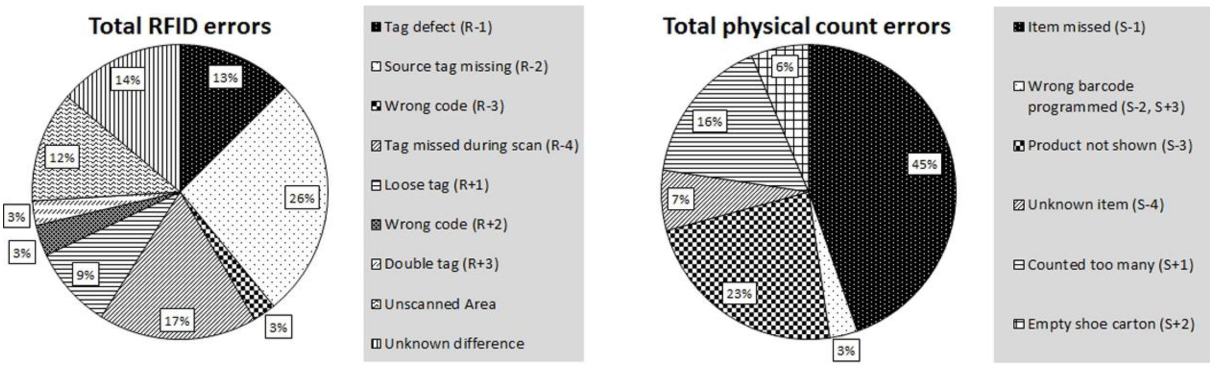

Figure 1. Total distribution of errors

Figure 1 visualizes the reason code totals in a different way. By this depictive representation it is easier to identify the types and quantities of errors. Apart from the 14% Unknown difference, where the reason for the specific error could not be distinctly determined, we assigned the specific RFID errors to various error sources. For example, 38% of 709 **RFID errors** (which represent 1.22% of the average of scanned and physically counted items) can be attributed to human issues:

- 17% of RFID error items were not caught during the scan. A reason for that type of error can be for example, that the scanning person did not follow the given instructions carefully.
- 12% of RFID error items were located in an area, which was not known as a stock area by the person, who did the RFID cycle-count.
- 9% of RFID error items were caused by loose tags. This could either be assigned to carelessness regarding the destroying of sold tags or to an evidence of shrinkage – a theft potentially detached the RFID tag in order to bypass the Electronic Article Surveillance, provided by a RFID antenna.

Technical issues cause 19% of all RFID errors:

- 13% of error causing tags were defective and can be assigned to the tag-printers for instance.
- 6% of error causing tags were equipped with wrong codes leading to a wrong stock quantity.

Distribution center or production center issues cause 29% of all RFID errors:

- 26% of error items did not have a source tag.
- 3% of RFID error producing items each were provided with two tags. Therefore the staff at the production centers or at the distribution center did not apply any tag or applied to many tags to the respective products.

The 681 **Physical count errors** represent 1.17% of the average of scanned and counted items. 45% of these error items were missed or overseen. This can happen if merchandise simply slid down below a shelf/rack or if the person was not highly concentrated during the counting process. 6% of the physical count errors were produced, because shoe cartons were counted though they were empty. Comparable to the not scanned RFID area, 23% of all physical count error items were not shown to the third party doing the count. System issues caused 10% of all errors (3% wrong barcodes programmed and 7% unknown items) whereas 16% of all physical count error items were size-mismatches.

4 Discussion

All explored figures finally answer *RQ1* and show situations in the form of reason codes, which cause errors for both count-types. In addition our analysis reveal, that the total error rate of a physical count is just slightly better (1.17% error rate compared to 1.22% error rate for a RFID count). It even can be said that a RFID cycle-count is on a level with a physical count, if instructions are given to the persons who conduct the count. Hence, consulting only those figures, we can answer *RQ2* with a plain “yes”.

Beside these absolute numbers, more facts have to be considered. RFID errors can be eliminated for instance by teaching the staff how to do a careful count, how to handle tags of sold articles correctly, how to show up all scanning areas and how to tag products in the DC or at the production centers. As opposed to this, physical count errors barely can be eliminated by teaching an external party who conducts the count. When human caused errors during a RFID cycle-count are eliminated, it potentially corrects most of the identified errors of a physical count. Missed items during a physical count (for example items which were slipped under a rack) are scanned with RFID because no line of sight is necessary. A size mismatch (counted too many or too less of a certain size of a specific item) is no issue during a RFID cycle-count, because the corresponding EPC codes are unambiguous and based on item-level. For instance, if a shoe carton is empty and the tag is attached on the shoe which is physically not inside, a RFID scan would not add this item to inventory. All facts show as related to *RQ3*, that a RFID cycle-count has more potential to eliminate occurring errors of both count-types.

Contiguous to all reasons given above, a RFID cycle-count can be accomplished by one trained staff member. We measured a pick rate of one item per 1.1 seconds while doing a careful count. Considered an average stock level of 7000 pieces, a total scan of one store takes about 116 minutes. A third party bringing at least 5 persons who conduct the count claims a much longer period of time. When it comes to *RQ4*, it is difficult to give a clear answer. Our gathered data show, that technical issues of a RFID cycle-count are rare and thus negligible. Based on that fact, a physical count potentially could completely be replaced by a RFID count. However, for replacing the end of the year stock take, legal requirements also have to be considered while recurring cycle-counts can be completely substituted.

5 Conclusion

From a practitioner’s perspective, the study allows for a number of implications. The cycle-count is an essential tool for keeping the stock accuracy up to date, but still is connected with enormous personal and time effort when conducted physically. Our research affects the decision for using RFID for cycle-counts, due to the fact that the reliability and performance of that process is empirically tested. The potential of RFID implementations in retailing is even more substantial, since stores in certain markets perform physical counts every day. We also show current weaknesses of RFID and propose solutions for error situations, which could be helpful for a store manager to increase the RFID data reliability.

As for other studies of this kind, our research is not without limitations. In particular, error codes cannot always be assigned with 100% accuracy to a certain situation. For example, loose tags are a huge problem because these tags are picked up during each RFID cycle-count and lead to an incorrect stock level. Furthermore, these ‘items’ cannot be sold because they physically do not exist and subsequently even possibly are never replenished. However, the reason for these loose tags can be different – either, this could be assigned to carelessness regarding the destroying of sold tags or to external theft, where the staff is not directly to blame for. Moreover, a total of 98 error producing RFID items (14% of RFID errors and 0.23% of total scanned items) could not be investigated. Either the reason for the error was ambiguous or the limited timeframe did not allow to investigate all documented differences between the two count-types. Due to space considerations, we also can not include any cost factors, which certainly affect the decision for implementing RFID in retail stores.

Our study may serve as a basis for further research in various directions. Future research could include empirically testing of other RFID in-store processes like goods receiving or in-store replenishment. In addition to that, RFID data mining still is an broadly untapped area of research. However, more reliable RFID data enables more meaningful analyses and even new methods of RFID data mining.

References

Angeles, R. (2005) “RFID Technologies: Applications and Implementation Issues”, Information Systems Management 22(1), pp. 51-65.

Bhattacharya, M., Chu, C., Mullen, T. (2008). A Comparative Analysis of RFID Adoption in Retail and Manufacturing Sectors, in: Proceedings of the 2008 IEEE International Conference on RFID, pp. 241-249 Las Vegas, Nevada, USA.

Bose, I. and R. Pal (2005) “Auto-ID: Managing Anything, Anywhere, Anytime in the Supply Chain”, Communications of the ACM 48(8), pp. 100-106.

Bottani, E., Rizzi, A., "Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain. International Journal of Production Economics", 112, 548-569, 2008.

Condea, C., Thiesse, F. and Fleisch, E. (2012). RFID-Enabled Shelf Replenishment with Backroom Monitoring in Retail Stores, Decision Support Systems 52(4) (2012) 839-849.

Gaukler, G.M., Seifert, R.W., Hausman, W.H. (2007). Item-Level RFID in the Retail Supply Chain Production and Operations Management 16(1), pp. 65-76.

Hardgrave, B.C., Aloysius, J., Goyal, S. (2009). Does RFID improve inventory accuracy? A preliminary analysis, International Journal of RF Technologies: Research and Applications 1(1) (2009) 44-56.

Kärkkäinen, M. and Holmström, J. (2002). “Wireless product identification: enabler for handling efficiency, customisation and information sharing”. Supply Chain Management: An International Journal 7(4), pp. 242-252.

Kotzab, H. and Teller, C. (2005) Development and empirical test of a grocery retail instore logistics model, British Food Journal 107(8) (2005) 594-605.

Lee, H. L., O. Ozer. 2007. Unlocking the value of RFID. Production and Operations Management 16(1) 40–64.

Suhong Li, Danielle Godon, John K. Visich, (2010),"An exploratory study of RFID implementation in the supply chain", Management Research Review, Vol. 33 Iss: 10 pp. 1005-1015.

Reyes, P.M. and Jaska, P. (2007). “Is RFID right for your organization or application?". Management Research News, Vol. 30 Iss: 8 pp. 570-580.

Tzeng, S., Chen, W.P. (2008) Evaluating the Business Value of RFID: Evidence from five case studies. Internation Journal of Production Economics, vol. 112(2), pp. 601-613.

Wong, C.Y., McFarlane, D. (2007). Radio frequency identification data capture and its impact on shelf replenishment, International Journal of Logistics: Research & Applications 10(1) (2007) 71-93.