A STUDY OF INVOICELESS PROCESS USING RFID IN CONSTRUCTION FIELD

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ABSTRACT : Application of radio frequency Identification (RFID) technology in construction industry is not that progressive compared with other industries, because of it's high price experimental research. This research focus on potential application of RFID which eliminate manual data entry and introduce the potential for automated processes to increase project productivity, construction safety, and project cost efficiency. This paper suggest an invoiceless system using RFID technology, Process productivity and efficiency for material management is observed through WebCYCLONE and is compared with other processes.

Key words : RFID, Invoiceless,Web CYCLONE

1. INTRODUCTION

The era of ubiquitous is blossoming thanks to technological advancements, social and political supports. In particular, RFID (Radio Frequency Identification), a core sensor of ubiquitous networks, has been recognized as bringing innovations to logistics operations and applied in various industries. The engineering and construction industry has also been influenced by this trend, but it sees less performance on RFID applications than other industries. Most of studies have concentrated on RFID-applied framework and prototype. However, they have failed to raise productivity through comparison between RFID tools and existing tools.

Therefore, this study is designed to find empirical data through a study of productivity of existing process tools and RFID. Further, it aims to contribute to various applied studies by proving efficiency of RFID.

To this end, this study reviews technological level, possibility of application, and coverage of RFID, which can be applied to construction sites. With based on this, we propose and review a RFID-applied model for truck mixer's invoice process requiring timely delivery.

For objective verification, we observe features of individual processes in order to compare and analyze existing invoice process, BarCode-attached invoice, and the process for which invoice is replaced by RFID. And we make simulation by using Webcyclone so as to draw objective data on productivity. Basic data necessary for modeling are acquired from interviews with researchers of documents.

2. RFID

2.1 The technical status of RFID

Radio Frequency IDentification (RFID) is a method of storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is a small object, such as an adhesive sticker, that can be attached to or incorporated into a product, animal, or person. RFID tags contain antennas to enable them to receive and respond to radio-frequency queries from an RFID transceiver

RFID's tag is classified into active type requiring power sources and passive type functioning with the electromagnetic field of reader without supply of electric power from the inside or the outside. Active type may reduce required electricity for reader and lengthen recognition distance from reader. However, it has the limitation in working time because it requires power supply unit, and it is more costly than passive type. On the other hand, passive type is lighter and cheaper than active type, and it can be used almost permanently. But it has such demerits as shorter recognition distance and consuming more electricity than active type.

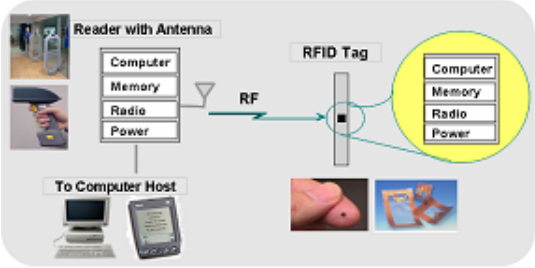

Figure 1. RFID Component

<Table 1> shows differences between general RFID and similar media. Unlike magnetic cards and IC cards, RFID and Bar Code can read data without contacting them within a certain distance. In addition, RFID can be used almost permanently as there is little damage despite continuous use unlike Bar Code. Meanwhile, since recognition of Bar Code covers 0cm to 30cm, its rate of recognition sharply decreases as the distance from reader grows. However, passive type of RFID shows more than 99.9% of recognition and relatively quick recognition within up to a 27m distance. As well, it can keep security intact because it is impossible to reproduce, and it has permeability through the use of frequencies and can read several RFIDs at one reader simultaneously. It can also be reused since it is able to read and write and record sufficient information because it has the capability of saving 64000byte.

Table 1. Media Classification

	BarCode	Magnetic Card	IC Card	RFID
Sensing Method	Untouch	Touch	Touch	Untouch
Sensing Distance	~ 30cm	Insert (0cm)	Insert (0cm)	~27m
Sensing Speed	2~4 sec	4 sec	1 sec	0.01~1sec
Sensing Rate	less 95%	99.9 over	99.9 over	99.9 over
Permeability	X	O	O	X
Using Times	-	Less than 10000 times (4 Years)	Less than 10000 times (5 Years)	Less than 100000 times (60 Years)
Data Save (byte)	1~100	1~100	16~64000	~64000
Data write	X	O	O	O
Damage Rate	Very High	High	High	Very Low
Cost	Cheapest	Cheap	Expensive ($10 over)	Normal ($0.3~$1)
Reproduction	Almost Nothing	Almost Nothing	Almost Nothing	Never
ReUse	X	X	O	O

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2.2 Development possibility of RFID

The global RFID market is expected to grow from $3 billion in 2005 to $10 billion in 2010 (as for Korean market, W66 billion in 2003 and W318 billion in 2007). This is based on the trend that the global RFID market has grown by more than 25% every year starting 1996 ($600 million recorded). This trend appears to be continued.

Since the international standard for RFID frequency bandwidth was determined in 2004, discussions about integration of international standards have continued. In particular, Korea has established world-level telecommunication infrastructures conducive in applying ubiquitous technologies as well as mobile communication networks, high-speed Internet technologies. In addition, the government policy (IT839) associated with IPv6 adds potentials to RFID application.

2.3 Application of RFID in Construction Field

In the engineering and construction industry, RFID is expected to be applied to tremendous construction equipment, transportation means like vehicles, or construction materials and human resources management. To this end, recognition distance and speed are important. Given that, 433Mhz Active type and 866~915Mhz Passive type are expected to be used as applicable RFIDs. <Figure 2.>

433Mhz Tag as Active type has its own power and can recognize up to a 50m distance. So it is expected to be applied to a variety of divisions such as linkage to ubiquitous sensing components, prevention of safety accidents, equipment and magnitude managements. But it will probably be difficult to commercialize because its price is nearly $20 and its lifetime is limited due to problems of battery.

Figure 2. The Specific of RFID TAG as the Frequency Term, Korea Institute of Construction Technology

Table 2. Frequency classification of RFID application In Cons.

	433Mhz Active Tag	866~915Mhz Passive Tag	2.52Ghz Passive Tag
Construction management	-Resource procurement management - Progress management -Tool & facilities management - Truck mixer management - Waste management\		
Personnel management		- Labor management - Manufacture management	
Security Management	- Safety accident protection - Construction field Security		
Maintenance management	The soft ground and Foundation monitering - slope collapse monitering -facilities Maintenance management		

On the other hand, 866~915Mhz tag as Passive type can recognize more than 1m and priced at merely $1. Moreover, its price is expected to fall further. (See Figure 3) In addition, it can be applied to almost all matters including procurement of materials, magnitude management, and maintenance of facilities.

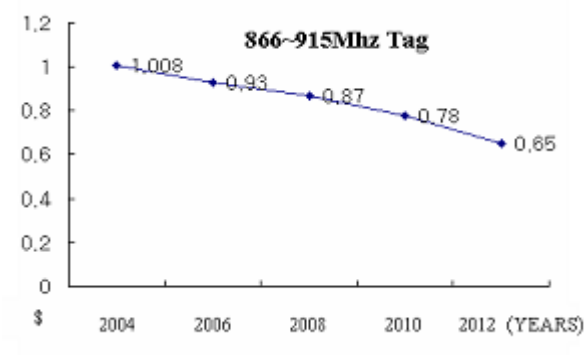


Figure 3. 866~915Mhz Tag Price

3. INVOICELESS WORK PROCESS USING RFID

Invoice as on-site document for materials management plays the role of conveying information. With respect to invoice flow, a factory receiving orders issues three copies of invoice, delivers two copies (1 copy for builder and 1 copy for order placer) to on-site managers after materials are carried into the site and inspection is made by on-site managers), and then keeps the remaining 1 copy under the existing invoice method.

Invoice checks on the site are normally made once to prevent delay, but information processing through invoices must slow as kinds and inputs of materials increase. Should invoices are collected for a certain period of time, they will be compiled en bloc and become DB to the level of headquarters. But this job requires considerable time and energy. If it is resolved, efficiency will be more raised. So this study is intended to propose RFID-using Invoiceless Process.

If RFID is used in place of invoice, we can store additional information on RFID's memory, in addition to existing information on materials. As all information may be readable when passing the reader installed on the site, required jobs can be done without human resources. As well, the information stored in RFID can be linked to various types of information systems because they are read and accumulated on Data Base. Using it, we can figure out progress of operations from order placer, materials factory, and builder on a real time base over the Internet. This will secure transparency and safety of construction and raise efficiency. In addition, RFID reader can receive information on more than 30 RFIDs.

Considering the afore-mentioned features of RFID, we can expect the following effects in using Invoiceless Process using RFID.

- Grasping the time of carrying-in of materials
- Improvement of communications between on-site managers and materials factory
- Accumulation and application of real-time date
- Strong control over materials transporting vehicles
- Efficiency in jobs of persons in charge of materials
- Efficiency in on-site jobs

Table 3. Process comparison by Invoice tool

	Invoice Process	Barcode Process	RFID Process
Product	Paper	BarCode+Paper	RFID
Info. Range	All(Standard)	Little	All / More
Sensing range	Direct	Short	Long
Permeability	×	×	O
Reuse	×	×	O
Detecting Location	×	×	O
Data process	Long time by Term	Real time using DB	Real time using DB
Data size	Normal	Normal	Big
Safety	×	O	O
Linkage with IT system	×	O	O
Monitering	×	O	O

4. PROCESS ANLAYSIS BY CYCLONE SIMULATION

4.1 Simulation Engine(Program) Selection

Designing a simulation model for any process is dependent upon the simulation engine(Program) that is used. Therefore, simulation modeling for the same process is different from one simulation one engine to the other according to its functions and code requirements. The simulation engine that has been used in this study is WebCYCLONE developed by Division of Construction Engineering and Management, Purdue University USA. This program uses different elements that represent each construction process activity. The elements of WebCYCLONE that are used to model and simulate Construction process activities are shown in Table 3.

CYCLONE stands for CYCLic Operations NEtwork. It is a modeling technique that allows the graphical representation and simulation of discrete systems that deals with deterministic or stochastic variables.

Construction processes simulation using the CYCLONE methodology, abstracts the reality into a graphical

representation by dividing the process into discrete pieces or work task and by representing how these interact.

Invoice process, Barcode-invoice process and Invoiceless process using RFID model design are shown and explained in detail in the following section

Table 4. CYCLONE Element Description

Name	Symbol	Function
Combination (COMBI) Activity		This element is always preceded by Queue Nodes. Before it can commence, units must be available at each of the preceding Queue Nodes. If units are available, they are combined and processed through the activity. If units are available at some but not all of the preceding Queue Nodes, these units are delayed until the condition for combination is met.
Normal Activity		This is an activity similar to the COMBI. However, units arriving at this element begin processing immediately and are not delayed.
Queue Node		This element precedes all COMBI activities and provides a location at which units are delayed pending combination. Delay statistics are measured at this element
Function Node		It is inserted into the model to perform special function such as counting, consolidation, marking, and statistic collection
Accumulator		It is used to define the number of times the system cycles
Arc		Indicates the logical structure of the model and direction of entity flow

4.2 Factors that Affect Process productivity & Process Modeling

This study rules out moving time of truck mixer, pouring time, and other environmental factors in order to only consider Invoice, Barcode-Invoice, and RFID's access time.

As seen in <Table 5>, factors influencing the process's productivity are inspected through documentary survey, on-site visits, and interviews with on-site managers.

As for invoice and barcode-invoice, we consider printing time since it has to print paper invoices. And we set checking time at less than 30 seconds due to the necessity for artificial checks except for delivering time.

As for barcode and RFID, we set recognition speed with the reference to data of <Table 1> and set breakdown in modeling by considering recognition rates.

Table 5. MicroCYCLONE Element Description

	Invoice Paper process	Barcode Invoice Process	Invoiceless Process
Element	Invoice paper Com & Printer Officer Truck Truck Driver Worker	Invoice paper Com & Printer Officer Writer BarCode Truck READER in fac. Truck Driver READER in con. Worker	Officer Truck on RFID Writer/Reader in fac. Computer Writer/Reader in con.
Access Time (sec)	Printing : 5~20 Checking : : 10 30sec	Printing : 5~20 Checking : 10~30 sec Sensoring : 1~4 sec Reread : 2~8sec	Sensoring : 0.01~0.1 sec Rereadiing : 5~20 sec

4.3 Process CYCLONE modeling and Description.

4.3.1 INVOICE PROCESS

- At the beginning of simulation, The Invoice paper, computer with Printer and officer have to available as shown in Ques 1, 2 and 3, respectively.
- The printer will be ready for printing as shown in node 4.
- After Printing the Invoice paper, the printed Invoice paper, Truck with material and Driver has to be available as shown is Ques 5, 6 and 7 for checking at Node 8.
- Truck is moved to another location for pouring as shown in node 9.
- After Pouring as in node 10, the Invoice paper is checked by worker which is shown Ques 11, 12 and node 13.
- Finally the Invoice paper is Distributed to stakeholder, contractor and Factory officer

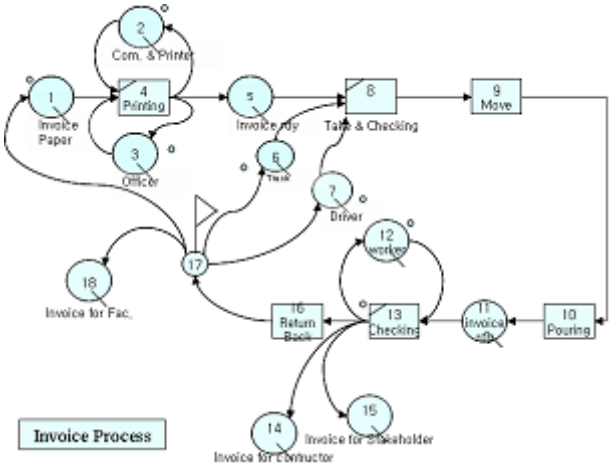


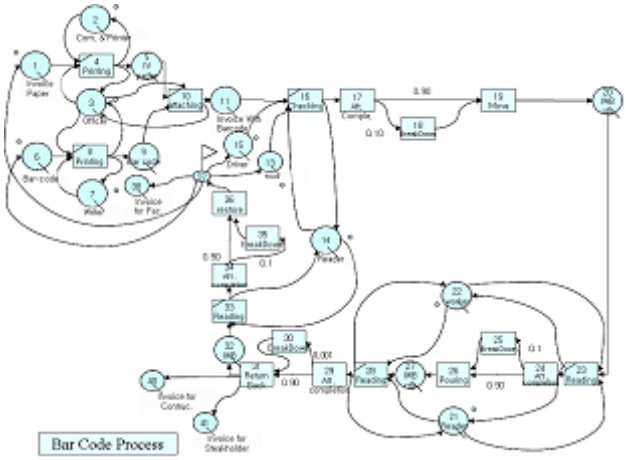
Figure 5. Invoice Process Model

4.3.2 BAR CODE PROCESS

- At the beginning of simulation, Invoice paper, Computer with Printer and officer have to available as shown in Ques 1, 2 and 3, respectively.
- The printer will be ready for printing as shown in node 4.
- Invoice paper is made ready for attaching Bar code as

shown in Que 5.

- Prior to attaching the bar code in the invoice paper the bar code is written using a writer and printed which is shown in Ques 6, 7 and node 8.
- The printed bar code as shown in Que 9 is attached to the paper at node 10.
- The invoice with Bar code, Reader, Driver and Truck has to be available as shown in Ques 11, 13 and 15 for checking at node 16.
- As sensing rate for Bar code is less than 95% there is chance of breakdown which is shown in node 18, 25, 30 and 35.
- Worker, Reader and Invoice paper must be available as shown in Ques 20, 21, and 22 for reading at node 23.
- After completion of reading as in node 24, pouring is done as in node 24.
- The Invoice paper with Bar code is again made to read using the Reader as shown in node 28.
- After completion of reading as in node 29, the Invoice paper is distributed to stakeholder and contractor as shown in Ques 40 and 41
- Finally using reader the invoice paper is made read and delivered to the Factory officer



Figuire 6. Bar-code-Invoice Process Model

4.3.3 Invoiceless Process using RFID

- At the beginning Truck, Computer and RFID reader/Writer machine has to available as shown in Ques 1, 3 and 4.
- Being available, the machine will write in the RFID tags as shown in node number 2.
- As the sensing rate of RFID is nearly 99.9%, so the chances of breakdown are very less which is shown in no 6.
- The truck with RFID tag on it is moved to another location as shown in node no 7 for Writing/Reading which is shown in node 10.
- After pouring concrete as in node 13, the truck with RFID tag is again made to write/read as in node 15.

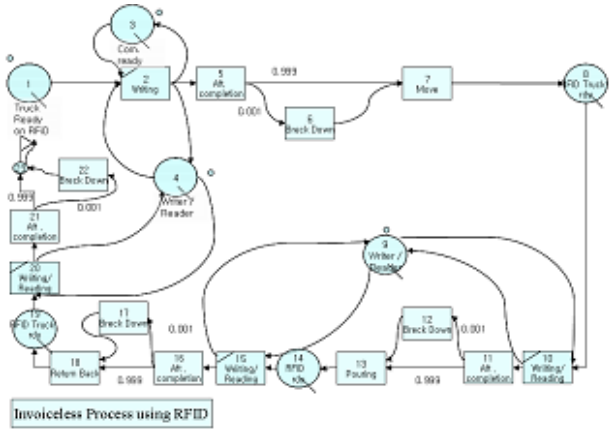


Figure 7. Invoiceless Process using RFID Model

4.4 Results analysis.

Since RFID process requires faster sensing time without workers on the site unlike other processes, it shows approximately 4.7256 of productivity in the simulation using CYCLONE. This figure is 241 times higher than Invoice Process (0.0195) and 544 times higher than Barcode process (0.0087).

As well, the productivity for Barcode-invoice Process is 2.25 time lower than that of Invoice process.

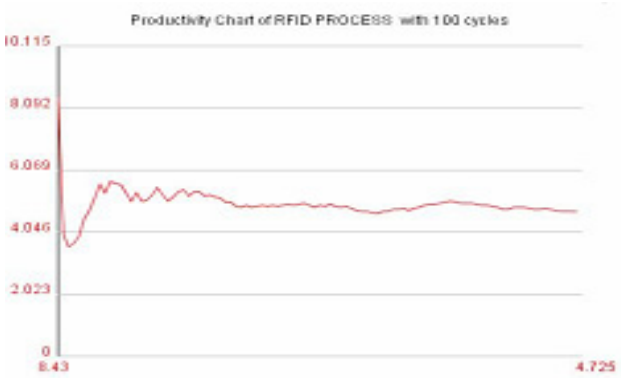


Figure 8. Productivity chart of Process Using RFID

Table 5. CYCLONE Simulation Results

	Invoice Paper process	Barcode Invoice Process	Invoiceless Process Using RFID
Sim. time	5122.5	11543.0	21.2
Productivity	0.019521534752	0.008663246049	4.7246097883

5. CONCLUSION

This study reviews the possibility and coverage of the application of RFID technologies that can be used on the construction site and looks into several effects of RFID applications on existing invoice processes with respect to procurement of truck mixer within a limited time.

Through this study, we can know that the number of human resources dispatched to Invoice Process, Barcode-invoice process, and RFID-using process has been reduced. As well, we obtain the data that RFID's productivity is 241 times higher than Invoice Process and 544 times higher than Barcode process as the result of CYCLONE-using simulation.

Wrapping up this, it is expected to not only raise productivity of the process itself through the replacement by RFID but also increase efficiency for construction management by making use of a lot of data information stored on a real-time basis. It is also understood to shorten a term of works through the application of 'Just in Time' technique at metropolitan areas where it is difficult to store materials on an open area.

Once international standards for RFID are incorporated, RFID's applications will be more expanded through ubiquitous sensing technologies and linkage and contribute to informatization of the construction industry.

ACKNOWLEDGMENT

This work was supported by the Brain Korea 21 Project and R&D of Construction and Transportation in Korea

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