A Study of the SMART container monitoring system in the ocean shipping industry

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Abstract: There are more than 146,172,823 TEUs containers handled through the top ten container ports in 2006. With such a large amount of container throughput, how to accurately read the container I.D. at the gate during their entering into and leaving from a container yard is a major issue. An appropriate monitoring system can not only improve the yard's operation efficiency but also reduce the yard's operation cost.

There are two types of technology currently employed to help identify the container external markings with detailed cargo information, namely, (1) Optical Character Recognition (OCR) and (2) Radio Frequency Identification Tag (RFID). According to the author's knowledge, there is no academic study to compare the cost and benefit of the two container monitoring technologies systematically. This research employed the AHP methodology to find out the major criteria influence the container yards' monitoring system selection decision by distributing AHP expert questionnaires to major stakeholders in the ocean container shipping industry in Taiwan.

The initial finding indicates using an OCR system could result in a higher benefit /cost ratio, which means OCR is perceived to be the better container monitoring systems by most of the major carriers in Taiwan.

Key Words: AHP, OCR, RFID.

Introduction

There are more than 4600 container vessels serve the 4000 container terminal. More than 80% of international general cargo trade is shipped by containers, and there is around 72 million containers fleet available in the maritime transportation industry (The Economist, 2002). Each container has its own serial number which is similar to a citizen's social security card number in the United States. The container serial number is also used by shipper, carriers, custom, and consignees to identify the cargo content and track the container flow. The container serial number is shown in six different positions of the container, thus the users can have convenient access to identify the serial number. Currently, most serial number of the container is identified manually in most container terminals. In another word, it is read by the container inspector without resorting to any automation gadget. Misread number could be occurred due to the distance, angle, insufficient intensity of light, and poor container position in the yard between the inspector and the container. Reading errors could be also resulted from the inspectors' oversight. These omissions and errors usually result in lengthy delivery delay and extra expenses.

To avoid the risk of inspectors' omission and negligence, two types of techniques are normally suggested to improve the container identification process, namely, Optical Character Recognition (OCR) and Radio Frequency Identification (RFID). Some modern container vessels have reserved spaces for installing RFID readers, but RFID is not used currently by any major ocean container carriers to identify container numbers. APL was the pioneer to invest several million US dollars to install RFID tag (the so called Auto Equipment Identification tag, AEI tag) on its containers fleet around the 1990s. The AEI tag scheme was abandoned by the APL because of the emergence of alliance operation. The AEI tag cannot function in a terminal operated by the APL's alliance carriers because the AEI reader was just not available in APL's alliance carriers' terminals.

Optical character recognition (OCR) is the technology to translate the printed or handwritten text and images into a machine-readable data, transfer information from a non-computer-retrievable medium into computer retrievable ones (Sun et al., 1992), and it was used by the United States Postal Service in as early as 1965. The OCR is also employed by many professionals in the semiconductor, automotive, and pharmaceutical industries to track and control cargo flows (Menard, 2008). Printing and image quality of an OCR code will influence its reliability. In addition, OCR is usually used in a harsh environment where the image quality is not easily obtained by the OCR reader.

The commercial application of RFID was firstly initiated by the Raytheon Corporation by releasing its 'Raytag' product, and similar RFID tag were produced by RCA, Fairchild Semiconductor, and Schlage Electronics (Shepard, 2005). A typical RFID system should include three major components, the transponder (can be active/passive transponder), the reader, and the data collection application. An active RFID transponder is battery powered and has a read range as much as 15 meters. Thus it can be used to identify individual containers in a shipping environment. For highway toll-collection and container shipping applications, a typical RFID device is operated in the ultra high frequency or microwave range (e.g. 900 MHz or 2.45 GHz in the U.S.A., or 5.8 GHz in Europe). The function of RFID can be adversely affected by moisture, and the UHF and microwave range RFID device is not licensed in Japan and parts of Europe respectively (Shepard, 2005). RFID cannot be used globally without a universal standard, the electronic product code (EPC), for immediate, automatic, and accurate product identification. The EPC was firstly developed by MIT to establish an internet-based system to identify products anywhere in the world in the early 2000s.

Strength and Weakness of the RFID and OCR Techniques

Ocean container carrier is a third party logistics service provider, it take cargo from the shippers and use trains or trailers to move container to a container depot or a container terminal to await the container vessel's loading operation. Without the cargo manifest, truckers, container carriers, and terminal operators cannot acquire the cargo information they need. Supply chain management is strived to pursue the integrated logistics management (Blanchard, 2006). Manufacturers and suppliers embedded the RFID tags into their products during the manufacturing processes, and stored their products information in the active RFID tag on the containers during their loading and discharging stage. Thereafter, the container and cargoes can be traced ubiquitously by the RFID reader. Information of container number, shippers, cargo contents, quantity, booking number, loading/discharging ports, and consignee etc. can be easily obtained and managed. The RFID tag used in the container shipping industry is normally an active, and microwave-length tag, class 2 RFID tag is potentially to be used by the carriers to track their containers. With a unique container serial number, it is reported the RFID reader can almost 100% obtain the container information correctly (Kima, 2007). However, there are problems in using RFID to monitor container movement. Firstly, the active RFID tag is more expensive than the OCR, and the battery in an active RFID tag can only be used up to 6 years. Secondly, the industry wisely prevalence of RFID reader in container terminals is not available.

Most literatures on the OCR are limited to the static character recognition. According to the authors' knowledge, extant academic research on the OCR application in container shipping industry is not available. Post 911 catastrophe in 2002, ISPS (International Ship and Port Facility Security Code) demand foreign containers destined for USA have to be inspected by the Integrated Container Inspect System(ICIS). ICIS includes vehicle and cargo inspection, radiation portal monitor, optical character recognition, and pulsed-neutron elemental analysis subsystems. Containers with OCR serial number can be recognized by the OCR reader if the trailer speed is below 40 kilometers per hour (Orphan et al., 2005). Nonetheless, there are still two problems to be overcome by using the OCR in container shipping industry. Firstly, container OCR serial number is printed on a long-effect sticker and the image quality of the characters on the containers would be deteriorated over a long traveling between continents. Damage of the sticker can be occurred due to container collision, scratch, and seawater erosion. Secondly, OCR reader is normally installed in a fixed place without moving it around. Thus, the reliability of OCR reader installed on the gantry cranes, transtainer cranes, and straddle carriers is greatly reduced.

The pros and cons of the application of OCR and RFID techniques in container shipping industry is summarized in the Table 1, and the authors also use them to build the AHP decision-making structure as shown in the Figure 1.

Table 1. Comparing OCR and RFID application in the Container Shipping Industry

Criteria	Alternatives	OCR	RFID
Start-up Cost	Equipment Cost	Long-effect OCR sticker cost below US$2 each	US$20~30 for each active RFID tag
	Facility Cost	US$100k ~400k for an OCR reader	US$400~500 for each RFID reader
Repair & Maintenance Cost	Facilities	**Low**	**High**
	Equipment	OCR has longer product life without paying extra maintenance cost	Each active RFID can be used up to 6 years before the battery is run out. RFID tag is likely to be damaged during loading and discharging operation.
Information Quality	Accuracy	90%~98%	Near 100% (Kima, 2007)
	Data Capacity	Only the container serial numbers are identified to be used to link with a container database in the yard or terminal.	Information can be stored in the RFID tag up to 256 bytes (Wamba, 2007).
	Information Addibility		
Processing Time	Time needed for Container positioning	High: OCR readers can be easily installed in most container ports.	Low: RFID tag can only be functioned in a port with the RFID reader (Nagi et al., 2005).
	Gateway Inspection Time /Tallying Time	Low: Reader can only be installed in a fixed position, and the OCR containers can only recognized if its speed is less than 40km/hr.	High: Active RFID tag can be installed on a moving container, and the reader can be installed anywhere in the terminal.

Note: Facilities includes infrastructure and readers of the OCR and RFID data acquisition system. Equipment cost includes the RFID tag cost and the OCR printing cost.
Source: this research.

Research Structure and Methodology

Analytical hierarchic process is firstly proposed by Saaty (1978) and is widely used as a decision-making technique. It can be used to take quantitative and qualitative criteria into consideration at the same time. The basis of an AHP structure includes the goal, criteria, sub-criteria, and the alternatives. The sub-criteria and criteria are usually obtained from previous literatures or the interview with managers in an industry. AHP is use the questionnaire to extract the respondents' perception, and human beings are said to be used to evaluate the performance of system in semantic wordings (Tsaur et al., 1997 & 2002). Thus, the fuzzy logics can be applied in this research to make the fuzzy semantic wordings into a crispy numerical number. In addition, Saaty (2001)pointed out often the alternatives are associated with both costs and benefits, thus it is appropriate to construct separate costs and benefits hierarchies and make the benefit/cost analysis (BCA) to choose a project with the highest BCA ratio.

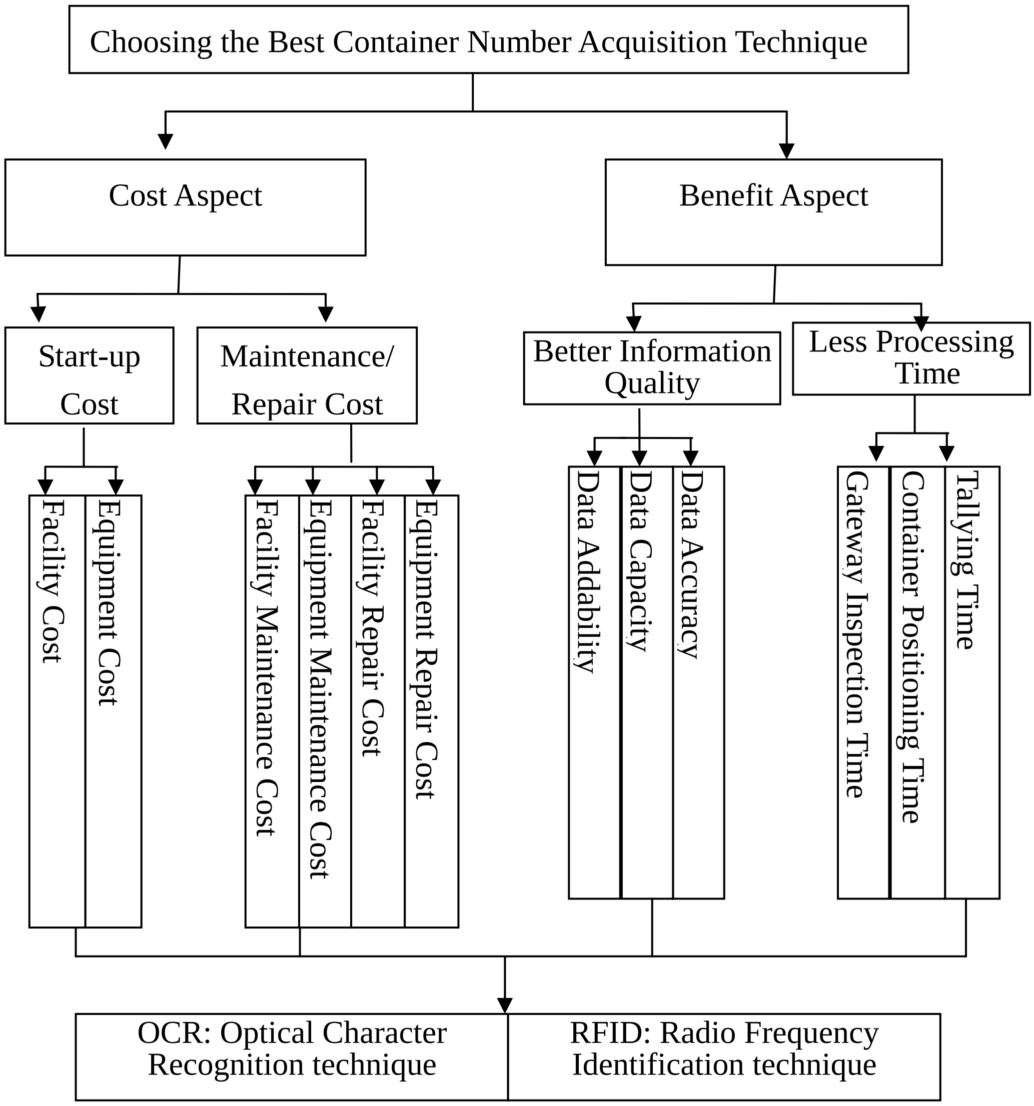

Figure 1 Cost Structure and Benefit Structure of the container monitoring system

Pilot Study in Taiwan

Pilot study questionnaires were send to four ocean container carriers in Taiwan. There are three major container shipping companies in Taiwan, they are ranked as the top twenty container carriers in terms of their container fleet capacity. Another major regional container carriers in Taiwan is also surveyed. This research employs the fuzzy AHP methodology to survey these carriers' perception on the relative importance of criteria influencing their selection of the two container number recognition system. Responses from the four managers of the four major Taiwanese ocean container carriers were obtained and analyzed by the fuzzy AHP technique and Expert Choice software[1]. The fuzzy AHP technique compare the relative importance of two criteria pairwisely, and the sub-criteria priorities of the benefit and cost aspects in using the RFID and OCR system

[1] As one of the carrier is very conservative and it is almost impossible to collect the replied questionnaire from the carrier. Thus, a questionnaire was send to a senior manager recently retired from that carrier.

are shown in Figure 2 and Figure 3 respectively.

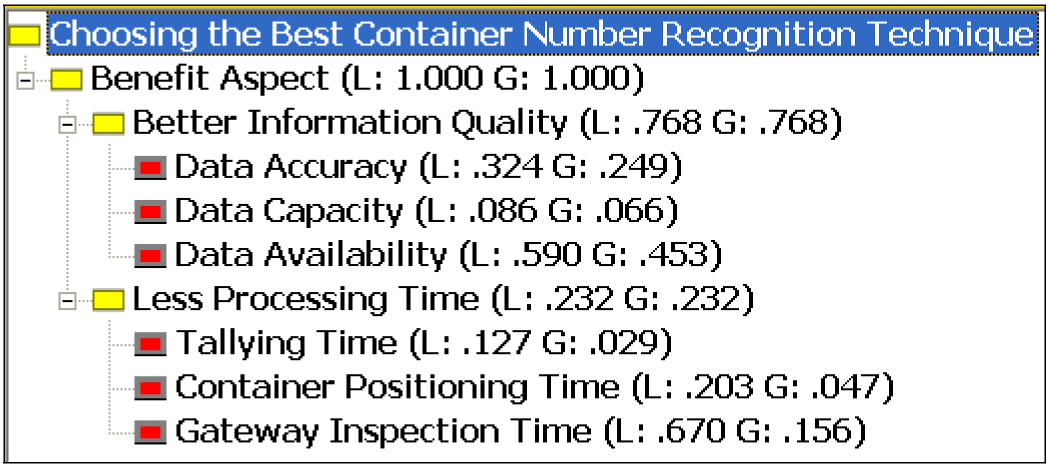

Figure 2. Importance of different sub-criteria in benefit aspect

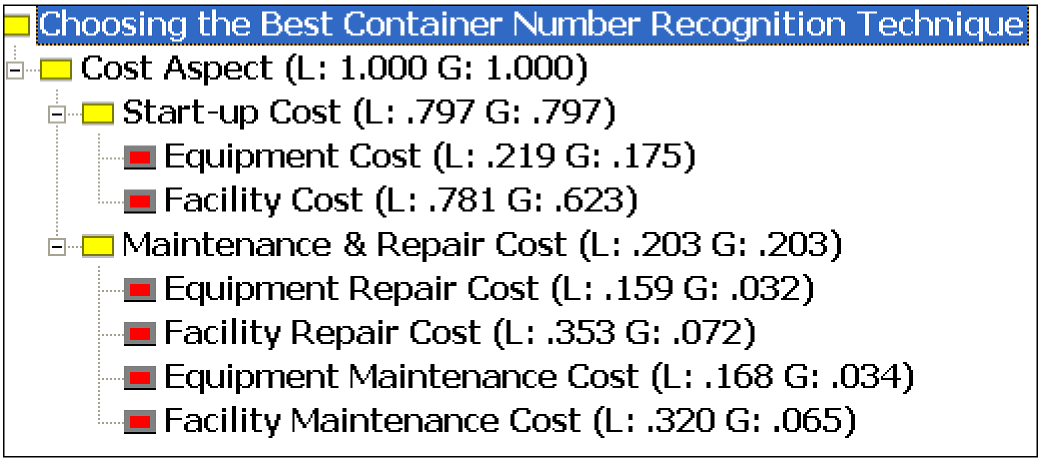

Figure 3. Importance of different sub-criteria in cost aspect

Research findings and Suggestions

Using Tsaur's (2002) defuzzying formula, different degree of semantic wordings on benefit and cost aspects are become crispy numbers (see Figure 4). Although RFID system has a better overall benefit scores (358.71), its overall cost score is even higher (364.89). Thus the BCA (Benefit/Cost Analysis) ratio of the RFID system is approximated 0.983, and similar ratio for the OCR system is 1.05 (see Figure 5) . The higher the BCA ratio, the better the container monitoring system perceived by the ocean container carriers. The RFID system has a very outstanding performance over OCR system on the "Data Availability" sub-criteria. RFID system has a comparatively poor cost structure to the OCR system on the 'Start up cost of the RFID equipment' sub-criteria. Future cost reduction on the active RFID tag could possibly make the RFID system become a more attractive container monitoring system from major Taiwan container carriers' viewpoint. As security issue is the most important factor influencing the passengers' transportation mode choice behaviour, a study on the historical development of OCR and RFID's applications in the passenger transportation industry can be another possible avenue for future research.

Table 4 Defuzzyfication of Semantic Wordings

Degree of Benefit	Respondent 1	Resp. 2	Resp. 3	Resp. 4
Very Good = VG	88.00	89.33	92.67	95.33
Good = G	85.33	85.33	86.00	88.00
Fair = F	80.00	82.33	82.00	84.00
Poor = P	76.67	76.00	74.67	75.00
Very Poor = VP	65.00	60.00	43.33	43.00

Degree of Cost	Respondent 1	Resp. 2	Resp. 3	Resp. 4
Very Costy = VC	88.00	89.33	92.67	95.33
Costy = C	85.33	85.33	86.00	88.00
Fair = F	80.00	82.33	82.00	84.00
Less Costy = LC	76.67	76.00	74.67	75.00
Least Costy = LTC	65.00	60.00	43.33	43.00

Source: this research.

Table 5. Comparison of Benefit/Cost Ratio between OCR and RFID techniques

	OCR Performance perceived by the respondents							
			Importance	Resp. 1	Resp. 2	Resp. 3	Resp. 4	Total Benefit Score of the OCR
		Better information Quality	0.768					
		Data Accuracy	0.249	88.00 VG	85.33 G	86.00 G	88.00 G	86.48517
		Data Capacity	0.066	80.00 F	85.33 G	82.00 F	84.00 F	21.86778
		Data Availability	0.453	76.67 P	82.33 F	82.00 F	75.00 P	143.148
	Benefit Aspect							
		Less Processing Time	0.232					
		Tallying Time	0.029	80.00 F	85.33 G	82.00 F	75.00 P	9.34757
		Container Positioning Time	0.047	85.33 G	82.33 F	86.00 G	84.00 F	15.87002
		Gateway Inspection Time	0.156	76.67 P	82.33 F	86.00 G	88.00 G	51.948
Benefit								328.66654
	RFID Performance perceived by the respondents							
			Importance	Resp. 1	Resp. 2	Resp. 3	Resp. 4	Total Benefit Score of the RFID
		Better information Quality	0.768					
		Data Accuracy	0.249	88.00 VG	89.33 VG	92.67 VG	95.33 VG	90.96717
		Data Capacity	0.066	88.00 VG	89.33 VG	86.00 G	95.33 VG	23.67156
		Data Availability	0.453	88.00 VG	85.33 G	92.67 VG	88.00 G	160.362
	Benefit Aspect							
		Less Processing Time						
		Tallying Time	0.029	88.00 VG	89.33 VG	92.67 VG	88.00 G	10.382
		Container Positioning Time	0.047	85.33 G	89.33 VG	92.67 VG	88.00 G	16.70051
		Gateway Inspection Time	0.156	85.33 G	89.33 VG	92.67 VG	95.67 VG	56.628
								358.71124
	OCR Performance perceived by the respondents							
			Importance	Resp. 1	Resp. 2	Resp. 3	Resp. 4	Total Cost Score of OCR
		Start-up Cost	0.797					
		Equipment Cost	0.175	76.67 LC	76.00 LC	82.00 F	75.00 LC	54.19225
		Facility Cost	0.623	80.00 F	76.00 LC	82.00 F	75.00 LC	194.999
	Cost Aspect							
		Maintenance & Repair Cost	0.203					
		Equpiment Repair Cost	0.032	76.67 LC	82.33 F	74.67 LC	84.00 F	10.16544
		Facility Repair Cost	0.072	80.00 F	82.33 F	74.67 LC	84.00 F	23.112
		Equpiment Maintenance Cost	0.034	76.67 LC	82.33 F	74.67 LC	75.00 LC	10.49478
		Facility Maintenance Cost	0.065	76.67 LC	76.00 LC	74.67 LC	75.00 LC	19.6521
Cost								312.61557
	RFID Performance perceived by the respondents							
			Importance	Resp. 1	Resp. 2	Resp. 3	Resp. 4	
		Start-up Cost	0.797					Total Cost Score of RFID
		Equipment Cost	0.175	88.00 VC	89.33 VC	92.67 VC	95.33 VC	63.93275
		Facility Cost	0.623	88.00 VC	89.33 VC	92.67 VC	95.33 VC	227.60059
	Cost Aspect							
		Maintenance & Repair Cost	0.203					
		Equipment Repair Cost	0.032	88.00 VC	82.33 F	92.67 VC	95.33 VC	11.46656
		Facility Repair Cost	0.072	80.00 F	89.33 VC	92.67 VC	95.33 VC	25.72776
		Equipment Maintenance Cost	0.034	88.00 VC	89.33 VC	92.67 VC	95.33 VC	12.42122
		Facility Maintenance Cost	0.065	88.00 VC	89.33 VC	92.67 VC	95.33 VC	23.74645
								364.89533
		OCR Benefit/Cost =	1.051344116					
		RFID Benefit/Cost =	0.983052428					

Source: this research.

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