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Cost-Benefit Analysis of Implementing RFID System in Port of Kaohsiung

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Abstract

The largest port in Taiwan, Port of Kaohsiung port, has the geographic advantage in East Asia. More than one million of Transshipment containers export and import in Port of Kaohsiung each year. In order to reduce smuggling cases, Taiwan Customs requests all Transshipment containers should be escorted while transferring from carrier yard to the port terminal. Therefore, Taiwan government decides to replace manual escorts with RFID e-seal system to be more security and efficient. The new system can save the inspection time, the expenses for additional Customs, and the escort fee for liner companies. This paper presents a scenario analysis to evaluate the cost and benefit analysis (CBA) of implementing the RFID E-seal system in Port of Kaohsiung. This is the first study on Transshipment containers by implementing new technology. In order to achieve the purpose, this research establish cost-benefit model, and evaluate the CBA with proposed scenario. Finally, the cost-benefit ratio can be determined by the model and two scenarios analyses were concerned to evaluate the RFID system in the future. The result indicated that the implementation of RFID e-seal system does not significantly favor to the Customs although the overall benefits to the whole system is greater than the cost. The results of CBA can be beneficial to the different stakeholders in allocating the limited monetary resources.

Keywords: Cost and Benefit Analysis (CBA), Transshipment Containers, Liner Companies, RFID

1. Introduction

Statistics from the Ministry of Transportation and Communications (MOTC) in 2011 showed that approximately 45% of the containers at Port of Kaohsiung are Transshipment containers. During the discharge and loading process at six container centers of Port of Kaohsiung, Transshipment containers must pass through a harbor police checkpoint before being transported to another center. According to the regulations on Transshipment cargo clearance and management passed by the Kaohsiung Custom Office, high risk cargos are escorted manually to prevent Transshipment containers from being lost and smuggled. Yet this approach increases the cost of manpower and liner companies. In an effort to improve the abovementioned situation and enhance the efficiency at the harbor entrance control post, a Radio Frequency Identification (RFID) E-seal system project was launched as part of the "Project of
Escort Free for Transshipment Containers in Port of Kaohsiung” promoted by the MOTC to replace manual escorting with new technology.

The E-seal system can be either active or passive based on the RFID design (Ngai et al., 2007). Currently most of the international shipping control is conducted by active RFID tags combined with on-board unit, GPS, and GPRS networks (Mullen, 2005). Despite of its advantage in real-time monitoring, an active RFID tag has relatively high cost and requires additional electricity. Even with its tag recycling mechanism, the cost is merely counterbalanced without substantial profits. Compared with an active RFID tag, a passive RFID tag has to be read at a shorter distance with the lack of active tracking ability. Yet the greatest advantage of a passive tag is its low cost. Therefore, ultra high frequency passive RFID tags are adopted for escort monitoring in Port of Kaohsiung. The tag chip, which conforms to ISO standards, is embedded with anti-counterfeiting codes. The accuracy of Transshipment containers is ensured based on the completion of passive RFID E-seals locked on the containers. The containers are monitored and identified by fixed readers attached at gates as well as handheld readers at container yards. The objective of automatic escorting is thus achieved.

The “Project of Escort Free for Transshipment Containers in Port of Kaohsiung” was launched in December 2008 by the MOTC with on-site tests completed in Port of Kaohsiung. The project was formally initiated on February 20, 2009. When Transshipment containers in the Port are sealed with RFID E-seals, drivers adopt citizen digital certificates, and trucks are installed with on-board units, technology replaces humans to escort Transshipment containers. The Custom Office, Harbor Police Office, Trade-Van Company, and liner companies are able to be connected through computer networks. The objective of automatic management on cargo and vehicle entry is thus reached. Port of Kaohsiung is no longer heavily trafficked; the entry speed of personnel, vehicles, and cargos is greatly increased; the management cost of carrier companies and cargo owners is reduced. Quick clearance, cargo control, international-level port facility, and secured shipment are all achieved.

The benefit analysis on transportation system consists of technical, financial, and economic aspect. The technical aspect includes project planning, design, construction, and maintenance. The financial aspect involves policy budget and cost. The economic aspect is related to cost, benefit, and the relation between the two. This research analyzes cost and benefit of the RFID E-seal escorting system for Transshipment cargos from the economic aspect.

Cheung (2006) analyzed the implementation of smart card system for public transportation system in Netherlands, the benefits are categorized into direct, indirect, external benefits under the conditions of paying cash and IC card. While the direct benefit includes the reduction of queuing time for purchasing tickets, the reduction of fraudulent travel, and increase the circulating of the ticket. The indirect and external benefits are considered as less disturbance to the users and also environment improvements. In addition, sensitivity analyses were undertaken to enhance the study’s robustness. The results indicated that the project would involve a wide range of socioeconomic advantages and that, overall, benefits would exceed costs.

Berger (2007) utilize two scenario analyses, Scenarios A and B, to evaluated the establishment of Intelligent Transportation System (ITS) on the seven main corridors at east queen area. Scenario A has greater coverage and more facilities than Scenario B, and the EMFITIS model was used to calculate the quantitative benefits from ITS. The result indicated that the area with greater traffic volume Scenario A will result in a better benefit-cost ratio than Scenario B and vice versa.

Li et al. (1999) referred that electronic toll system is a mature technology. The structure of an ETC system is divided into three main interests: the road user, the electronic payment industry, and the society. They also account for the direct and indirect costs and benefits in the case of the Carquinez Bridge (near San Francisco Bay). In the conclusions, they estimated the toll system for Carquinez Bridge could have the benefit-cost ratio up to 40. Besides major benefit in travel time saving, other benefits include saving fuel, reducing pollution, and improving the quality of services.

Chu et al. (2009) presents a scenario analysis on the benefit-cost evaluation for the Electronic Toll Collection (ETC) system in Taiwan’s National Freeway No.1 and No.3. A mathematical and engineering economic methods to justify the benefits and costs associated with different stakeholders. Three traffic scenarios were investigated the parameters by changing its assumptions on time-saving, fuel-saving, environmental improvement and user’s cost, as well as the resulting variations in different stakeholders. The result indicated that under the current mechanism, the ETC system in Taiwan does not favor to the investor.

To evaluate the feasibility of public projects, a cost-benefit analysis is a quantitative analysis that converts cost and benefit into present value with an appropriate discount rate. Then the order of the projects is arranged according to the benefit-cost ratio. In other words, the purpose of a cost-benefit
analysis is to ensure the appropriateness of each project. The maximization of the objective function can be taken as guidance for enhancing resource using efficiency and citizens’ economic welfare. This research conducts a cost-benefit analysis with a case study of the RFID E-seal escorting system applied to Transshipment containers at the Port of Kaohsiung. This research focuses on present and future cost and benefit of implementing RFID E-seal escorting system to Transshipment containers at the Port of Kaohsiung.

Here introduce the paper, and put a nomenclature if necessary, in a box with the same font size as the rest of the paper. The paragraphs continue from here and are only separated by headings, subheadings, images and formulae. The section headings are arranged by numbers, bold and 10 pt. Here follows further instructions for authors.

2. Process of Analysis

The RFID e-seal system is implemented to Transshipment containers in Port of Kaohsiung, while three major stakeholders, liner companies, customs and the society, are taken into concern for the CBA. Basically liner companies charge the shipping fee to shippers and forwarders for the shipping space, and the shipping fee includes the RFIC e-seal cost and transportation expense. The RFID e-seal system for Transshipment containers is invested and built by the customs, which is also responsible for the future maintenance cost. The new construction RFID e-seal system can reduce the environmental impact that is benefit to the society. Therefore, the cost-benefit analysis model is formulated for the three stakeholders. The items of benefits and costs considered in the developed model are referred to the framework from Li et al. (1999) and the field situations in Port of Kaohsiung.

The framework of this study includes the fixed and variable costs, the direct and social benefits of the three stakeholders. The fixed costs are included the installation, operation, and maintenance cost for the customs. However, the variable costs are based on the amount of liner's Transshipment containers which are installed with RFID e-seal. As for the benefits, the travel time saving and cost saving are the direct benefits to the liners and customs. When Transshipment containers installed with RFID e-seal, the drivers do not have to stop at the check points. Two major time-saving items in this process are considered as the vehicle passes the check point at certain high speed, and the saving time of the inspection. The key costs saving in this study are the reduced cost of customs for escort and inspection, documentation fee, and fuel consumption. The main discrepancy cost is the escort fee since the adoption of RFID e-seal. Once the vehicles with RFID do not need to significantly change their speeds, therefore, the fuel consumption and air pollutions can be reduced in a considerable amount. This environment improvements will have the benefit to the society.

The mathematical and engineering economic methods to justify the benefits and costs associated with different stakeholders are developed in this study. In the following, the details of the models are introduced under which the three stakeholders are considered:

\[ B / C = \frac{\sum_{j=0}^{n} TB_j (1 + i)^j}{\sum_{j=0}^{n} TC_j (1 + i)^j} \]  

(1)

\[ TC^C_j = TSCC^C_j + TGC^C_j \]  

(2)

\[ TB^C_j = TSCB^C_j + TGB^C_j + TSB^C_j \]  

(3)

where,

- \( TC^C_j \): Total cost in year \( j \), $NTD
- \( TSCC^C_j \): The cost for liner companies in year \( j \), $NTD
- \( TGC^C_j \): The cost for Customs to install the new system in year \( j \), $NTD
- \( TB^C_j \): Total benefit in year \( j \), $NTD
- \( TSCB^C_j \): The benefit for liner companies in year \( j \), $NTD
- \( TGB^C_j \): The benefit for Customs in year \( j \), $NTD
- \( TSB^C_j \): Social benefit in year \( j \), $NTD

A. The Liner Companies Model

(1) Cost Model for Liner Companies
Since the implementation of RFID E-seal system, there will be no escort cost generated by the Customs. The cost for the liner companies is reflected by the price of RFID and the amount of Transshipment containers. The total cost for the liners is shown in Eq. 4:

\[ TSCC_j^L = P_{RFID} \times C_j \]  

(4)

where,

- \( TSCC_j^L \): Total cost for liner companies in year \( j \), $NTD
- \( P_{RFID} \): The price of RFID E-seal, $NTD/unit
- \( C_j \): Transshipment containers in year \( j \), TEU

(2) Benefit Model for Liner Companies

Since the implementation of RFID E-seal system, liners will save the escort and documentation fees. Transshipment containers must pass through a harbor police checkpoint before being transported to another center, therefore, liners can save the cost for paying the freight fuel consumption. The total benefit for liners are included three components shown in Eq. 3-5

\[ TSCB_j^L = EFB_j^L + FSB_j^L + PSB_j^L \]  

(5)

- \( TSCN_j^L \): Total benefit for liner companies in year \( j \), $NTD
- \( EFB_j^L \): The saving of escort fee in year \( j \), $NTD
- \( FSB_j^L \): The saving of fuel consumption in year \( j \), $NTD
- \( PSB_j^L \): The saving of documentation in year \( j \), $NTD

B. The Customs Model

(1) Cost model for the Customs

Two major components, the costs of construction and maintenance, are considered in the operation of RFID E-seal system shown in Eq. 6.

\[ TGC_j^C = C_j^C + C_j^M \]  

(6)

where,

- \( TGC_j^C \): The total cost of Customs in year \( j \), $NTD
- \( C_j^C \): The cost of construction RFID E-seal system in year \( j \), $NTD
- \( C_j^M \): The cost of maintenance RFID E-seal system in year \( j \), $NTD

(2) Benefit model for the Customs

The benefits of the Customs are the reduction of employees for the escort and also the number of on duty harbor police at inspection points can be reduced due to the electronic paper work. The total benefit for Customs is shown in Eq. 7.

\[ TGB_j^C = SE_j^C + PB_j^C \]  

(7)

where,

- \( TGB_j^C \): The total benefit of Customs in year \( j \), $NTD
- \( SE_j^C \): The benefit of reducing employees for the escort in year \( j \), $NTD
- \( PB_j^C \): The benefit of reducing harbor police in year \( j \), $NTD

C. The Society Model

We study the environmental improvements by focusing on the impacts of the RFID freights when entering and leaving the check points. Due to the less slowdown and speedup in the prevailing speeds, the emissions are reduced. Air pollutions come from car usage include nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO), suspended particulate (PM), lead (Pb) and sulfur Oxides (SOx), and so on. The emissions vary by types of fuel and vehicle characteristics. In general, the emissions of petrol vehicles contribute the major air pollutants, such as HC, CO, NOx and Pb, and emissions of diesel vehicles contribute to major pollutants, including PM, SOx and NOx. Following is the quantitative model (Eq. 8,9) of the environmental benefits of the RFID system.

\[ TSB_j^S = EB_j^S \]  

(8)

\[ EB_j^S = \frac{1}{3600} \times C_j^S \times (t_f - t_e) \times V_j \times (E_{PM} + E_{SOx} + E_{S0x}) \times H_j \]  

(9)
EB\textsubscript{j}: The environment benefit in year j, $\text{NTD}$
C\textsubscript{j}: Transshipment containers in year j, TEU
\(t_T\): Inspection time without RFID, sec
\(t_R\): Inspection time with RFID, sec
V: Average freight operation speed, KM/hr
\(E_{PM}\): The parameter of freight PM emission, g/KM
\(E_{SOx}\): The parameter of freight SOx emission, g/KM
\(E_{NOx}\): The parameter of freight NOx emission, g/KM
\(H_i\): The unit cost of pollution prevention for exhaust, \(i = \text{PM} \cdot \text{SOx} \cdot \text{NOx}, \text{NTD}\)

3. Case Study of the RFID System in Port of Kaohsiung

The data collected in this study is from the Kaohsiung Customs Office and the R&D organization of RFID E-seal system. According to the interview with technician, the system will be replaced for every 5 years, therefore, we estimate the number of transshipment containers from 2008 to 2018. To conduct the benefit and cost evaluation of the RFID system in Port of Kaohsiung, we use the data in year 2008 as the based year and estimate the expected benefits and costs of the current RFID systems from 2011 to 2018. The parameters adopted in the benefit and cost evaluation model are shown in Table 1.

Table 1 Parameters Used in the Benefit-Cost Model

| Item                                                   | Symbol | Unit     | Value |
|--------------------------------------------------------|--------|----------|-------|
| The price of RFID E-seal                                | \(P_{RFID}\) | NTD/piece | 200\$  
| Escort Fee                                             | EF     | NTD/trip | 1200\$ |
| Average Escort Transshipment Containers                | AE     | TEU/trip | 2$  
| Inspection Time without RFID                           | \(t_T\) | sec/veh  | 240$  
| Inspection Time with RFID                             | \(t_R\) | sec/veh  | 10$  
| Fuel Consumption of Freight                            | L      | L/hr     | 6$  
| Average Freight Operation Speed                        | V      | KM/hr    | 30$  
| Average Fuel Cost for Freight                          | \(C_F\) | NTD/L    | 26.5$  
| Documentation Fee                                      | \(C_D\) | piece/veh | 0.5$  
| Average Escort Time                                     | \(T_E\) | min/trip | 50$  
| Escort Employee Salary                                  | \(S_E\) | NTD/hr   | 250$  
| Number of Harbor Police                                 | \(D_P\) | people/day | 48$  
| Harbor Police Working Hours                             | \(T_P\) | hr/people | 2$  
| Harbor Police Working Days                              | \(T_d\) | day/year | 365$  
| Harbor Police Salary                                    | \(S_P\) | NTD/hr   | 250$  

Data Source: a. Port of Kaohsiung b. Bureau of Energy c. Kaohsiung Customs Office

Currently twenty sets of RFID E-seal systems has been installed in Port of Kaohsiung, and prepared 35,000RFID tag for Transshipment containers. The related facilities of items and numbers are indicated in Table 2. Noted that the total cost for setting up this system is 25 million dollars.

Table 2 RFID E-seal System Items and Numbers

| Items                                                      | Numbers  |
|------------------------------------------------------------|----------|
| READER Middleware                                          | 20 sets  |
| Website Monitor System                                     | 1 set    |
| Interface of Gate System                                   | 20 sets  |
| PDA                                                        | 1 sets   |
| Interface of Freight Monitor System                        | 1 set    |
| IBM Advanced Server                                        | 2 sets   |
| IBM Basic Server                                           | 1 set    |
| PC                                                         | 5 sets   |
| Portable Reader                                            | 26 pieces|
| UHF TAG                                                    | 35,000 pieces |
| UHF RFID READER(including Antenna)                         | 40 sets  |
| Pipes, Cables and Wiring                                   | 20 sets  |

Data Source: Chung-Shan Institute of Sci. and Tech. (2007)
The annual increasing rate of Transshipment containers at Port of Kaohsiung is 1%. The benefit and cost evaluation results are indicated in details for the three stakeholders, while the total cost and benefit estimation are estimated in Table 3. The annual net benefit value is also converted to its net present value (NPV) shown in Table 4.

Table 3 Total Cost and Benefit Estimation

| Year | Total Cost | Total Benefit | Net Benefit | Unit: Thousand NTD |
|------|------------|---------------|-------------|--------------------|
| 2008 | 25,000     | Under construction | -25,000     |                    |
| 2009 | 15,122     | 46,173        | 31,051      |                    |
| 2010 | 17,187     | 52,545        | 35,358      |                    |
| 2011 | 17,924     | 54,819        | 36,895      |                    |
| 2012 | 18,718     | 57,267        | 38,549      |                    |
| 2013 | 19,573     | 59,906        | 40,333      |                    |
| 2014 | 35,496     | 62,754        | 27,258      |                    |
| 2015 | 21,494     | 65,832        | 44,338      |                    |
| 2016 | 22,574     | 69,162        | 46,588      |                    |
| 2017 | 23,743     | 72,768        | 49,025      |                    |
| 2018 | 25,011     | 76,678        | 51,667      |                    |
| Total | 241,844   | 617,905       | 376,061     |                    |

Table 4 Total Cost and Benefit Estimation – 3% NPV

| Year | Total Cost | Total Benefit | Net Benefit | Unit: Thousand NTD |
|------|------------|---------------|-------------|--------------------|
| 2008 | 25,000     | Under construction | -25,000     |                    |
| 2009 | 14,681     | 44,828        | 30,146      |                    |
| 2010 | 16,200     | 49,529        | 33,328      |                    |
| 2011 | 16,403     | 50,167        | 33,764      |                    |
| 2012 | 16,630     | 50,881        | 34,251      |                    |
| 2013 | 16,884     | 51,675        | 34,791      |                    |
| 2014 | 29,728     | 52,556        | 22,828      |                    |
| 2015 | 17,477     | 53,528        | 36,051      |                    |
| 2016 | 17,820     | 54,597        | 36,777      |                    |
| 2017 | 18,425     | 55,771        | 37,346      |                    |
| 2018 | 18,841     | 57,056        | 38,215      |                    |
| Total | 208,091   | 520,587       | 312,497     |                    |

The whole system bears the total cost of NTDS 208.091 billion dollars (NPV for 11 years) and gains the benefit of NTDS 520.587 billion dollars from the implementation of the RFID system. The benefit-cost ratio is 2.5 (greater than 1) shown in Table 3, indicating the implementation of the RFID system is a worthy project for Port of Kaohsiung as a whole.

Table 3 Benefit-Cost Ratio of the RFID E-seal System by Stakeholders

|                      | Benefit | Cost   | Net Benefit | Benefit-Cost Ratio |
|----------------------|---------|--------|-------------|--------------------|
| Whole System         | 520,587 | 208,091| 312,497     | 2.50               |
| Liner Companies      | 299,094 | 96,319 | 202,775     | 3.11               |
| Customs              | 221,210 | 111,771| 109,439     | 1.98               |
| Society              | 283     | -      | -           | -                  |

4. CONCLUSIONS AND DISCUSSIONS

Based on the numerical analysis results, the benefits-cost ratio for the whole system is 2.50. As a result, we conclude that the RFID E-seal system is worthy to implement. From the liners' point of view, the RFID benefit-cost ratio is about 3.11, which makes the liner companies the biggest winner. Under the current escort regulation, the benefits-cost ratio for the Customs is just 1.98. That is for a short term, the benefit of the RFID for the Customs is not immediately justified. The main reason is that Customs still face the problem of shortage of employees at transshipment containers escort and inspection points. The RFID system has not reached its economic scale. This under-scale problem may underperform not only the benefit of the Customs but also to the liner companies. This result shows that the Maritime
Administration has not fully utilized the benefit of the RFID system yet. However, even under this situation, the benefits associated with the social environment are estimated about NTDS 283 million dollars, which is a significant amount of monetary benefit for the sake of environmental protection.

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