July 2011, Volume 8, Number 7
Journal of Communication and Computer, ISSN 1548-7709, USA

RFID Applications in Hospitals – A Case Study for Emergency Department

Yen-Chieh Huang[1,2], Chih-Ping Chu[1]
[1]*Department of Computer Science and Information Engineering, National Cheng-Kung University, Tainan, Taiwan*
[2]*Department of Information Management, Meiho University, Pingtung, Taiwan*

Received: March 1, 2011 / Accepted: June 8, 2011 / Published:

Abstract: Radio Frequency Identification (RFID) is a system that uses radio frequency to transmit identification wirelessly. Its functionality is much more powerful than bar code system, with which a contacting reader must be used to read the bar code. RFID, on the other hand, may read the information stored in a tag with a non-contact reader from a distance as far as tens of meters. Health care industry is highly valued throughout the world; applying the cutting edge technology in health care industry to improve patient health care has been the common goal pursued by the hospitals all over the world. The introduction of RFID as medical application is also being enthusiastically studied now. This Study finds the medical application of RFID application for the workflow of the most critical and the busiest unit in a hospital: the emergency department. The results of this Study may significantly increase the operation efficiency by improving the problems commonly experienced at the emergency room, such as congested queue for emergency treatment and sickbed space, understaffed medical personnel, and patient's leave without permission.

Keywords: RFID, Emergency Room, Health Care, Patient Satisfaction

1. Introduction

The Wal-Mart in the United States demanded the packaging of all merchandises delivered to its distribution center must have re-readable and re-writable passive RFID tags in compliance with the EPC (Electronic Product Code) standard attached before January 2005 from its top 100 suppliers and 2006 from all suppliers. The Food and Drug Administration (FDA) of the United States announced in 2004 to adopt RFID technology for the identification of counterfeit medicines and demanded all pharmaceutical manufacturers must have RFID tags attached to the packaging of their medicines starting from 2007 for the tracking, managing, and recycling of medicines. As a result, all wholesalers and retailers must follow and adopt RFID system [1]. While many researches are undergoing for other industries, the introduction of RFID for health care industry is still in the experimental stage. Plans of RFID application tests in hospitals have been proposed by many suppliers, such as medicine control, patients contact history, patient identification, equipment/ apparatus tracking, injection management, physician order monitoring, medical malpractice prevention, blood bag quality control, and operation room workflow; all of which concern primarily the safety of the patients. Medical application of RFID for patient health care enhancement is therefore the focal point of this Study.

The emergency room is the most complicate and busiest place in a hospital. It is the center for treating patients with accident injuries and/or acute sicknesses of different levels of medical needs on a daily basis that the patients must receive the most adequate treatment and care in the shortest possible time from both the physicians and the nurses. Upon the arrival at an emergency room a patient goes through a medical operation procedure, including triage, registration, treatment, cashier, pharmacy, and admission, which

Corresponding author: Yen-Chieh Huang (1969-), Lecturer, research fields: software engineering, RFID. Email: p7894121@mail.ncku.edu.tw.
Chih-Ping Chu(1949-), Ph.D., professor, research fields: compiler system, software engineering, e-learning.

require seamless collaboration with the medical treatment team [2].

A patient goes missing and leaves registration record but no clinical record is a frequent scenario in an emergency room. Such patient often leaves without excuse the hospital while waiting in queue, inhibiting hospital management from tracking the patient head count and location and making patient scheduling a difficult task for the hospital personnel [3]. It is therefore a crucial issue for the medical workers being allowed to control the accurate information of the patients' location in real time.

Some of the patients after diagnosis by physicians are concluded to be non-urgent cases and are redirected to the provisional observation room instead of hospitalization. However, chances are some of them have to stay and wait for hours before receiving any further attention from the medical personnel again and being left alone to deal with the anxiety brought by the emergency room surrounding on top of the stress of illness. Therefore, it is paramount to allow the patients to know the examination results and the diagnosis conclusion as soon as possible. The reduction of patients' waiting time is urgently needed [4, 5].

As a result, enhancing medical treatment quality, increasing patients' satisfaction toward hospital, making more time available for emergency treatment, and providing even better medical care environment in the emergency room through the use of information technology are now the common goals in the health care industry. The scope of this Study focuses on improving medical treatment safety through RFID applications in medical treatment process for the patients in the emergency room, including alert of excessively prolonged queue, patient location tracking, and alert of excessively prolonged stay.

2. Literature Review

A RFID system, in the simplest form, consists of three components: a Tag or Transponder, a Reader and an antenna. A passive tag (or powerless tag) has no battery built in and requires external energy to trigger and initiate signal transmission. An active tag, another common tag, has built-in battery to provide power to actively transmit signal. Both types of tag have a chip inside to carry and process information. Upon entering an electromagnetic zone a passive tag is triggered by the interrogating signal sent by the reader, from which it obtains power through induced current, and begins transmitting the product information stored on its chip. An active tag, on the other hand, as its name suggests, actively and constantly transmits the information on its own. As the reader receives the information, it relays the information to a central information processing center for further application. Other hardware and software are required to support RFID application [6, 7]. A tag may come in different shapes and sizes: business card, coin, button, price tag, wristband, and grain; the list can go on and on. In general, a tag may be passive, semi-passive, or active [8]. A passive tag has no battery built in to supply power and requires external induced current to power and trigger signal transmission. This is why its working range is limited to one meter or shorter. Both semi-passive and active tags have built-in battery, and that is the reason why their working distance ranges from several meters to tens of meters, only that a semi-active tag still needs external induced current from the reader to activate the built-in battery to supply power for signal transmission. An active tag will constantly transmit signal; if it detects the presence of a reader, it begins to transmit information. Because a passive tag is powered externally by a reader, its service length is virtually unlimited (until it is damaged). The service length of an active tag may last up to 8 years theoretically or merely one month in practice as it is limited to the battery life and power consumption.

The Ministry of Economic Affairs (MOEA) has taken initiatives to seek for preventive countermeasures since the SARS epidemic, and RFID application in medical care is one of them. Currently the pilot projects have been rolled out at the Taipei Medical University Hospital, Show Chwan Hospital, Sun Yat-sen Cancer

Center, and Kaohsiung Veterans General Hospital. With financial support from the MOEA, the Industrial Technology Research Institute is also cooperating with Hsinchu Dong Yuan Hospital for RFID trial project. Each of these medical institutes concentrates on different subjects of RFID applications: SARS control, area control, restricted area control, bio-medical waste control and monitor, and patient contact tracking.

Some hospitals in the United States are keen to adopt new technology for medical care application [9]. For examples, RFID time sheet for ER personnel [10] and medical record tracking by RFID [11]. These pilot projects have achieved quite satisfying results and these hospitals use 2.45GHz active tags, for which readers have a scope of signal interrogation as long as 30 meters, far more accurate than passive tags that allow less than one meter of scope.

Several human right groups in the United States oppose RFID applications on patients for the reason of privacy violation by unauthorized RFID tracking [12]. Some manufacturers in return respond with erasable tags [13].

RFID applications in Taiwan are still very limited. The policies of the Bureau of National Health Insurance have caused great reduction in hospital profitability and, consequently, displaced the available budget for the induction and application of new technology. Another factor is that it is inherently difficult to change the status quo of the operational workflow already in place and accustomed to hospital employee. The most critical issue, eventually, is the price of RFID system is not yet attainably acceptable to the majority of consumers. There are, practically, difficulties in applying RFID for any medical institute. The pilot projects of RFID, subsidized by the MOEA, are currently implemented at the Taipei Medical University Hospital, Show Chwan Hospital, Sun Yat-sen Cancer Center, Kaohsiung Veterans General Hospital, and Hsinchu Dong Yuan Hospital. Nonetheless, these projects are all not comprehensive and have still a long way to go before the full scale implementation [14,15,16,17].

Shiumn-Jen Liaw et al. (2002) had studied the factors of patient premature departure from emergency room with incomplete diagnosis procedure and categorized such patients into four types: (1) departure without diagnosis, (2) departure due to denied insurance of emergency coverage, (3) departure without excuse, and (4) voluntary departure. The departure without excuse is further sub-categorized as incompletely diagnosed and completely diagnosed. Liao concludes that these patients departed mostly because the excessively long waiting time for diagnosis, time poverty, or unpleasant encounter with hospital personnel. Liao suggests 42% of the patients expect the waiting time not to exceed 15 minutes, and 49% do not accept more than one hour of waiting time. Failure of either one shall result in dissatisfaction with the medical service provided by the hospital [3].

Su-chou Siao (2002) proposes that the major factors of prolonged patient stay for provisional observation in emergency room are (1) excessively long waiting time for available sickbed, (2) excessively long provisional observation time, (3) understaffed medical personnel, and (4) insufficient space [5]. Ming-ling Liou (2001) has conducted field investigations in emergency room to explore the distribution and variance of waiting times among the stages of medical care in emergency room, and studied their significances concerning patient satisfaction.

The literatures abovementioned reveal that most of the patients depart from hospital due to excessively long waiting time. The long the waiting time at emergency room, the more likeliness of patient dissatisfaction toward hospital will be and eventually cause patients to depart or even permanently abandon the hospital. There is a significant causal relationship between patient waiting time and departure.

3. System Environment Structure and Design

The goal of this Study is to design a query system using RFID, of which major function shall be actively

providing real-time information of the locations of the patients with excessively long waiting time.

A RFID system structure is a combination of tag, reader, and application system. The type of application system varies according to the needs of an industry and the structure may be specialized according to the specification of the tag used. The system structures in the case of passive or semi-passive tag and in the case of active tag, for example, are different. In this Study focuses on applying semi-active tag of UHF frequency on the patients at emergency room to propose a system structure for safe emergency room service. Upon the arrival of a patient at an emergency room for triage, a RFID wristband is printed and mounted to the wrist of the patient. All following procedures must be reconfirmed with a reader, including diagnosis by physician, medication distribution by nurse, injection, examination, urgent operation, and etc.

As shown in Figure 1, the process at emergency department in most hospitals begins with triage at the entrance. A patient of level one or two triage must complete registration first and then queue in the waiting room. A level three or four triage may proceed to emergency care by physicians first and complete the registration process afterward. The emergency departments in some larger hospitals may be specialized into different departments, such as emergency surgery, emergency internal medicine, and emergency pediatrics. Whatever the department it may be, the physicians after the initial diagnosis may request certain examinations, and prescribe medications accordingly. The relationship between physician diagnosis and radiology or laboratory department is expressed with two-way arrows in Figure 1, denoting that such process is not necessarily required depending on the physician's decision. If so required, the process following the examination is still the physician for further diagnosis.

Five areas of the process of emergency department are highlighted in Figure 1 as possible procedural problems. The first one is patients' excessively long waiting time for diagnosis by physician after triage and registration. In some cases large amount of patients are rushed to the emergency room, and the patients with critical conditions are prioritized by the physicians, causing longer waiting time for other patients. In some other cases the physician on duty at the emergency department is not specialized for the patient's condition and must wait for the qualified specialist, such as an

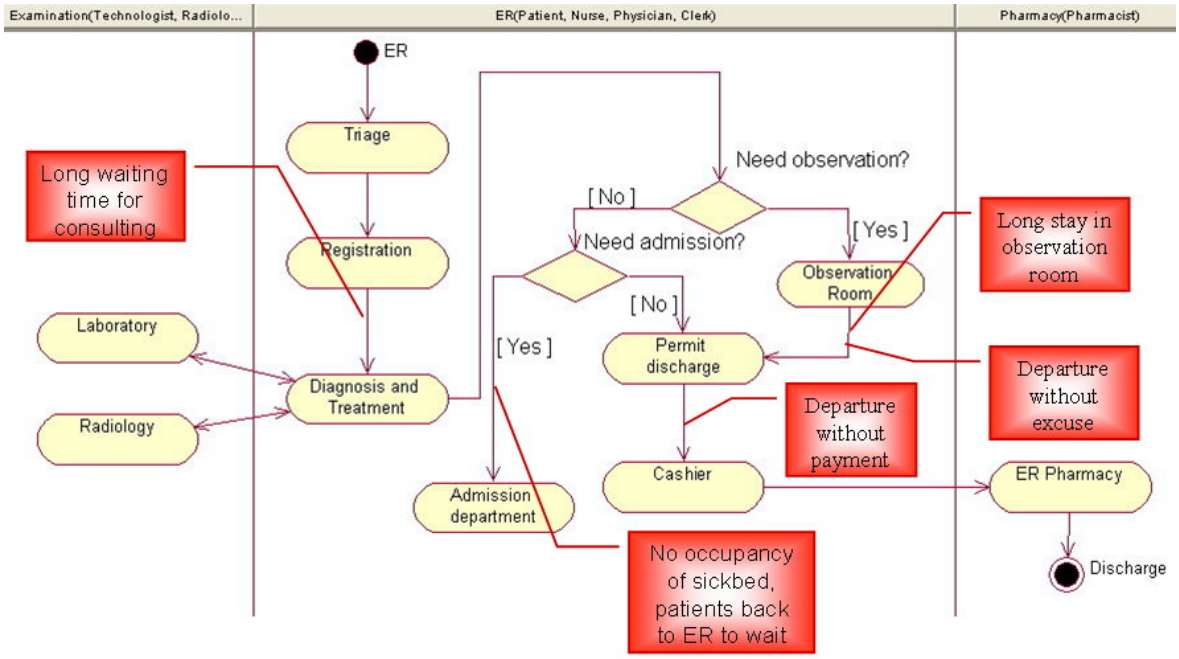

Figure 1. ER operation process and possible procedural problems

eye-related problem shall wait for an ophthalmologist, and an ear, throat, or nose (collectively referred as ENT) issue should be determined by an otolaryngologist. If a specialist is not available or not present, the patient will have to wait for even long time. Therefore, the first problem is excessively long waiting time for the patients. The second factor is patient after being determined as hospitalization is not necessary by physician receives no attention during provisional observation due to medical personnel is preoccupied by other tasks, causing the patients to endure excessively long waiting time. Therefore the second problem is excessively long stay in the provisional observation area for the patients, resulting in patients' departure without excuse compelled by their dissatisfaction toward the hospital personnel. This leads to the third problem: departure without excuse. A patient may depart from the hospital for certain reasons before the process of cashier after being acknowledged that leave is authorized. For examples, lack of money to pay the hospital or no medication is prescribed. This is the fourth problem: departure without payment. The fifth issue is no occupancy of sickbed after a patient is instructed after diagnosis to proceed with hospitalization process, causing the patient to wait in the emergency room for sickbed. The availability of sickbed in some popular hospital often runs out, and the waiting time for a sickbed may last for as long as two or three days, causing patients' dissatisfaction. Therefore, the fifth problem is no occupancy that drives patients back to emergency department to wait.

Because an emergency process is prone to negligence, the application of RFID in emergency department, as shown in Figure 2, by immediate printing and mounting a RFID wristband on the wrist of a patient at triage by the medical personnel before the patient is redirected to the waiting area. If a physician fails to diagnose the patient in due time stipulated by the hospital, a short message is immediately sent to the management center where high management may initiate an emergency protocol. For example, dispatching extra physician may avoid excessively long waiting time for the patient. This measure solves the first problem mentioned in above. A patient in the provisional observation area may be waiting for examination report or intravenous drip. However, if such patient is made to wait for excessively long time without further attention form the medical personnel, the RFID will not be read for a predetermined amount of time. The information of the patient will be automatically sent to the management center where the management of the hospital may respond accordingly, such as instructing the medical personnel to give further attention provide more medical service, or request the examination reports to be completed within a certain amount of time. This measure may solve the second problem mentioned in above. In the case that a patient is not yet authorized to leave, or that a patient is notified that leave is authorized before the cashier process, and the patient departs without excuse, the RFID reader at the exit of the hospital will automatically send an instant message to remind the medical personnel that the patient has departed. The intention of this message is helping the medical personnel to realize the absence of the patient, not necessarily policing on the patient's departure without excuse. There are times the patient is simply going out for lunch or having a cigarette outside. This measure takes care of the third and the fourth problems. Before a patient in need of a sickbed is assigned with one, the RFID will not receive the information of the completion of hospitalization process of the patient at admission counter. If the RFID after a predetermined period of time receives no such information, then it means the patient is suffering from excessively long waiting time and the RFID system will automatically send a short message to alert the management center where decision can be made to direct the medical personnel to assist the patient to proceed with transfer, and patient dissatisfaction of waiting time may be avoided. This measure eliminates the fifth problem.

4. Conclusions

As consumerism continues to rise in recent years, more scholars are studying the quality of the medical

care provided by medical service providers form the aspect of consumer. The term of medical quality in the eyes of the patients has escalated from the simple treatment result to customer satisfaction of the entire medical service experience. This phenomenon has confirmed that the medical service concept based on patient's right shall be the direction of medical quality development in the future. RFID can be adopted by a hospital for a variety of applications. The Emergency Department of the Kaohsiung Veterans General Hospital has adopted RFID for reconfirmation of medication distribution and injection. Dong Yuan Hospital has adopted RFID to manage SARS patient contact history. The Operation Room of Chang Gung Memorial Hospital has adopted RFID for reconfirmation of the surgical target.

This Study concerns the experimental introduction of RFID at the emergency department. It is expected that the introduction of RFID not only assures the five-step medical safety checklist (the right patient, the right medication, the right dosage, the right approach, and the right timing), but also solves the problems of excessively long waiting time of diagnosis, excessively long provisional observation period, unattended by medical personnel, excessively long waiting time of sickbed occupancy, and departure without excuse.

This Study has developed, by using Visual Basic, a RFID System for Emergency Department to solve the above-mentioned five problems of the emergency room process. However, the system has only been simulated in laboratory. Despite that the result of this Study is not implemented in any hospital in Taiwan, it indeed can enhance the service and safety for the patients, increase medical quality, and develop trustworthy image for a hospital. In addition, the doubt of privacy violation is also addressed by this Study. Tracking a patient's location in a hospital or preventing a patient from departure without settling medical bill is not the intention of the RFID system proposed by this Study, even though it may be so used. This Study aims to enhance medical quality by assisting medical personnel to seek for the location of an emergency patient and provide adequate assistance for the patients who have waited excessively long time.

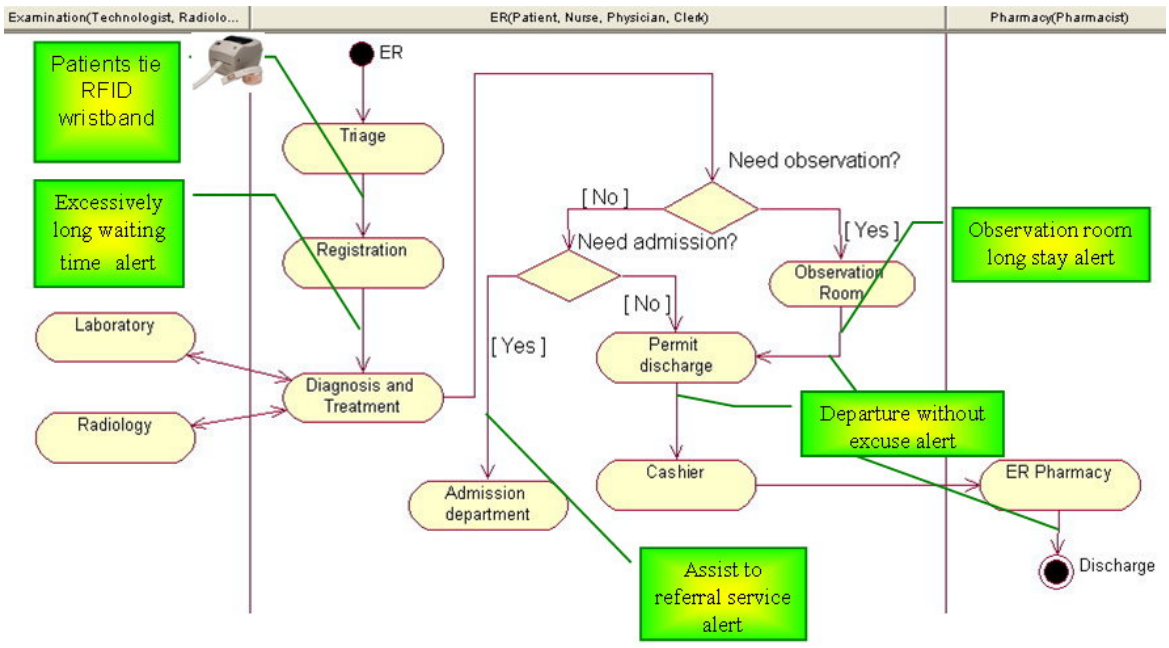

Figure 2. RFID apply to ER process

5. Discussion and Future Development

This Study focuses on the introduction of RFID for emergency department application that not only solves the problem of patients' excessively long waiting time, but also allows the hospital management to monitor the service for the patients provided by the medical personnel at any given time and reduce patient complaint, even prevent potential medical dispute. For the medical personnel, they may stay informed about the location of the patients at any given time, monitor the examination and medication for the patients, reduce data input time in the workflow, and serve more patients with the time saved. For the service provided for the inpatients, the RFID reader installed at the hospital entrance/exit monitors the location of the inpatients to protect them from criminal actions and prevent missing inpatient. For the academic circle, this is an excellent case study for industry-specific application. RFID not only may be applied in other departments of a hospital, but also in other industries, such as manufacturing, service, apparel, and food and beverage. RFID application is important more than ever for the enterprises that emphasize customer relationship management, cost reduction, and profitability.

The triage station personnel, registration/cashier clerks, physicians, nurses, medical technicians/radiologists, pharmacists, patients, and hospital management involved in the introductory stage of RFID application in the emergency department workflow may experience added workload, such as time pressure. However, they shall be enjoying the convenience brought by the new technology after the comprehensive implementation. Every step of the process may comply with the standard operational procedure, and medical safety may be greatly enhanced. If the implementation succeeds, it can serve as a fundamental paradigm for expanding the applications to other applications in the hospital and encourage the acceptance of RFID among the personnel concerned. The Information Management department is not only a logistic unit of a hospital; it should make the best use of information technology and apply in every process of a hospital to increase operational efficiency and competitiveness, assuring the sustainability of the hospital.

References

[1] Donna, Y., (2004), "FDA embraces RFID to protect drug supply", Am J Health-System Pharmacy, Vol. 61, No. 24, pp.2612-2615.

[2] Rui-Yu Rao, (2002), "Use PDCA management style to improve emergency patients' healthcare", Annual Conference of Emergency Medicine, pp.133.

[3] Shiumn-Jen Liaw, Pai-min Hu, and How-chin Liao, (2002), "Patients Who Leave Emergency Departments Prematurely", Journal of Taiwan Emergency Medicine, Vol. 4, No. 2, pp.40-49.

[4] Li-Hsiang Wang, (2001), "The difference of Patient Needs Among Patient, Caregiver and Nurse in The Observation Room of Emergency Department", Master Thesis, Chang Gung University, Taiwan.

[5] Su-chou Siao, (2002), "*Case of emergency observation to improve patient retention*", Annual Conference of Emergency Medicine, pp.136.

[6] Wei Zhang, (2003), "RFID Application Discovery", Journal of the Mechatronic Industry，Vol. 249, pp.88-94.

[7] Yu-Hong Chen, (2004), "RFID System Introduction", Unalis, Taipei Taiwan.

[8] Xiang-Qi Zhou, (2004), "RFID Technology and Application", Flag, Taipei Taiwan.

[9] Glenn, M.H., Robert, D.R., and Mark, E.M., (2004), "Report to the Congress: New Approaches in Medicare," New Jersey, pp.157-181.

[10] Intermec, (2005), Saving Time and Improving Patient Care, http://www.imtermec.com/.

[11] Jonathan, C., (2005), Tracking Medical Emergencies, RFID Journal, http://www.rfidjournal.com/.

[12] David, M., and David, W., (2004), "Privacy: Privacy and security in library RFID: issues, practices, and architectures", Proceedings of the 11th ACM conference on Computer and communications security.

[13] Ari, J., Ronald, L.R., and Michael, S., (2003), "The Blocker Tag: Selective Blocking of RFID Tags for Consumer Privacy", Proceedings of the 10th ACM conference on Computer and communications security, pp.103-111.

[14] Zhi-Qiang Wei, (2004), "Survey Research of RFID application to discuss the RFID promotion in our country." Ministry of Economic Affairs E-navigation, Vol.6, No. 20, pp.1-11.

[15] Rong-Xing Xiao, Wei-Ru Wang and Wei-Ren Su, (2004), "RFID Application Case Study", Ministry of Economic Affairs E-navigation, Vol.6, No. 15, pp.1-16.

[16] Rong-Xing Xiao, Wei-Ren Su, and Yu-Jai Xu, (2004),"The nerve center of RFID technological operation- RFID Middleware", Ministry of Economic Affairs E-navigation, Vol.6, No. 14, pp.1-13.

[17] Rong-Xing Xiao, and Yu-Jai Xu, (2004), "The application of FRID and development trend", Ministry of Economic Affairs E-navigation, Vol.6, No. 13, pp.1-15.