



## Design and Implementation of ICT-Based Recycle-Rewarding System for Green Environment

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### ABSTRACT

This paper proposes a collaborative system called Recycle Rewarding System (RRS), and focuses on the aspect of using information communication technology (ICT) as a tool to promote greening. The idea behind RRS is to encourage recycling collectors by paying them for earning points. In doing so, both the industries and individuals reap the economical benefits of such system. Finally, and more importantly, the system intends to achieve a green environment for the Earth. This paper discusses the design and implementation of the RRS, involves: the architectural design, selection of components, and implementation issues. Five modules are used to construct the system, namely: database, data entry, points collecting and recording, points rewarding, and web modules. The RRS has been deployed at the Universiti Sains Malaysia (USM) to encourage the collectors to support the green environment.

**Keywords:** RFID, recycling, information engineering, software engineering, ICT.

### تصميم وتنفيذ نظام لاعادة التدوير والمكافأة للبيئة الخضراء المستند على تكنولوجيا المعلومات والاتصالات

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#### الخلاصة

يقترح هذا البحث تصميم وتنفيذ نظام تعاوني محوسب لاعادة التدوير والمكافأة للبيئة الخضراء، ويركز على جانب استخدام تكنولوجيا المعلومات والاتصالات كأداة لتعزيز تخضير الأرض. الفكرة وراء هذا النظام هي تشجيع جامعي المواد القابلة للتدوير عن طريق احتساب نقاط لهم، ومن ثم دفع أجور مقابلة للنقاط المكتسبة. وبذلك، فإن كلا من المصانع والأفراد تجني فوائد اقتصادية من هذا النظام. والأهم من ذلك، نحقق البيئة الخضراء للأرض. تناقش هذه الورقة تصميم وتنفيذ النظام المقترح، وتتضمن: التصميم المعماري، واختيار المكونات، وقضايا التنفيذ. فضلا عن ذلك، يقترح البحث خمسة وحدات لتشبيد النظام، وهي: قاعدة البيانات، وحدة إدخال البيانات، وحدة جمع وتسجيل النقاط، وحدة مكافأة النقاط، ووحدة شبكة الإنترنت. وقد تم وضع النظام المقترح حيز التطبيق في جامعة السابيس الماليزية لدعم البيئة الخضراء.

**الكلمات الرئيسية:** تحديد الهوية باستعمال الموجات الراديوية، التدوير، هندسة المعلومات، هندسة البرمجيات، تكنولوجيا المعلومات والاتصالات.



## 1. INTRODUCTION

During the past decade, radio frequency identification (RFID) systems have been incorporated into a wide range of industrial and commercial systems, **Chen, et al., 2010**. Its low cost provides a wide spectrum of applications that have never been seen in literature, **Akyildiz, et al., 2002**. RFID is a form of automatic contactless data capturing technique that uses radio frequency electromagnetic waves. An RFID system is comprised of a transponder (tag), a reader, and a host computer (software application), which is usually connected to a distributed database. The readers are usually placed in certain places to recognize the tags, **Ali, et al., 2010; Mahmood, et al., 2013**. A wide scale of applications is well studied in the literatures, **Nambiar, 2009; Idris, et al., 2009; and Lien, et al., 2012**. These applications involve, but are not limited to, supply chain, production and manufacturing, healthcare and medicine, construction, hospitality, parking management, transportation, attendance, tracing, and tracking. Thus, RFID becomes cost effective because the price of individual tags is reduced with the increase in manufactured volumes. Other opportunities will arise as the technology develops. Building on earlier works, this paper proposes the use of RFID in developing a recycling rewarding system (RRS).

Recycling involves processing the used materials into new products to prevent the wastage of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from land filling) by decreasing the need for conventional waste disposal, and lower greenhouse gas emissions compared with virgin production, **Murphy, 1993**. Recycling is a key component of modern waste reduction and is the third component of the “Reduce, Reuse, and Recycle” waste hierarchy, **EPA, 2013**.

To understand the environmental effects of recycling, consider the fact that recycling 1 kg of aluminum saves up to 6 kg of bauxite, 4 kg of chemical products, and 14 kWh of electricity, **EPA, 2013**. In other words, aluminum recycling provides up to 95% savings for both energy, **Murphy, 1993**, and air pollution, **EPA, 2013**. As another example, cited from Proclamation 7250 on America Recycles Day: “Buying recycled products conserves resources, reduces water and air pollution, saves energy, and creates jobs. Producing 1 ton of paper from recycled pulp saves 17 trees, 3 cubic yards of landfill space, and 7000 gallons of water. It also reduces air pollutants by 60 pounds, saves 390 gallons of oil, and conserves 4200 kilowatt hours of energy—enough to heat a home for half a year. Estimates show that 9 jobs are created for every 15,000 tons of solid waste recycled into new products”, **Clinton, 1999**. Thus, the importance of recycling on green environment is summarized as follows:

- Recycling reduces our reliance on landfills and incinerators.
- Recycling protects our health and environment when harmful substances are removed from the waste stream.
- Recycling conserves our natural resources because it reduces the need for raw materials.

An economic value creation in a proactive green manufacturing strategy results from an incremental contribution margin due to the sales of products made from regenerated materials. This measure identifies whether the take-back and regeneration of end-of-life products can also be justified from an economic viewpoint aside from the environmental considerations, **Azzone,**



**and Noci, 1998 A; Azzone, and Noci, 1998 B.** A second approach for firms involves cost savings. Some examples of potential cost savings include reducing energy consumption, waste reduction, lowering pollution emissions, smaller environmental fines, improving economic efficiency, and decreasing environmental cleanup costs , **Characklis, and Richards, 1999.**

Advances in manufacturing technology have enabled most recycled products to compete both in price and quality, with products made from virgin materials. However, only 12% of consumers are True Greens (regularly involved in recycling), 68% are Light Greens (sometimes involved in recycling), and 20% are Never Greens (never involved in recycling). The so-called True Greens are still a minority, whereas the Light Greens are the majority of consumers. Thus, there is a need to encourage the majority of consumers to be True Greens , **Hanas, 2007.** One way to achieve this objective is through rewards.

Earlier studies on the role of rewards in environmental management indicate a positive effect on environmental performance , **Daily, et al., 2007; Zutshi, and Sohal, 2003; and Chinander, 2001.** For instance, supervisor support behaviors advocating rewards motivate employees to introduce novel environmental initiatives, **Ramus, 2002.** Massoud et al. advocate the utilization of the Scanlon Plan as catalyst to green organizations. This institutionalization serves as a potential mechanism to enhance the environmental performance of a firm. In summary, the model is based on the following features: 1) collectiveness and cooperation, 2) employee participation, 3) quantifiable performance and bonus measures, and an equitable reward system. A firm predetermines with its employees an allocation ratio for gains in productivity or cost savings. Employee participation plays an ultimate role in gauging the fairness of the ratio, and as a result, the ratio remains open to adjustments, **Massoud, et al., 2008.**

Recycling is important for green environment because it has economical benefits and provides job opportunities. However, the persons involved in the recycling process, especially the item collectors, need to be encouraged. Thus, a rewards system is required to make them satisfied. This will improve recycling significantly, **Ramus, 2002; Massoud, et al., 2008.** Moreover, both the industries and individuals will reap the economical benefits of such system. Finally and more importantly, the system intends to achieve a green environment for the Earth.

Motivated by such goal, this paper proposes a collaborative system, that is, an RFID-based RRS. The remainder of this paper is organized as follows: Section 2 presents the specification of the RRS; Section 3 gives the architectural design; Section 4 discusses the implementation issues; and finally, Section 5 gives the conclusion and suggestions for future works.

## **2. RRS SPECIFICATION**

To state the RRS specification, an inspection technique is used, by considering the following scenario for recycling in the inspection phase.

A collection center (e.g. a university) is responsible for collecting the recycling material, storing the recycling items, declaring the types of material, determining the points for each material and the formula to convert the points to benefits, and reporting the amount available in stock for each type of material. Recyclable materials include different kinds of glass, paper, metal, plastic, textiles, and electronics. The types of materials, their corresponding points, and the formula are controlled by the supervisor of the center. The materials to be recycled are brought



to a collection center by the collectors. Any person who would like to collect points should register himself/herself in a collection center. After registration, the collector brings the material and identifies himself/herself to the system. The weighing operator weighs the material and selects the type of the collected material from a computerized dialog to update the points for the corresponding collector in the system. The collector can withdraw his/her points from any branch of the collecting center (e.g. a cafeteria in a university). Finally, the industrial tracker tracks the amount of the recycled items available in stock in the recycling center and their corresponding price formula.

The RRS system involves many actors. The role of each actor is illustrated below:

- Supervisor Member(s) – The role of the supervisor is to administrate the whole system. The tasks include the following:
  1. Select the materials to be collected.
  2. Consult the environment, ICT, and economical experts to derive a suitable formula for earning and withdrawing points. There are two formulas based on economics: the first formula is for buying the collected materials from the collectors, and the second formula is for selling the collected materials to the industry.
  3. Decide on the scalability of the center and the members involved in the system (i.e., number of branches for the collecting center, number of operators and their salaries, method for announcement of the available materials, and their price formula).
- Weighing operator – The role of the weighing operator is to obtain the collected materials from the collector or to give the collected materials to the industry. In both cases, the weighing operator selects the material to be weighted and the corresponding (buying or selling) formula.
- Cashier – When the collector wants to withdraw points, he/she identifies himself/herself and then enters the amount of points to be withdrawn. The system calculates the corresponding cash to be given to the collector. Similarly, when an industry wants to buy a material from the collection center, the person who represents the industry identifies the firm, selects the type of the desired materials, and enters the required amount. The system calculates the corresponding cash to be received from the firm.
- Registrar – The role of the registrar is to assign an identity and enter the information (i.e., user name, identity, contact address, e-mail, and mobile phone number) for both the collectors and industries involved in the recycling system.
- Collectors – They are the people involved in collecting the recycled materials. The collectors should register themselves in the collecting center. The collectors are familiar with the materials and the corresponding formula to earn the points. They can withdraw their points from the cashier.
- Industries – These are the firms involved in buying the collected materials from the center. The industrial trackers (employees), similar to the collectors, are familiar with the amount of the materials and their corresponding formula to buy from the center. The



employees either track the availability of the materials or provide material information according to the strategy of the center.

### **3. RRS ARCHITECTURAL DESIGN**

To simplify the work of the operators and save time for the individuals, RRS uses an RFID tag for user identification. This process can significantly improve the automation of identifying the persons in the system. Clearly, many tags are required, and the tag type should have a short distance between the tag and the RFID reader, consume less power, and have low cost, **Ali, et al., 2010**. For these reasons, the passive tags are chosen for person identification.

The RRS consists of five modules, namely, database, data entry, points collecting and recording, points rewarding, and a web module. Each module is described as follows.

#### **3.1. Database Module**

The database module is used to store, update, and retrieve all the information on the tags of the industrial firms as well as the collectors and their corresponding points. The database also includes the type of recycling material, the points awarded for each material, the amount available for each type, and the formulas for selling/buying items. For scalability purposes, the database is shared logically with other RRS modules and connected through a reliable network.

#### **3.2. Data Entry Module**

The data entry module is the software used to enter data into the database through a graphical user interface (GUI). The data entry module consists of two sub-modules that are described as follows:

**3.2.1. Registrar data entry module** – The registrar uses this module to enter the information for each industry/collector into database, and activate their corresponding identities in the system.

**3.2.2. Supervisor data entry module** – The supervisor uses this module to add/remove material, update the points for each material, and enter/update the name for the payment algorithm (e.g., buying and selling).

#### **3.3. Points Collecting and Recording Module**

This module consists of a weighing machine, a passive reader, and a PC. The PC is connected physically to the weighing machine and the passive reader. The PC running the points collecting and recording application software. In addition, this module is logically connected to the database. This module works as follows.

When the collector brings a material for recycling, the operator weighs the material using the weighing machine. Next, the collector presents his/her tag to an antenna attached to the passive reader. The passive reader detects the tag and sends the detected information to the PC. The application software asks the operator through the GUI about the type of the material, in addition, informs the operator the weight of the material. The application then queries the database and determines the points for the corresponding material. Next, the application software displays the old and new points of the collector. The operator can select the type of



material or cancel the detection process. When the operator presses the proceed button in the GUI, the application software updates the database for both the collector points and the available recycling weight of the selected material (i.e., the new weight is added to the old weight). Otherwise, the operator can cancel the transaction. Similarly, the operator can select to withdraw material when a firm would like to buy a material. The procedure is similar for the firm except that the updates of available material are subtracted from the total available material.

### **3.4. Points Rewarding Module**

This module consists of a passive reader and a PC. The PC is physically connected to the passive reader. The PC running the points rewarding application software is logically connected to the database. This module is used by the cashier and works as follows.

In the case of the collector, the cashier selects the collector transaction. The collector then presents his/her tag to an antenna attached to the passive reader. The passive reader detects the tag and sends the detected information to the PC. The application software sends a query to the database and then retrieves the total amount of points. The software calculates the corresponding money of the retrieved points (using the buying formula). The software then displays the user name, total points, and the corresponding money. The application software asks the collector to enter the amount of money to be withdrawn. If the collector agrees on the withdrawn transaction (by clicking proceed), the total number of points and the total money are updated. The cashier gives the cash to the collector. To terminate the transaction, the operator can press a cancel button.

Similarly, in the case of a firm, the cashier selects the firm transaction. The employee then presents his/her tag to an antenna attached to the passive reader. The passive reader detects the tag and sends the detected information to the PC. The application software sends a query to the database and then retrieves the total amount of materials and their corresponding points. The application software asks the employee to select the material(s) and the desired weight through the GUI. Next, the software calculates the corresponding money of the desired amount of materials (using the selling formula). The software then displays the firm name, the weight of materials, the corresponding points, and the amount of money. If the employee agrees on the transaction (by clicking proceed), the total amount of the selected materials is updated. The cashier takes the cash from the employee. To terminate the transaction, the cancel button is pressed.

### **3.5. Web Module**

This module consists of a web server and has a logical connection to the database. The web module retrieves the information stored in the database and displays the name of materials, the corresponding points, the total available amounts of the materials, and the formulas for buying and selling. The web module also displays the desired information for remote users. The user can be the collector (to check their points or the buying formula) or the industry (to see the items provided by the collection center and the corresponding amounts and selling formula).

## **4. RRS IMPLEMENTATION**

This section describes the implementation issues for RRS. It should be noted that various implementations are possible.



The weighing machine is chosen as a third-party commercial machine. MySQL server is selected as the database server and Apache Tomcat as the web server. An in-house USMUHF passive reader serves as the RFID reader, **Ali, et al., 2010**. The Java programming language is used for the software application. These components are selected for their cross-platform functionality, that is, they support different hardware and operating systems.

The weighing machine is connected to the PC using the serial communication port (RS232), whereas the passive RFID reader is connected to the PC through the LAN. The application software has a configuration management feature. This feature is useful in setting the serial port and the TCP/IP port during the first run of the application.

A typical entry to the database for the supervisor is illustrated in **Table 1**. The first column presents the materials, the second column presents the green points for each material, and the third and fourth columns are the buying and selling formulas, respectively. The entry for the buying/selling formula shows the class name and the corresponding method to be invoked for the calculations. The algorithm for buying and selling is simple, that is, paying one cent and two cents, respectively, for each point.

Aside from the monetary benefits, the supervisor offers other incentives for collectors. For example, any collector with more than 300 points can own a locker for one semester for free. Moreover, a gift worth 1000 Malaysian Ringgit (RM) will be given to the green student who can collect the maximum earning points during the semester.

The points collecting and recording GUI starts in the waiting state of the module, that is, no tag is detected. When the tag is detected for a collector, the GUI shows the identity of the tag, the earned points, and the weight displayed by the weighing machine in grams (g). Finally, the GUI enables the operator to select the type of material or even cancel the operation as depicted in **Fig. 1(a)**. When the operator selects the material, a dialog will appear to verify the information entered. The weight shown by the weighing machine, the tag identity, the current points, the points to be given, and the total cumulative points will be shown on the display. The operator can press the “Proceed” button to confirm the information or press the “Cancel” button to terminate the operation and return to the waiting state, as shown in **Fig. 1b**. The updating of the points is conducted using the following formulas:

$$\text{New Points} = \text{Weight (kg)} * \text{Green Point of the material} \quad (1)$$

$$\text{Total points} = \text{Old points} + \text{New points} \quad (2)$$

For instance, when a collector (already with 78.2 points) brings 440 g of metal tin, the operator presses the “Metal tin” button, **Fig.1a**, and then

$$\text{New points} = 440/1000 * 15 = 6.6 \text{ points.}$$

$$\text{Total points} = 78.2 + 6.6 = 84.8 \text{ Fig.1b.}$$

In the points awarding software, the card’s number (CN) can be entered in two ways: manually or through the RFID tag-detection system (depends whether the passive reader is available at the payment branch or not). After identifying the tag for a collector, the payment system enables the cashier to check, enter the amount of points to be withdrawn by the collector, trace the record of the collector, and finally proceed or cancel the transaction, as depicted in **Fig. 2**.



Similarly, when a firm tag is detected, the dialog appears to the employee and enables him/her to enter the desired amount for each material. Next, a dialog displays the total amount of points and the corresponding cash to be paid to the center. For example, consider a firm that wants to buy 1 ton of aluminum tin can, 500 kg of computer paper, and 100 kg of compact disc. In this case:

$$\begin{aligned} \text{Total Points} &= 330 * 1000 + 500 * 48 + 55 * 100 \\ &= 359,500 \text{ points.} \end{aligned}$$

Using the USM\_Selling formula, the cash amount = RM 7190.00.

## 5. CONCLUSION

This paper presented a recycling system called RRS that aims to keep the environment green. The use of low-cost passive tags significantly reduces the cost of modernization and identification automation. This paper also presented the design and implementation of the system. An incremental prototype was discussed as a case study. The modular design of the system makes it scalable, easy to use, and extendable horizontally (by adding more functionality to the system) and vertically (by supporting various implementations of the system). For instance, instead of tracking the available material passively from the web site, an alternative active tracking system can be achieved by sending an e-mail or SMS to the interested firm or industry. Currently, a pilot testing of the system is undergoing in Universiti Sains Malaysia (USM). As part of future work, a web-based material tracking and tracing system is currently being developed to make the industry track and trace materials around different universities and countries.

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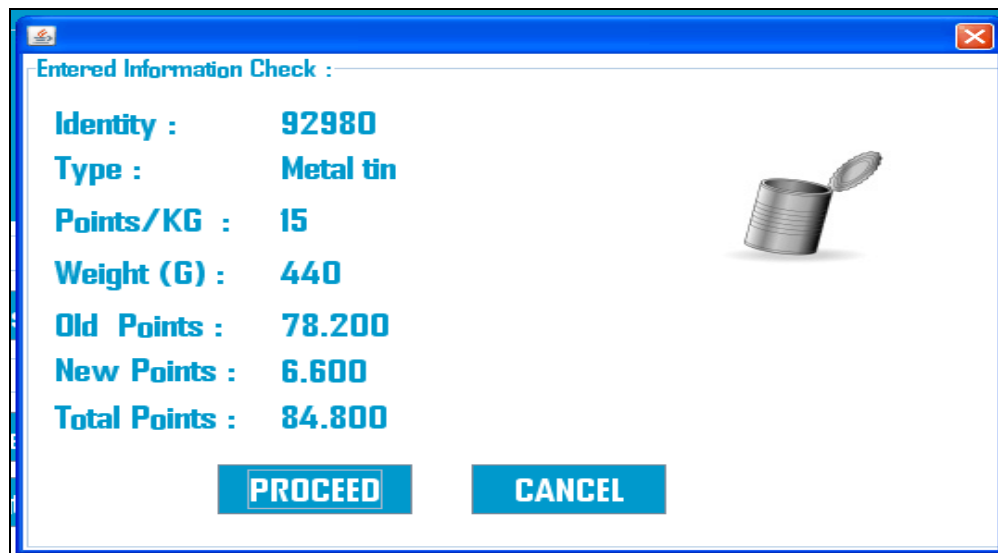
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**Table 1.** Typical data entry for supervisors in the USM recycling center.

<b>MATERIALS</b>	<b>Green Points/kg</b>	<b>Buying Formula</b>	<b>Selling Formula</b>
All types of paper	25	USM_Buy	USM_Sell
Computer paper	48	USM_Buy	USM_Sell
Mineral water bottles	50	USM_Buy	USM_Sell
Aluminum tin can	330	USM_Buy	USM_Sell
Glass bottles	2	USM_Buy	USM_Sell
Metal tin (milk tin, biscuit tin)	15	USM_Buy	USM_Sell
Mixed-plastics (PVC, water containers)	30	USM_Buy	USM_Sell
Compact Disc (CD-ROM, Audio CD, VCD, DVD)	55	USM_Buy	USM_Sell
Mixed-metals	20	USM_Buy	USM_Sell



(a) Tag detection and type selection process for an authorized tag.



(b) Confirmation dialogue

Figure 1. Snapshots of the points collecting and recording.

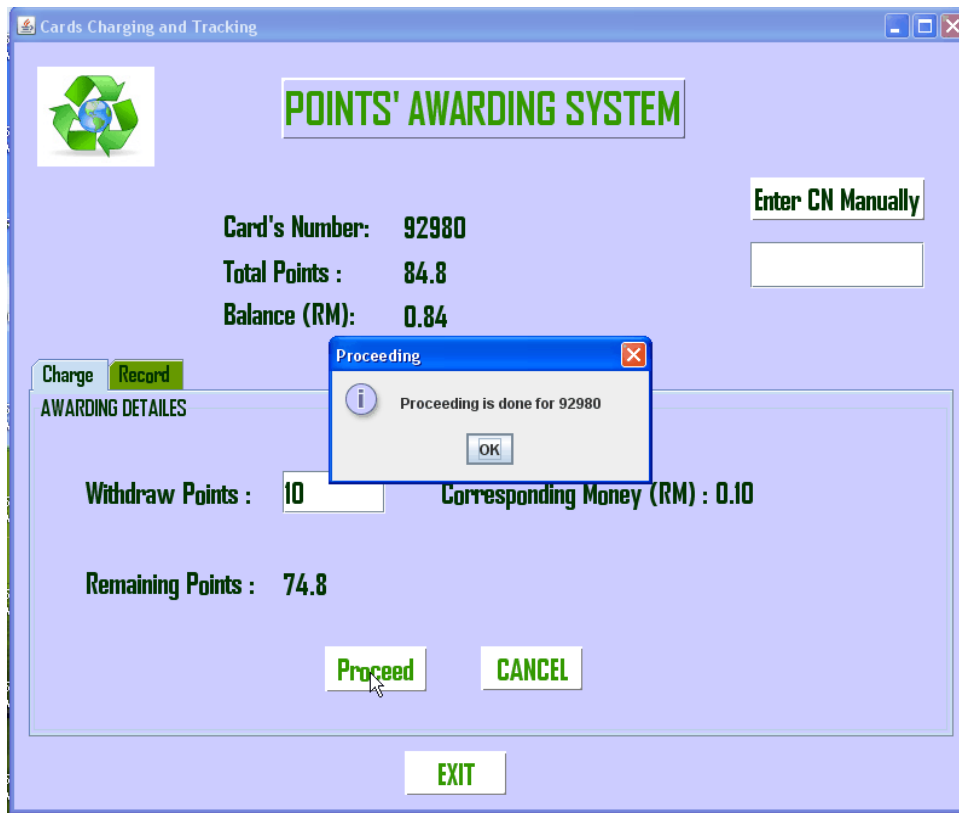


Figure 2. Snapshot of the points awarding system.