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A DECISION SUPPORT SYSTEM PROPOSAL BASED ON INTERNET OF THINGS FOR RECYCLABLE WASTE COLLECTION

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Abstract *– Waste management is the whole of process including the collection, transportation, storage, recycling, disposal and control of these for all of the waste types. The process of collection and transportation are covered for recyclable waste in this study. A decision support system has been proposed to plan waste collection according to real-time data in this study. Currently, all containers are visited in fixed frequency. In the proposed system, it is desirable to establish a smart and dynamic waste collection system to prevent the unnecessary use of resources and to collect the wastes on time by knowing fullness of the containers in advance. By using internet of things (IoT), the occupancy rates of the containers are known and the collection plan is prepared according to these rates. Vehicles do not visit the containers until they reach the specified fullness. Thanks to the IoT system, real-time data can be gathered so that waste in containers can be collected at the right time. In the proposed model, it is aimed to reduce the route length and total time traveled. The current and proposed system are compared with a simulation study. Systems have been compared in terms of total time they traveled and as a result of the study, it is seen that there is a significant difference in terms of the total time between the proposed system and the current system.*
Keywords – internet of things, real time data, recyclable wastes, simulation

INTRODUCTION

The world is undergoing a transformation. This transformation is reflected in our life together with technology. One product of this transformation is also the smart cities. Smart city systems are a system that comes with the use of different information technologies together. Smart City applications can be implemented in every area of the city management such as infrastructure, transportation, traffic system, waste management, building management. With smart city applications, the quality of life of residents and the efficiency of urban infrastructures are increased (Cicirelli et al., 2017). The most important of the purposes of smart city design is to optimize the use of resources in monitored systems, continuously. "Internet of things" which appeared as a radio frequency based system by Kevin Ashton in 1999 is a concept that has the ability of sensing and communicating objects. The internet of things (IoT) provides to monitor, manage, control and emerge new information in real time (Kim et al., 2017). So it creates smart systems. IoT creates a smarter environment by saving time and energy. IoT consists of connected devices that can transfer data to optimize their performance (Mahdavinejad, et. al., 2018). The basic structures required for smart cities based on IoT are identification, sensing, communication, computation, services, and security (Khan, 2017). A smart city system design is possible with the construction of these bases. There are numerous IoT based system that can be included such as traffic, logistics, health, agriculture, smart metering, retail, monitoring, automation, etc. (Čolakovića & Hadžialić, 2018). In this study, it is focused waste management based IoT.

Waste management is an important part of the smart city system. Rapidly growing technology have accelerated the rate of urbanization and population growth, the increase in community living standards, and the rate of waste

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generation in developing countries. Waste management is a comprehensive process and critical issue. It covers many processes such as collection, separation, transport, conversion and disposal of waste etc. By utilizing information and communication technologies, each stage of waste management can be tracked as real-time. The use of information technology in waste management provides both economic and environmental efficiency as it is in other smart city applications. To provide the connections of the system components, "Internet of Things (IoT)" can be utilized. The use of IoT will provide many advantages for waste management in smart cities (Anagnostopoulos, 2015). The main objective is to use the resources efficiently. In this context, by optimizing the utilization of resources, economic advantages, collection of wastes on the time and the use of less energy can also provide environmental advantages.

Faccio et al. (2011) simulated multiple vehicle routing for solid wastes. Economic analyzes were also included in the study by using the stocastic data. Anghinolfi et al. (2013) proposed a GIS based dynamic optimization model in order to minimize the collection and transportation costs. Islam et al. (2014) has proposed a system that recognizes the amount and type of waste in the waste box with image processing technique. With this system, waste estimations and system decisions can be made. Mes et al. (2014) study with sensors. They proposed a heuristic approach to the reverse inventory routing problem. Medvedev et al. (2015) has proposed a cloud-based decision support system that includes all system elements for dynamic routing. Elia et al. (2016) has studied the IOT-PSS based hybrid vehicle modeling with dynamic routing for e-waste. Lozano et al., (2018) simulated capacity constrained vehicle routing using data obtained from wireless sensor network. The model proposed in the study provides savings in the distance covered by the static model. In addition, wireless sensor network (Longhi et al., 2012; Narendra et al., 2014; Lozana et al., 2018), IoT and wireless sensor network (Lata et al.; Mustafa & Azir, 2017; Rajkumar et al., 2017; Saranya et al., 2017), GSM sensor technologies (Zavare et al., 2017), Radio Frequancy Identification (RFID) (Hong et al., 2014) are the information system structures used in studies that proposes the decision support systems for waste collection.

The aim of the study is to suggest an IoT based decision support system for the collection of recyclable wastes, where the waste accumulation rate varies according to the regions. In this study, the collection of waste containers has been studied according to the real-time data by utilizing IoT. With this decision support system, vehicle circulation is done according to the occupancy information of the containers and it is aimed to complete the route with the shortest traveled time of the vehicle. The current and the proposed system are simulated and the difference between them is evaluated in terms of total traveled time. In the later part of the study, problem description, proposed system structure, simulation study and results are presented.

PROBLEM DESCRIPTION AND PROPOSED SYSTEM STRUCTURE

Cities are now designed with smart systems. Smart designs made with environmental and ecological expectations are being offered to the community. This study focuses on the collection of recyclable household waste, where recyclable waste accumulates in a relatively more irregular manner. Because the rate of accumulation of recyclable wastes is affected by many demographic characteristics such as the population in the region, the education level of the region, and consumption habits. This means that waste accumulation can occur at different rates even within the same region. Waste accumulates more slowly in recyclable waste containers. Some of the containers are not yet full, while others have a capacity surplus. Both cases are undesirable situations, considering both unnecessary resource consumption and damage to the environment.

IoT based system is proposed for transportation which is part of a smart waste management system. In the study, the current and proposed systems are compared with the simulation study. In the current system, the containers in the region are collected all of them on a certain day and hour of the week. Some of the containers are not yet full, while others have a capacity surplus. In which case the collecting vehicle completes the tour with a longer distance. This causes both resources to be wasted and in terms of the environment, negatively. In the proposed model, the vehicle travels to the containers reaching the specified occupancy level thanks to the containers in which the sensor is placed. The tour is completed without other containers. The proposed model provides a dynamic scheduling. The flow diagram of the proposed model is given in figure 1.

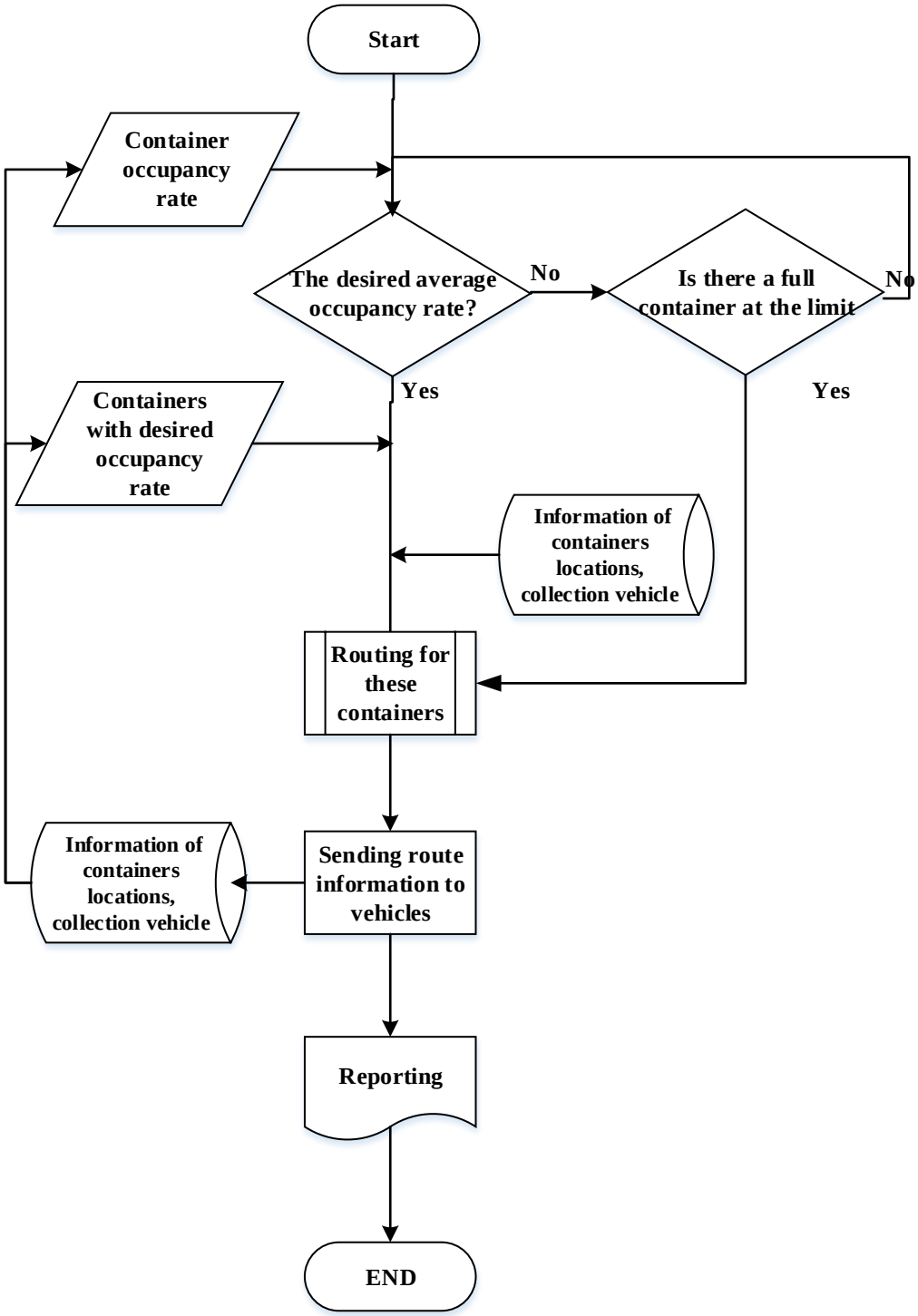

Figure 1. Flow Chart of Proposed System.

The occupancy information of the containers in which the sensor is placed is transmitted to the main server according to the network protocols. When the average occupancy rate of the container in the district reaches the desired level of the system, warning is given to the management center and the waste collection vehicle is removed for the containers that have reached the specified occupancy rate. Information such as location and waste amount of containers is transmitted in real time and necessary information is reported.

SIMULATION MODELS

The study has simulated for a small sample. In the current case, the collection of wastes is modeled at a fixed time once a day. In the proposed model, if the average occupancy rate of the containers in the area reaches to 75%, the vehicle completes the tour by 50% and over filled containers. New wastes are allowed to come into the model during the collection period. The two cases were evaluated in terms of traveled times of the vehicles in a certain simulation running period. Figure 2 and Figure 3 show the simulation model of the current and proposed model, respectively.

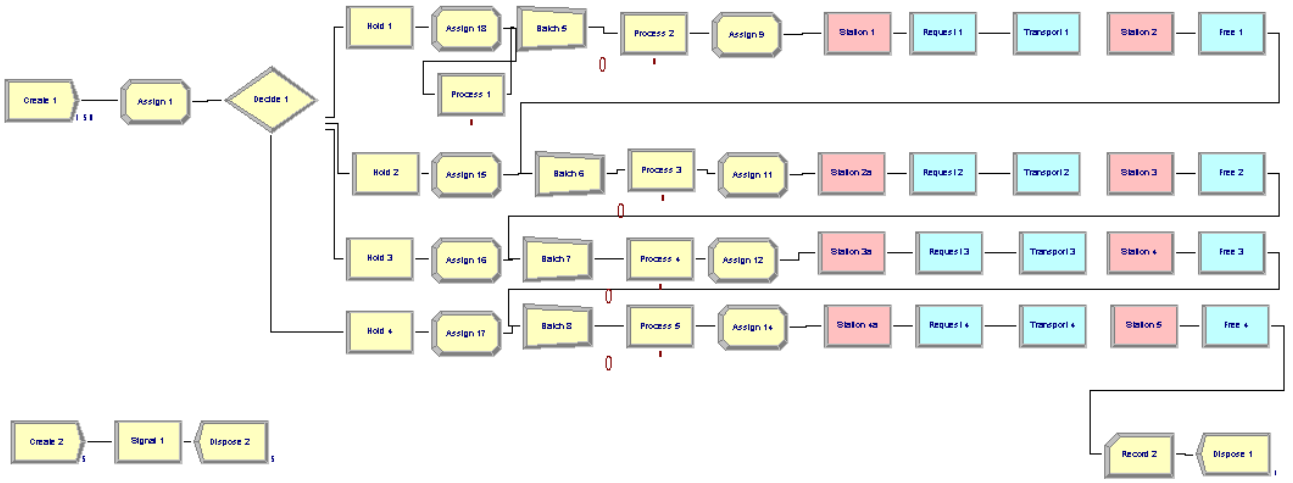

Figure 2. Simulation Model of Current System.

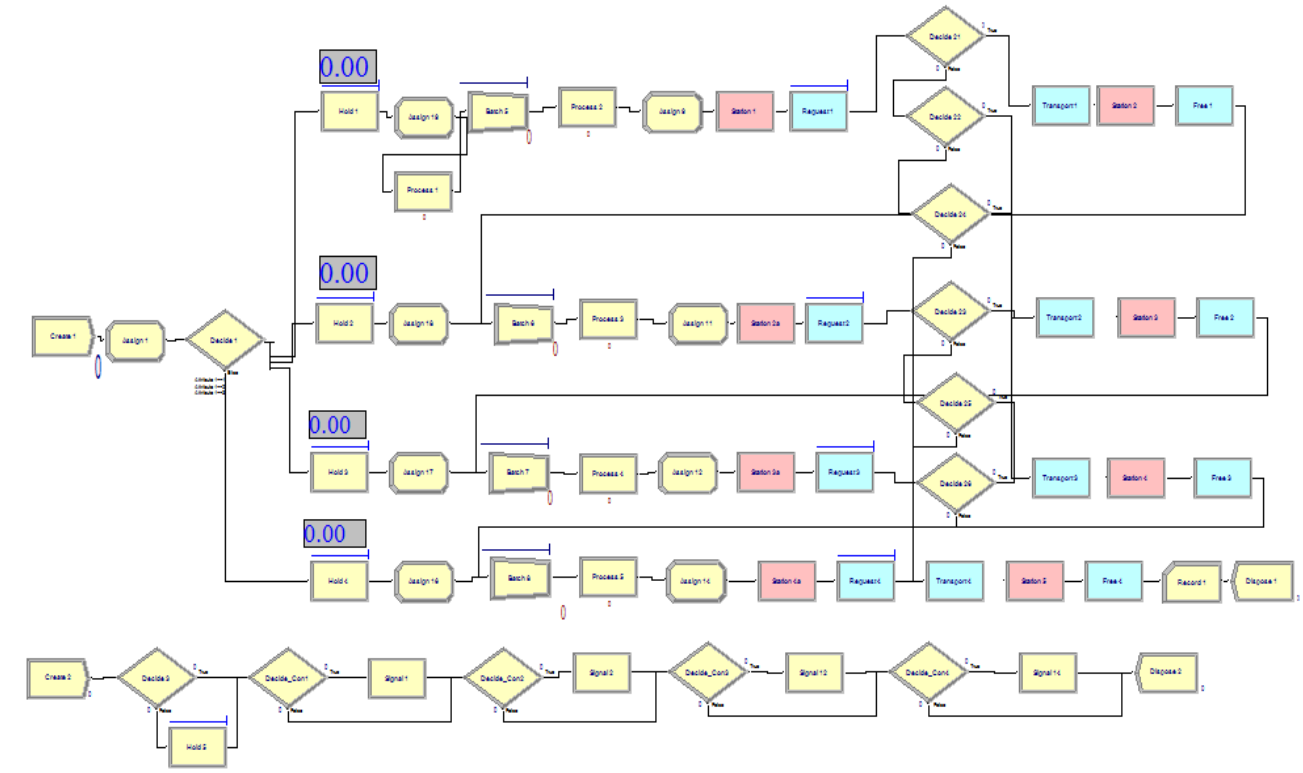

Figure 3. Simulation Model of Proposed System.

Table 1. Results of Simulation Models (min)

Replication	Model of Current System	Model of Proposed System
1	41,166	30,228
2	37,518	31,692
3	38,328	31,02
4	39,102	28,26
5	40,41	23,826
6	40,98	23,16
7	47,04	34,122
8	37,674	30,798
9	44,244	27,276
10	37,884	31,44

The current system and the proposed system results in the simulation study are given in table 1. The simulated length is 5 days in the model running 10 times. It was concluded that there is a significant difference between the average travel times of each run and the confidence interval test conducted at the 1% significance level with the proposed model results.

CONCLUSION

A waste collection system based on the Internet of Things has been proposed for the collection of recyclable wastes in the study. The speed of accumulation of recyclable waste are not same the household waste and it is also influenced by different demographic characteristics of the region, the location of the container, consumer behavior etc. Accordingly, a different chart is required for each region. Instead of scheduling for each, planning with a smart system will be easier and more cost-effective. With the proposed system, carbon emission and total traveled distance are also reduced as well as transportation costs. In the study, the proposed model and the current system are compared with ARENA simulation program. The comparison revealed a difference between the average traveled times. Progressive studies can be tried for a larger sample by giving information of the technical infrastructure. Container locations, economic analysis studies can be done.

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