DESIGN OF EFFICIENT ALGORITHM FOR WASTE MANAGEMENT

BY

UMMI NUR KAMILAH BINTI ABDULLAH DIN

A dissertation submitted in fulfilment of the requirement for the degree of Master of Science (Communication Engineering)

Kulliyyah of Engineering
International Islamic University Malaysia

SEPTEMBER 2018

ABSTRACT

Maintaining current municipal solid waste management (MSWM) for the next ten years would not be efficient anymore due to waste overflow in relation to the way of handling waste collection. This practice has brought too many environmental and health issues such as air pollution and typhoid fever respectively. Therefore, this project has proposed two Artificial Neural Network (ANN) based prediction algorithms that can forecast future Solid Waste Generation (SWG) based on two factors; population growth and household size, which can improve MSWM in Malaysia. For the population growth factor, the project can deduct that the SWG based on human population will always increase linearly with respect to time. However, the SWG based on household size would not increase linearly with time. Hence, two prediction algorithms are needed for the two factors. An online survey has been conducted to observe the human behaviour which motivates this research. Also, a smart waste bin has been developed that can measure the weight, detect the emptiness level of the waste bin, stores information and have direct communication between waste bin and collector crews. Collection of data for the prediction of SWG based on population growth factor uses the Malaysian population as sample size and the data is acquired via authorized Malaysia statistics' websites. Whilst, Kulliyyah of Engineering (KOE) in International Islamic University Malaysia (IIUM) has been chosen as the sample size for household size factor. All data will be normalized in the pre-processing stage before proceeding to the prediction using Visual Gene Developer. Statistical measure that was used in this project to evaluate the performance was the R^2 value. For population growth factor, two hidden layers with ten nodes and five nodes in the first and second layers were used respectively. Whilst, for household size factor, two hidden layers were used and the number of nodes for the first and second layers were five and ten each. After the prediction is done, the result portrayed that there will be an increase of 29.03 percent of SWG in year 2031 compared to year 2012. Whilst, for household size factor, the average rate of increment is only 2.05 percent from week one until week twenty. The limitation to this study is that the data for population growth factor is not based on real time as it is restricted by the government.

خلاصة البحث

إن الحفاظ على الإدارة الحالية للنفايات الصلبة البلدية (MSWM) للسنوات العشر القادمة لن يكون فعالا بعد الآن بسبب الفائض في النفايات فيما يتعلق بطريقة التعامل مع جمع النفايات. جلبت هذه الممارسة الكثير من القضايا البيئية والصحية مثل تلوث الهواء وحمى التيفوئيد على التوالي. لذلك ، اقترح هذا المشروع خوارزميتي التنبؤ بالشبكة العصبية الاصطناعية (ANN) التي يمكن أن تتنبأ بالتوليد المستقبلي للنفايات الصلبة (SWG) بناءً على عاملين النمو السكاني وحجم الأسرة ، مما يمكن أن يحسن MSWM في ماليزيا. بالنسبة لعامل النمو السكاني ، بالامكان استنتاج أن المجموعة SWG القائمة على السكان البشريين ستزداد دائمًا خطيًا فيما يتعلق بالوقت. ومع ذلك ، فإن مجموعة SWG القائمة على حجم الأسر المعيشية لن تزيد خطياً بمرور الوقت. ومن ثم ، هناك حاجة إلى خوارزمي التوقع اثنين من العوامل. تم إجراء مسح عبر الإنترنت لمراقبة السلوك البشري الذي يحفز هذا البحث. كما تم تطوير صندوق النفايات الذكية الذي يمكنه قياس الوزن ، والكشف عن مستوى الفراغ في صندوق النفايات ، وتخزين المعلومات ، والاتصال المباشر بين صندوق النفايات وأطقم المجمعات. جمع البيانات للتنبؤ SWG على أساس عامل النمو السكاني يستخدم السكان الماليزيين كحجم العينة ويتم الحصول على البيانات عبر مواقع إحصاءات ماليزيا المعتمدة. في حين تم اختيار كلية الهندسة (KOE) في الجامعة الإسلامية الدولية في ماليزيا (IIUM) كحجم عينة لعامل حجم الأسرة. سيتم تطبيع جميع البيانات في مرحلة ما قبل المعالجة قبل الشروع في التنبؤ باستخدام Visual Gene Developer. كان القياس الإحصائي المستخدم في هذا المشروع لتقييم الأداء هو القيمة R^2. بالنسبة لعامل النمو السكاني ، تم استخدام طبقتين مخفيتين مع عشرة عقد وخمس عقد في الطبقتين الأولى والثانية على التوالي. في حين أنه بالنسبة لعنصر حجم الأسرة المعيشية ، تم استخدام طبقتين مخفيتين وكان عدد العقد للطبقتين الأولى والثانية خمسة وعشر طبقات لكل منهما. بعد الانتهاء من التنبؤ ، أظهرت النتيجة أنه سيكون هناك زيادة قدرها 29.03 في المئة من SWG في عام 2031 مقارنة بسنة 2012.بينما بالنسبة لعامل حجم الأسرة ، فإن الزيادة هي 2.05 في المائة فقط من الأسبوع الأول إلى الأسبوع العشرين. الحد من هذه الدراسة هو أن البيانات الخاصة بعامل النمو السكاني لا تعتمد على الوقت الفعلي لأنها مقيدة من قبل الحكومة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering).

……..
Siti Hajar Yusoff
Supervisor

……..
Nur Shahida Midi
Co-Supervisor

……..
Hasmah Mansor
Co-Supervisor 2

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering).

……..
Sheroz Khan
Internal Examiner

……..
Faridah Abd. Rahman
External Examiner

This dissertation was submitted to the Department of Electrical and Computer Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Communication Engineering).

……..
Mohamed Hadi Habaebi
Head, Department of Electrical and Computer Engineering

This dissertation was submitted to the Kulliyyah of Engineering and is accepted as a fulfilment of the requirement for the degree of Master of Science (Communication Engineering).

……..
Erry Yulian Triblas Adesta
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Ummi Nur Kamilah binti Abdullah Din

Signature ..... Date .....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

DESIGN OF EFFICIENT ALGORITHM FOR WASTE MANAGEMENT

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialization policy.

Affirmed by Ummi Nur Kamilah binti Abdullah Din

……..…….. ……..
Signature Date

ACKNOWLEDGEMENTS

"In the name of Allah, the Most Gracious and the Most Merciful"

Alhamdulillah, praise be to Allah S.W.T for giving me the health and strength throughout the completion of my masters degree. Without His Blessings to help me through ups and downs during my time of need, this degree would have been very impossible.

Deepest gratitude and appreciation towards my highly motivated, positive and helpful supervisor, Dr. Siti Hajar Yusoff for her never ending support, courage, motivation and words of wisdom throughout my masters' journey. No words can describe how blissful I am to be working under her supervision. It was a great pleasure to be able to work hand in hand with her, for which I learnt a lot what it means to be in a research pursuit. Her valuable assistance has guided me in the right direction for which I will forever remain grateful.

I would also like to extend my appreciation towards my co-supervisors, Dr. Nurshahida Midi and Dr. Hasmah Mansor for their time and guidance regarding the masters' project and report. Also, to Prof Aisha Hassan for helping me during my toughest time, May Allah bless you. Not to be forgotten, my husband; Luqman Naim Mohd Esa, my friends; Syasya Azra, Nur Izzati, Nur Alia Batrisya and Mueen for always lending me their hand in my time of need. There have been lots of ups and downs during my master's journey, yet they prove me that good people do exist.

Last but not least, special thanks to my parents, Abdullah Din Mohamed and Norhawati Embong as well as my siblings for their endless prayers and support to achieve the goal. May Allah S.W.T rewards all of them the good in this Dunya and the Hereafter for their uncountable kindness and morale support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANFIS	Adaptive Neuro-Fuzzy Inference System
ANN	Artificial Neural Network
ARIMA	Autoregressive Integrated Moving Average
CDMA2000	Code Division Multiple Access 2000
FCM-ANFIS	Adaptive Neuro-Fuzzy Inference System with fuzzy c-means clustering
GSM	Global System for Mobile
IoT	Internet of Things
IS-95	Interim Standard-95
ISDN	Integrated Services Digital Network
KDEB	Kumpulan Darul Ehsan Berhad
k-NN	*k*-Nearest Neighbours
KOE	Kulliyyah of Engineering
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
ML	Maximum Likelihood
MLP	Multi-Layer Perceptron
MSE	Mean Square Error
MSWM	Municipal Solid Waste Management

NARnet	Nonlinear Autoregressive Neural Network
NARX	Nonlinear Autoregressive Network with Exogenous Inputs
NSWMD	National Solid Waste Management Department
OLS	Ordinary Least Square
PCA	Principal Component Analysis
PCA-Regression	Principal Component Analysis-Regression
PIR sensor	Passive Infrared sensor
PSTN	Public Switched Telephone Network
R^2	Correlation Coefficient
REML	Restricted Maximum Likelihood
RMSE	Root Mean Square Error
RTC	Real-time clock
SMS	Short Messaging Services
SPST	Shortest Path Spamming Tree
SVM	Support Vector Machine
SWG	Solid Waste Generation
Ts	Threshold Statistic
USA	United States of America
Wi-Fi	Wireless Fidelity
WNLS	Weighted Nonlinear Least Squares
WWW	World Wide Web

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

As years passed by, municipal solid waste management (MSWM) will remain to be one of the crucial problems faced in most of the developing countries including Malaysia. This problem has mainly resulted from the increment of population and variation in the household size (Saini, Ahuja, & Bahukhandi, 2017). Same situation also happens in Indonesia, where increased in population is greatly triggering the MSWM issues (Gita, Tri & Benno, 2017).

There are two ways of managing municipal solid waste in Malaysia. First is the management of waste as a whole, whereby the future amount of waste generated is needed in order to plan for the landfill and second is the management of waste collection at household area to avoid public bin's overflow.

On another note, Rinkesh (2018) claimed that five major consequences of human overpopulation are the reduction of natural resources, deprivation of environment, landfill overload, higher chance of unemployment as well as increased of living cost. Clearly, poor management of solid waste will lead to one of the negative consequences stated by Rinkesh which is landfill overload. Then, it will eventually lead to another pressing problem which is the environmental issues. Common environmental issues related to this can be identified such as air pollution, water pollution as well as excessive generation of methane gas. This cycle will continuously repeat if early prevention is taken for granted.

According to a press release by the Department of Statistics Malaysia (2017), it is estimated that Malaysia is experiencing an increment of 1.3% population growth in 2017 compared to 2016 with approximately 32.0 Million people are living in Malaysia in 2017. This statistic is supported by the United Nations estimations' technique where the forecasted Malaysia population are summarized in Figure 1.1 ("Malaysia Population (2018) - Worldometers", 2018). Based on the Figure 1.1 estimation's technique, Malaysia is experiencing a continuous increase in the amount of human population since 1955 and this population covers 0.42% of the total world's population. Figure 1.1 also estimates that in year 2050, the population in Malaysia will be quintuple compared to the population in year 1955.

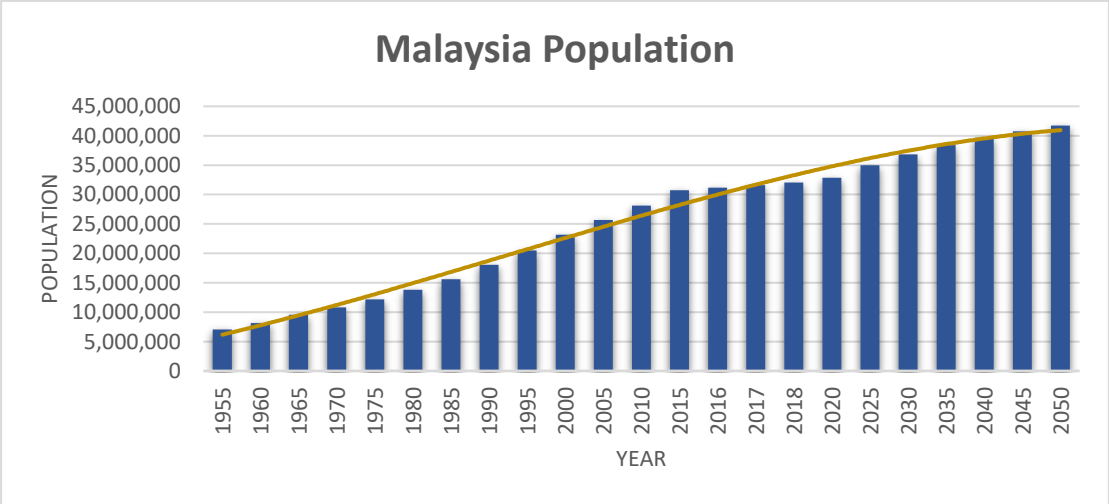

Figure 1.1 History and projected Malaysia Population based on United Nation estimation's technique

Undeniably, waste generation will continually to increase with the growth of population over time. A statistic (Performance Management and Delivery Unit (PEMANDU), 2015) has outlined from year 2012 until year 2015, the increased amount of waste generated is increasing from 32,800 tonnes per day to 38,500 tonnes per day.

The amount of waste generated is laid out as in Figure 1.2. This statistic shows that as years pass by from 2012 to 2015, the amount of waste generated is always increasing. For instance, the waste generated in year 2015 has increased more than 5000 tonnes per day than in year 2012. From Figure 1.2, the increased in waste generated can be identified as linear increment.

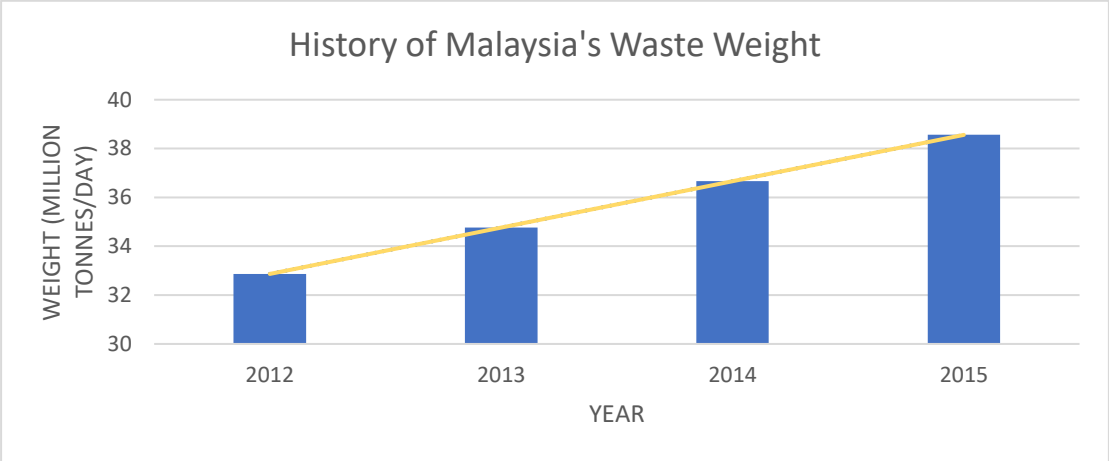

Figure 1.2 History of Malaysia's waste weight from 2012 until 2015

On top of that, another pressing factor to the difficulties in managing the MSWM is the difference in the household sizes. On 1st July 2016, a new smartphone application has been officially launched by Selangor Government based on Pek Mei (2017). "iClean Selangor" is assumed to cater the problem of solid waste management in household area. This technique is meant for the people in Selangor to lodge a report to Kumpulan Darul Ehsan Berhad (KDEB) Waste Management if there is any waste related problem arise in Local Council of Klang, Selayang, Ampang Jaya and Kuala Langat area. KDEB Waste Management is the new garbage collector operating under the Selangor State Government (Anand, 2016). Nevertheless, this system is considered impractical because of some possibilities that might occur which are:

1. Not all residents have access to the internet especially in the remote area thus making them harder to lodge the report.

2. It has been almost two years since the launching of this system in 2016, yet the record of the downloads is only 500 which is very little. It shows the impracticality and unawareness about the system itself.

Nevertheless, public waste bins will be filling up faster than ever due to the increasing number of population. Inevitably, many of the bins end up overflowing before collection time, causing not only cluttered streets and bad odors, but also negative health and environmental impacts. Consequently, negative impacts that bring harm to the environment will slowly be the alarming issues to the society (Juutinen, 2016). Consequences that could happen due to poor handling of solid waste management are:

1. The spread of bacteria and insects from waste can increase the possibility of people facing salmonella bacteria which will lead to food poisoning, fever and other severe illnesses.

2. Overflow of garbage prompt the air pollution index from good to bad drastically. It will eventually disrupt the human respiratory processes and affect our health condition as the bad gases are absorbed by the lung and spread to other parts of the body.

3. Garbage can contaminate surface waters, which can affect all ecosystems.

There are many techniques (Marandi & Ghomi, 2016; M.A. Abdoli, M.F. Nezhad, R.S. Sede, S. Behboudin 2011; R. Noori, M.A. Abdoli, A. Ameri Ghasrodashti, & M.J. Ghazizade, 2008; Sun & Chungpaibulpatana, 2017; Saini et al., 2017; Younes, M. K., Nopiah, Z. M., Basri, N. E. A., Basri, H., Abushammala, M. F. M., & Maulud, K. N. a., 2015; Abbasi & El Hanandeh, 2016) that are already being applied to forecast the waste generated. Back in 2008, the first ever solid waste generation prediction's technique has been invented by researchers in Mashhad, a city located in northeast of Iran (R. Noori et al., 2008). As mentioned by R. Noori et al., future information about waste generated in a country is vital thus it is the key component towards achieving an excellent MSWM. The question that everyone might have overlooked is how accurate is the current waste generation prediction technique? Can a prediction technique be used for different types of causes? Hence, continuous effort is highly needed to analyze significant approaches based on the latest practice of resource consumption (Kadir & Sani, 2016).

Preliminary work has been done to predict the amount of waste generated based on different types of prediction techniques. However, none of the previous research works (Marandi & Ghomi, 2016; Abdoli et al., 2011; Sun & Chungpaibulpatana, 2017; Saini et al., 2017; Younes et al., 2015; Abbasi & El Hanandeh, 2016) has considered using different algorithm for different factors. For instance, different household size will produce different amount of waste. This factor has been considered based on the survey conducted during the preliminary stage which is further discussed in Section 3.2 in Chapter 3. Hence, in order to cater the aforementioned problem, a new approach can be proposed by using an effective algorithm to project future waste generated based on the population growth and the household size categories.

1.2 PROBLEM STATEMENT

Maintaining current way of curbside collection for different household size would be very inefficient. The waste collector crews are only following their own schedule to collect the garbage at the respected scheduled area. Unfortunately, this will cause inefficient in term of fuel consumption and time management. Sometimes, due to the scheduled collection routine, the bins can get overflow way before the collection time. This will further cause diseases including typhoid fever, dengue and other major illnesses.

On the other hand, human overpopulation is one of the most unavoided causes for the environmental issue. As the population growth is escalating rapidly, there will be more people who will consume more resources. Undoubtedly, the excessive natural resource consumption for the development of the country will contribute to the same problem that this project has discussed earlier which is the increased of waste generation. MSWM in Malaysia do not have the exact statistic of how much waste is generated and how many times the waste bins get full per day. Without these statistics, it is very hard for the government to provide ample spaces of the compost sites and to plan for the garbage pick-up schedule for the future. Therefore, it is important to note the variations of the factors that contribute to managing the MSWM.

Currently, there are a few approaches on predicting the waste generation as elaborated in Chapter 2. However, majority of the research works that have been done focuses on the prediction of waste generation based on population growth. As per research done by Saini et al. (2017), the algorithm was to tackle the issue of SWG based on previous amount of SWG only but not mentioning any about the household size factor. Therefore, prediction algorithm using ANN is proposed to overcome those aforementioned issues due to its widely known of accuracy in prediction technique.

1.3 RESEARCH OBJECTIVES

The main objective of this research is to design efficient prediction algorithm for waste management to predict the generation of waste based on population growth and household size. The remaining objectives of this study are listed as follows:

1. To develop a mechanism that can automate real-time waste monitoring and collection.

2. To design efficient prediction algorithms that relates to waste production in reference to growth in population and household size.

3. To analyze the performance of the prediction algorithm based on population growth and household size for waste management.

1.4 RESEARCH METHODOLOGY

This section will lay out the overview of the methods used throughout the completion of this project. There are four main parts in this methodology, which cover the general human behaviour of Malaysian, data acquisition, pre-processing and evaluation stage. The stages are summarized in Figure 1.3.

For the general human behaviour of Malaysian, a set of questionnaires for a total of 108 respondents is analysed. This analysis is done during the preliminary stage of this project. During the survey, a total of twenty questions have been given. The details of the questionnaires will be further discussed in Section 3.2 in Chapter 3. The aim of the survey is to analyse the human behaviour in terms of their awareness towards waste management which can influence the society.

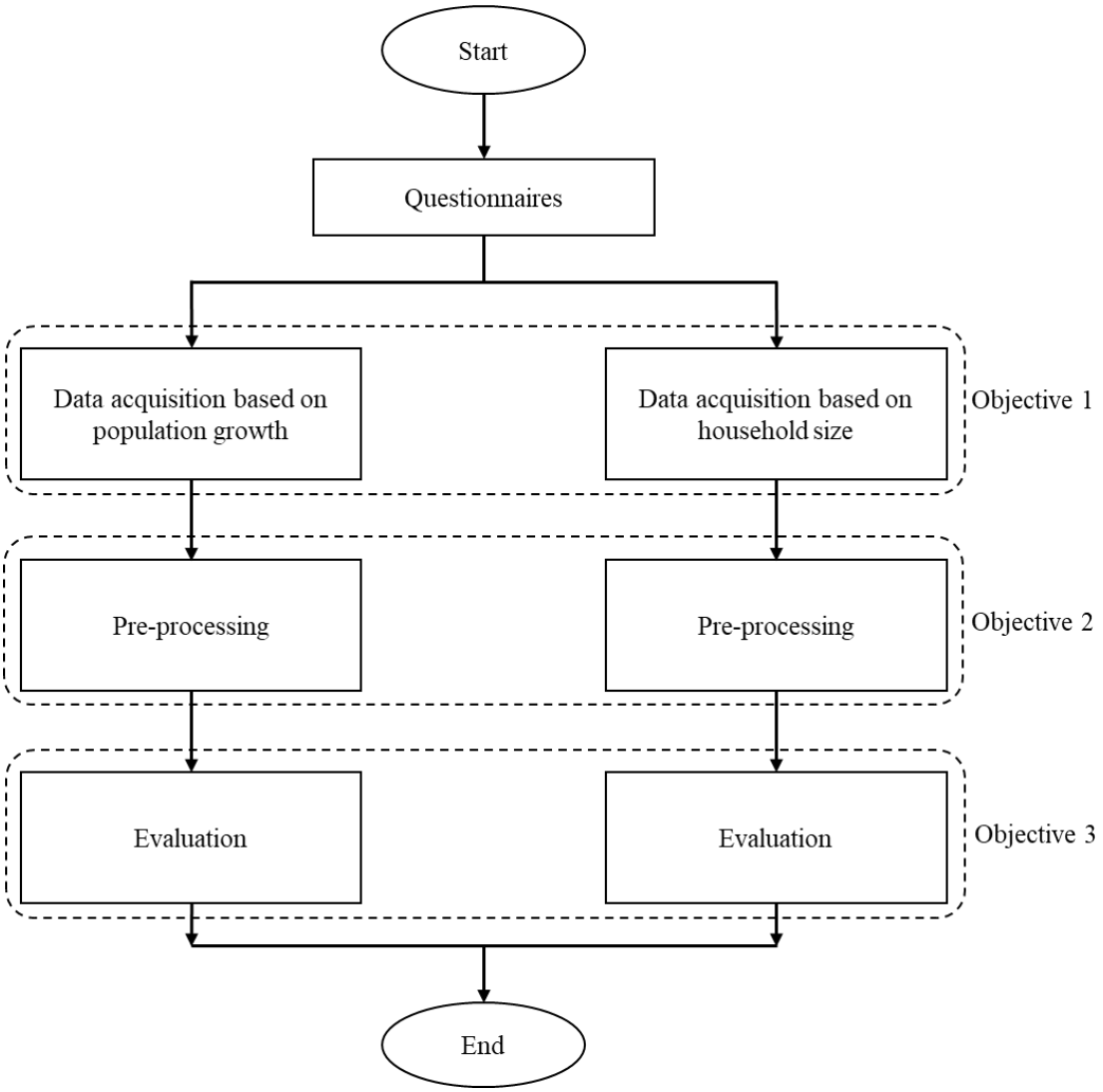

Figure 1.3 Research methodology overview

During the second stage of methodology, there are two factors that have been considered. These factors are population growth and household size. For population growth factor, the data of the waste amount that has been generated and the number of population in Malaysia will be obtained through authorised websites (DEPARTMENT OF STATISTICS MALAYSIA, 2017; "Malaysia Population (2018) - Worldometers", 2018; Performance Management and Delivery Unit (PEMANDU), 2015; Selangor @ a Glance, 2018). Meanwhile for household size, this project is only focusing on waste generated at KOE, IIUM. KOE is considered as sample size for this project. The

household size in KOE will be obtained through the Department of Academic Affairs in KOE. Whilst, the amount of waste is collected using a smart waste bin which have been equipped with few sensors respectively. Further discussion on the design smart waste bin is explained in Chapter 3.

Then, waste generation prediction algorithm will be done during the pre-processing stage which will be further explained in Chapter 3. This pre-processing stage will be divided into two different section which are the prediction algorithm based on population growth and the prediction algorithm based on household's size. Artificial Neural Network (ANN) will be used to forecast the SWG based on those two factors. Finally, the evaluation stage will be based on the statistical measure that represent the performance of each prediction algorithm.

1.5 SCOPE OF RESEARCH

While lots of open issues are related to the improvement of waste management, the focus of this research will be based only on the followings:

i. The prediction technique for waste generation based on population growth and household size.
ii. The prediction algorithm architecture is based on ANN.
iii. The design of the waste bin is made to cater these following specifications:
    a. To measure the waste's weight.
    b. To detect the waste bin's emptiness level.
    c. To enable real-time data storage.

d. To enable direct communication between the waste bin and waste collector crews.

1.6 SIGNIFICANCE OF THE STUDY

With the implementation of the proposed algorithm technique in this project, it will lead to major contribution to the waste management municipal in Malaysia. This is because, with the help of proposed algorithm technique, pre-planning of waste management can be obtained for years ahead. In this project, a prediction of waste generated up to year 2031 is estimated, thus will help the municipal to prepare enough land disposal for the coming years.

Meanwhile, this project will also benefit the KOE in terms of efficiency in collection time and manpower. Due to the proposed prediction algorithm and the design of the smart bin, this project can improve the handling of the waste in KOE by providing an estimation of the prioritised building in KOE. This priority is based on the number of size of population in each block in KOE.

With a very low cost, a smart bin is built to offer benefits to both citizens and upper management in improving the handling of waste collection in Malaysia to avoid bin's overflow at the household area. Furthermore, by implementing this smart bin, it will cut the cost and improve the time efficiency of the waste collector crews.

On the other hand, different prediction algorithms for different situations will give a more accurate result of prediction. Therefore, the proposed work is expected to improve the handling of waste management in Malaysia in the near future based on population growth and household size.