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Research Article

Recyclable Waste Forecasting with Statistical Assessment of Numerical Models

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Abstract: This research aims study on the data collection and forecasting in the recycle wastes of the 2 green schools are Prachaniwet school and Sainamtip school, from 2018 to 2020 through these 3 years. The large Prachaniwet school under Bangkok Metropolitan Administration (BMA) and The large Sainamtip school under Ministry of Education that had engaged in project of the green school locating on Bangkok city. The recycle wastes in 4 categories as recycling plastic, recycling glass, recycling paper and recycling can, compare between Prachaniwet school and Sainamtip school in range of 6 months.The statistical analysis from the data collection with 4 forecasting technics, are Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing.The recycling waste from both Prachaniwet school and Sainamtip school in 4 categories in range of 6 months from 2018 to 2020. The most recycling waste is plastic, which has a seasonal effect due to semester start. The others recycling waste are glass, paper, and can seem to be vanish after September of 2019. Recycle glass appeared in June of 2018 then emerging in September of 2018 then drop in March 2019 which is the closing semester period. The amount of recycling waste that produced from both Prachaniwet school and Sainamtip school 4 categories from 2018 to 2020. Waste plastic is the biggest among recycle waste in these 3 years, about 210 kilograms. Then, recycled glass appears to be 20 kilograms. Recycled paper waste and recycled can waste are 5 kilograms and 8 kilograms, respectively. The comparison in 4 categories between Prachaniwet school and Sainamtip school.Sainamtip school seem to have recycling plastic waste, recycling glass waste, and recycling can waste more than Prachaniwet school. In recycling paper waste, Prachaniwet school seem to have more than Sainamtip school. The 4 forecasting techniques for 4 types of recycling wastes in Prachaniwet school in 2021 Prachaniwet school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the recycling plastic has seasonal effect because the semester starts, the forecasting in 2021 for recycling plastic drop in March and November. And the others 3 recycling wastes lines seem to lay on 0 kilograms and then emerging about 2 months and then drop to 0 kilograms. The forecasting techniques for 4 types of recycling wastes in Sainamtip school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the forecasting line for Sainamtip school moving like forecasting line in Prachaniwet school. The research result benefits from The forecasting techniques of this research with the Moving average, the Weight moving average, the Simple exponential smoothing, the Holt's exponential smoothing can be used to prepare for what will happen in the future, gain the valuable in insight, and thee result from prediction methods could decrease cost for the environmental management on the green schools on the recycle waste.

Keywords: Forecasting, Recycle waste, School, Correlation, Statistic

1. Introduction

Recycling waste is valuable waste due to its potential to be used as raw material being thrown away instead of being collected and separated properly while the waste can also the environmental pollution because 2 main reasons cause people do not litter their waste appropriately as lacking of basic knowledge how to separate the valuable waste correctly, and lacking of motivation to separate the valuable waste. H olistic waste management system tries to tackle these problems using modern Information Technology. The system consists of 2 parts; the first one is the software design and implementation including web-based waste management application and mobile-application-based rewarding system; whereas the second one is the hardware design and implementation based on Internet of Things and Machine Learning technology. This part can recognize and separate 3 kinds of waste automatically, namely glass bottles, plastic bottles, and metal cans. The system is tested and it functions as expected. It can separate the mentioned 3 kinds of waste with good results. The rewarding system on mobile application allows the people to collect the points and get rewarded. This motivates them to litter their waste properly (Kittiya Thibuy et al., 2020). Construction and demolition waste (C&DW) as a direct consequence of rapid urbanization is increasing around the world. C&DW generation has been identified as one of the major issues in the construction industry due to its direct impacts on the environment as well as the efficiency of construction industry. It is estimated that an overall of 35% of C&DW is landfilled globally, therefore, effective C&DW management is crucial in order to minimize detrimental impacts

of C&DW for the environment. As the industry cannot continue to practice if the resources on which it depends are depleted, C&DW management needs to be implemented in an effective way. Despite considering many well-developed strategies for C&DW management, the outputs of the implementation of these strategies is far from optimum. The main reason of this inefficiency is due to inadequate understanding of principal factors, which play a vital role in C&DWmanagement. The concept of C&DW and its managerial issues in a systematic way to come up with the effective C&DW management. In order to achieve this aim, and based on a systematic review of 97 research papers relevant to effective C&DW management, this research considers two main categories as fundamental factors affecting C&DW management namely, C&DW management hierarchy including reduce, reuse, and recycle strategies, and effective C&DW management contributing factors, including C&DWmanagement from sustainability perspective, C&DW stakeholders' attitudes, C&DW project life cycle, and C&DWmanagement tools. Subsequently, these factors are discussed in detail and findings are scrutinized in order to clarify current and future practices of C&DW management from both academic and practical perspectives (Kamyar Kabirifar et al., 2020). Waste disposal was a significant challenge faced by the community and government. Customers buy and use goods that produce a considerable amount of waste. Waste management is a major problem since the number of consumers increased due to high waste generation. This has resulted in a huge amount of waste, which calls for enormous waste-management policies. Reduce; Reuse, Recycle, and Recover are the tools to reduce the adverse implications of retailing and manufacturing on the environment. Artificial Intelligence based Hybridized Intelligent Framework (AIHIF) has been proposed for automated recycling to optimizing the waste management process. The system will optimize waste collection with a short distance by utilizing machine learning and graph theory. AI design technology, which helps different approaches adapted to interest groups, collecting their specific information and greatly improving environmental planning and urban management performance, accuracy, and efficiency (Kan Hua Yu et al., 2021). A significant amount of solid waste generation from various streams become inevitable for large campuses due to their large population and variety of activities taking place on the campus. Therefore, it is a challenge to develop and implement an Integrated Solid Waste Management plan for large campuses to aid sustainable campus practices. The aim of this study is to develop sustainable strategies that will support the Integrated Solid Waste Management plan for Middle East Technical University which has one of the largest campuses in Turkey which the average daily solid waste generation factor is 0.40 kg/day/cap and the total amount of waste generated varies between 5.8 and 10.3 tons/day on a weekly basis on the campus. In addition, it was found that the total collected recyclable waste accounts for 13% of the total waste generated. The complete evaluation resulted in the development of strategies (behavioral, structural and managerial) to decrease the solid waste generation rate, increase the recyclable material collection rate and initiate compost activities (Ecem Bahcelioglu et al., 2020). Some of the latest technologies in waste management, and emphasizes the benefits that can be gained from the use of recycled products. Divided into four sections, it deals with phytoremediation, acquatic weed management and the treatment of solid- and water-based wastes, such as those arising from agricultural, industrial and medical activities. With its special emphasis on the utilization of recycled products, this volume will be of interest to students, academicians, policy makers and others who have a practical and academic interest in dealing with the waste society generates (Kalamdhad et al., 2019) . A life cycle and energy flow assessments of Municipal Solid Waste (MSW) using Artificial Neural Network (ANN) for integrated waste management system in Tehran Municipality, Iran. The initial data have been obtained from Waste Management Organization of Tehran Municipality. The results obtained from Life Cycle Assessment (LCA) indicate that transportation is considered the most important hot spot in the recycling of MSW while recycling papers is the main contributor to the redaction of environmental indicators in the recycling system. More intensity is observed for indicators related to toxicity due to the lack of waste disposal and to the entry of undesirable substances in natural resources. (Ashkan Nabavi-Pelesaraei et al., 2017).

The present statistical Analysis from the data collection case to forecasting with statistic numerical modelling. The forecasting techniques in the present are Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing. The forecasting technique of the Moving average as one of the simplest forecasting techniques have the benefits on the prediction values are stable and The simplest forecasting technique. The forecasting technique of the Weight moving average as more advanced by adding a weight as coefficient in the equation. The set of coefficients that will be assigned a greater weight to newer data point, while past data points are assigned to be less weight, have the benefits on adding the Weight parameter though time, the present data has more value than older data,and may capture present's event that affect the raw data. The forecasting technique of the Simple exponential smoothing as one of the techniques in exponential smoothing forecasting. The simple exponential smoothing technique is weighting between the observed data and the forecasting data, have the benefits on the easiest in exponential smoothing technique, and weight between past forecasting value and actual value could perform better than moving average. The forecasting technique of the Holt's exponential smoothing as the concept is to introduce a term of capturing the trend from the data. This research has done the exponential smoothing by using Python's library called statsmodel, have the benefits on

Holt's exponential smoothing technique can capture trend in raw data, and more accurate than simple exponential smoothing in general.

This research study on the data collection and forecasting of the recycle wastes of the 2 green schools are Prachaniwet school and Sainamtip school, from 2018 to 2020 though these 3 years. The recycle wastes in 4 categories as recycling plastic, recycling glass, recycling paper and recycling can, compare between Prachaniwet school and Sainamtip school.The forecasting techniques of this research are the Moving average, the Weight moving average, the Simple exponential smoothing, the Holt's exponential smoothing.

2.Materials and Methods

The data collection of the recycle wastes of the 2 schools are Prachaniwet school and

Sainamtip school, from 2018 to 2020 though these 3 years. The large Prachaniwet school under Bangkok Metropolitan Administration (BMA) and The large Sainamtip school under Ministry of Education that had engaged in project of the green school locating on Bangkok city.The recycle wastes in 4 categories as recycling plastic, recycling glass, recycling paper and recycling can, compare between Prachaniwet school and Sainamtip school in range of 6 months.

The statistical analysis from the data collection case to 4 forecasting technics, are Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing ;

1.Moving average: This technique is one of the simplest forecasting

techniques. The formula is as follow:

$$\hat{y}_{t+1} = \mathrm{MA(k)}_t$$

Parameter:

$\hat{y}_{t+1}$ forecasting value at t+1 period

k number of time periods

2.Weight moving average: This technique is more advanced by adding a

weight as coefficient in the equation. The set of coefficients that will be assigned a greater weight to newer data point, while past data points are assigned to be less weight. The formula is as follow:

$$\hat{y}_{t+1} = \mathrm{WMA(k)}_t$$

Parameter:

W coefficient value as weight

3.Simple exponential smoothing: This is one of the techniques in exponential smoothing forecasting. The simple exponential smoothing technique is weighting between the observed data and the forecasting data (Brown,1963)

$$\hat{y}_{t+1} = \alpha y_t + (1-\alpha)\hat{y}_t$$

Parameter:

$\hat{y}_t$ forecasting value at t period

y_t actual data at t period

α the smoothing factor, $0 \leq \alpha \leq 1$

4.Holt's exponential smoothing: The concept is to introduce a term of capturing the trend from the data (Holt,1957).This research has done the exponential smoothing by using Python's library called statsmodel (Seabold and Perktold,2010).

$$L_t = \alpha y_t + (1-\alpha)(L_{t-1} + T_{t-1})$$
$$T_t = \beta(L_t - L_{t-1}) + (1-\beta)T_{t-1}$$
$$\hat{y}_{t+p} = L_t + pT_t$$

Parameter:

α the smoothing factor for level, $0 \leq \alpha \leq 1$

β the smoothing factor for trend, $0 \leq \beta \leq 1$

3.Results

1.The recycle waste quatity comparison of the 2 schools are Prachaniwet school and Sainamtip school, from 2018 to 2020 through 3 years. The recyclable waste in 4 categories as recycling plastic, recycling glass, recycling paper and recycling can. The comparison of recycling waste between Prachaniwet school and Sainamtip school in range of 6 months (Table 1 and Figure 1).

Table 1 The comparison of recycling waste between Prachaniwet school and Sainamtip school in range of 6 months.

Date	Prachaniwet school	Sainamtip school
Jan 2018 to Jun 2018	16	18
Jul 2018 to Dec 2018	24	41
Jan 2019 to Jun 2019	19	21
Jul 2019 to Dec 2019	12	28
Jan 2020 to Jun 2020	16	17
Jul 2020 to Dec 2020	14	15

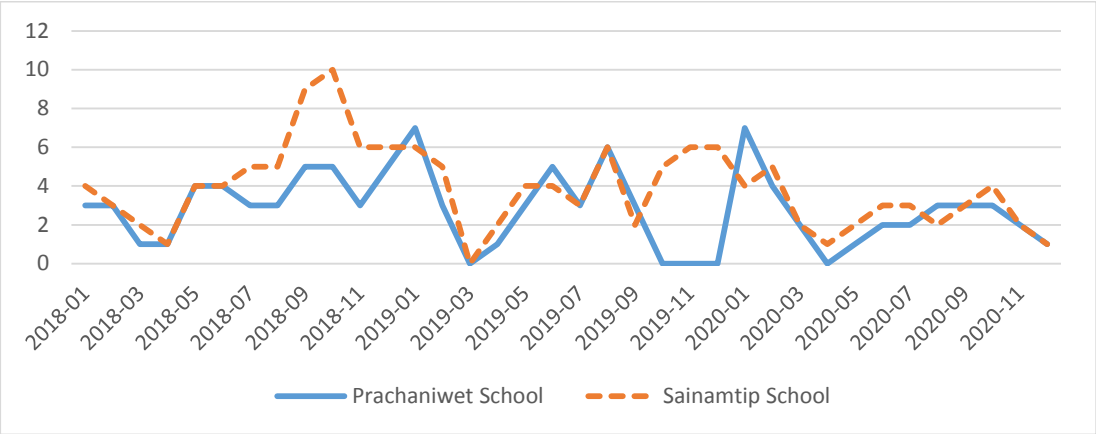

Figure 1 The amount of recycling waste in Prachaniwet school and Sainamtip School.

2. The recycling waste from both Prachaniwet school and Sainamtip school in 4 categories in range of 6 months from 2018 to 2020. The most recycling waste is plastic, which has a seasonal effect due to semester start. The others recycling waste are glass, paper, and can seem to be vanish after September of 2019. Recycle glass appeared in June of 2018 then emerging in September of 2018 then drop in March 2019 which is the closing semester period (Table 2 and Figure 2).

Table 2 The recycling waste from both Prachaniwet school and Sainamtip school in 4 categories in range of 6 months.

Date	Recycling plastic	Recycling glass	Recycling paper	Recycling can
Jan 2018 to Jun 2018	34	0	0	0
Jul 2018 to Dec 2018	45	14	3	3
Jan 2019 to Jun 2019	32	6	0	2
Jul 2019 to Dec 2019	35	0	2	3
Jan 2020 to Jun 2020	33	0	0	0
Jul 2020 to Dec 2020	29	0	0	0

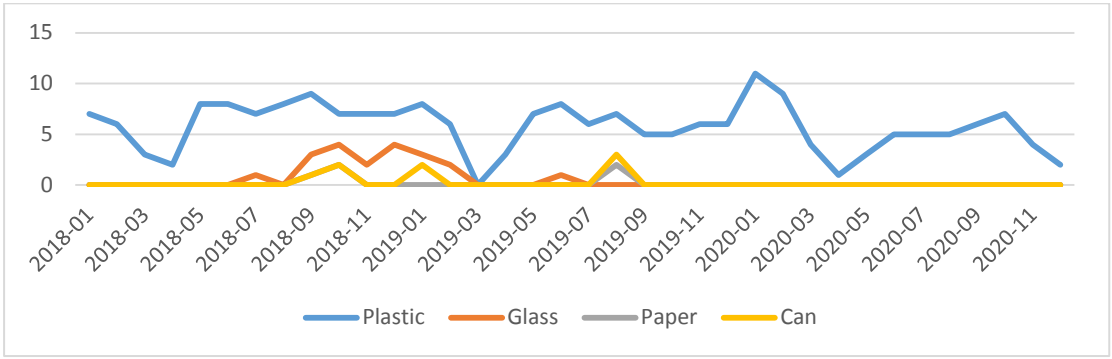

Figure 2 The recycling waste in 4 categories from 2018 to 2020.

3.The amount of recycling waste that produced from both Prachaniwet school and Sainamtip school 4 categories from 2018 to 2020.. Waste plastic is the biggest among recycle waste in these 3 years, about 210 kilograms. Then, recycled glass appears to be 20 kilograms. Recycled paper waste and recycled can waste are 5 kilograms and 8 kilograms, respectively (Table 3 and Figure 3).

Table 3 The amount of recycling waste that produced from both Prachaniwet school and Sainamtip school in 4 categories

Recycling plastic	Recycling glass	Recycling paper	Recycling can
208	20	5	8

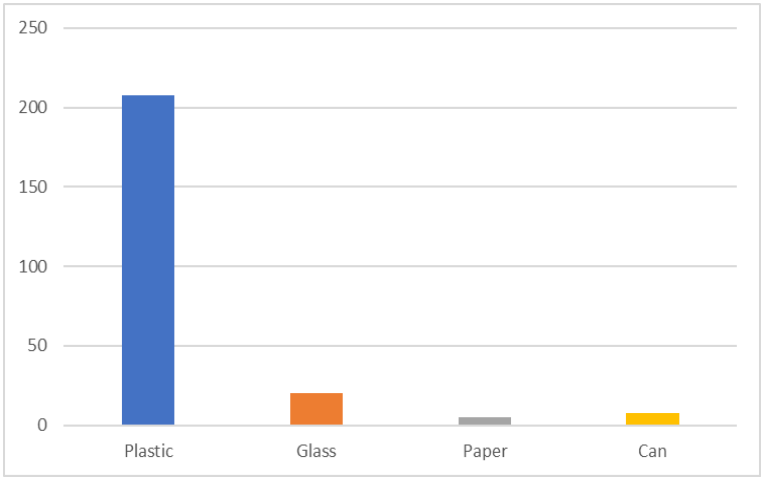

Figure 3 The amount of recycle waste in 4 categories from 2018 to 2020.

4.The comparison in 4 categories between Prachaniwet school and Sainamtip school.Sainamtip school seem to have recycling plastic waste, recycling glass waste, and recycling can waste more than Prachaniwet school. In recycling paper waste, Prachaniwet school seem to have more than Sainamtip school (Table 4 and Figure 4).

Table 4 The comparison in 4 categories between Prachaniwet school and Sainamtip school

Recycle waste	Prachaniwet school	Sainamtip school
Recycling plastic	89	119
Recycling glass	6	14
Recycling paper	3	2
Recycling can	3	5

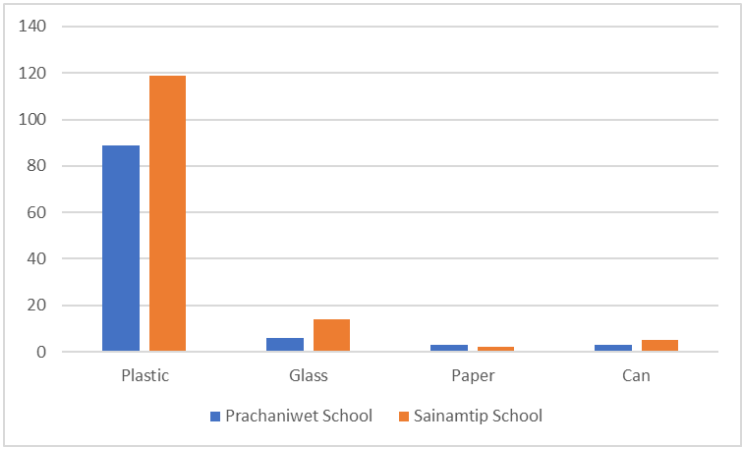

Figure 4 Amount of 4 categories recycle waste in Prachaniwet school and Sainamtip school.

5.The 4 forecasting techniques for 4 types of recycling wastes in Prachaniwet school in 2021 Prachaniwet school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the recycling plastic has seasonal effect because the semester starts, the forecasting in 2021 for recycling plastic drop in March and November. And the others 3 recycling wastes lines seem to lay on 0 kilograms and then emerging about 2 months and then drop to 0 kilograms (Table 5-8 and Figure 5-8).

Table 5 The prediction of recycling waste in Prachaniwet school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	4.67	5.3	3.50	5.99
Feb 2021	3.33	3.50	3.00	3.00
Mar 2021	1.00	1.17	0.49	0
Apr 2021	0.67	0.50	1.00	1.00
May 2021	2.67	2.17	3.49	1.00
Jun 2021	3.33	3.00	4.00	4.00
Jul 2021	2.67	2.50	3.00	3.00
Aug 2021	3.00	3.00	3.00	3.00
Sep 2021	3.33	3.17	3.49	1.00
Oct 2021	2.00	2.00	1.50	0
Nov 2021	1.67	1.50	1.50	0
Dec 2021	1.33	1.00	1.50	0

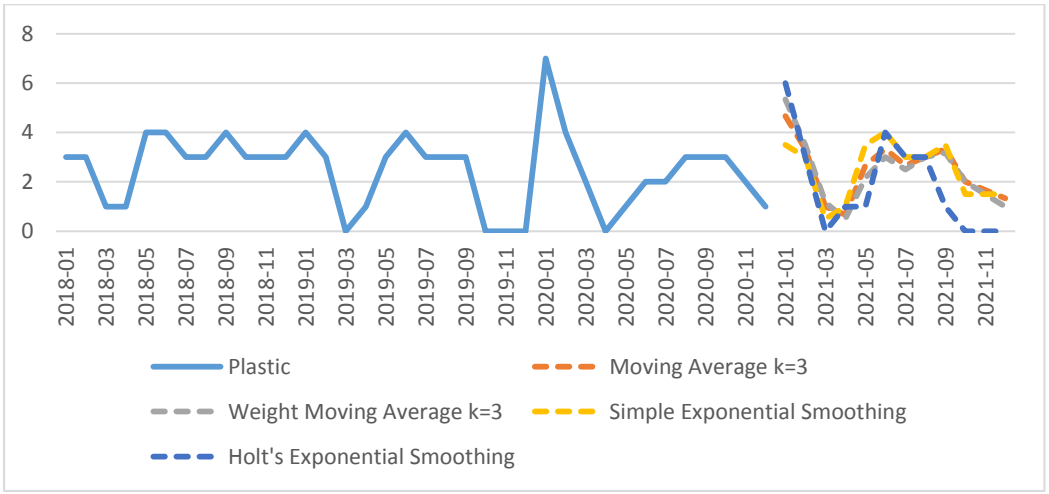

Figure 5 Forecasting techniques in recycling plastic for Prachaniwet school in year 2021.

Table 6 The prediction of recycling glass in Prachaniwet school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	1.00	0	0	5.33
Feb 2021	0	0	0	3.50
Mar 2021	0	0	0	1.17
Apr 2021	0	0	0	0.50
May 2021	0	0	0	2.17
Jun 2021	0.33	0	0	3.00
Jul 2021	0	0	0	2.50
Aug 2021	0	0	1.00	3.00
Sep 2021	0	0.33	0	3.17
Oct 2021	0	0.67	0	2.00
Nov 2021	0	0	0	1.50
Dec 2021	0.67	0	0	1.00

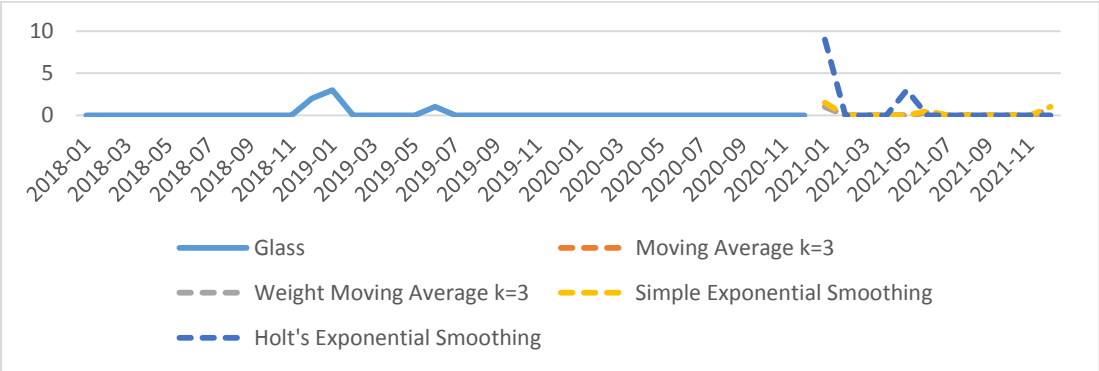

Figure 6 Forecasting techniques in recycling glass for Prachaniwet school in year 2021.

Table 7 The prediction of recycling paper in Prachaniwet school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	0	0	0	0
Feb 2021	0	0	0	0
Mar 2021	0	0	0	0
Apr 2021	0	0	0	0
May 2021	0	0	0	0
Jun 2021	0	0	0	0
Jul 2021	0	0	0	0
Aug 2021	0	0	0	0
Sep 2021	0.33	0.17	0.99	0
Oct 2021	0.67	0.33	1.00	0
Nov 2021	0	0	0	0
Dec 2021	0	0	0	0

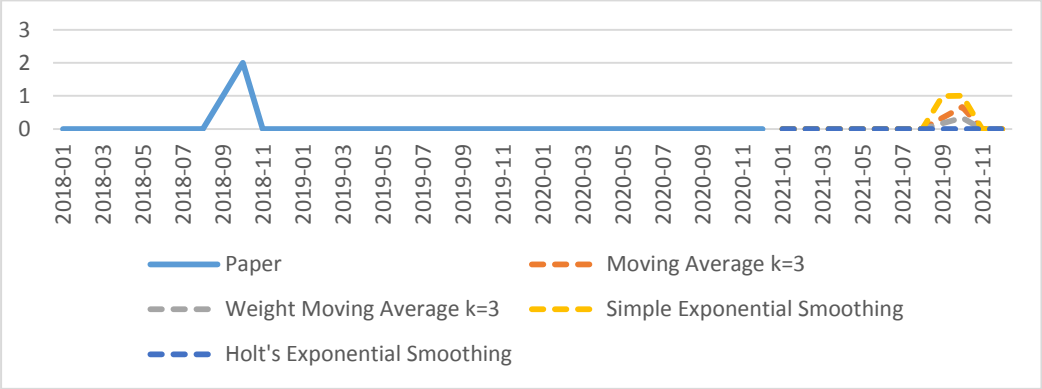

Figure 7 Forecasting techniques in recycling paper for Prachaniwet school in year 2020.

Table 8 The prediction of recycling can in Prachaniwet school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	0	0	0	0
Feb 2021	0	0	0	0
Mar 2021	0	0	0	0
Apr 2021	0	0	0	0
May 2021	0	0	0	0
Jun 2021	0	0	0	0
Jul 2021	0	0	0	0
Aug 2021	1.00	1.00	1.50	8.999
Sep 2021	0	0	0	0
Oct 2021	0	0	0	0
Nov 2021	0	0	0	0
Dec 2021	0	0	0	0

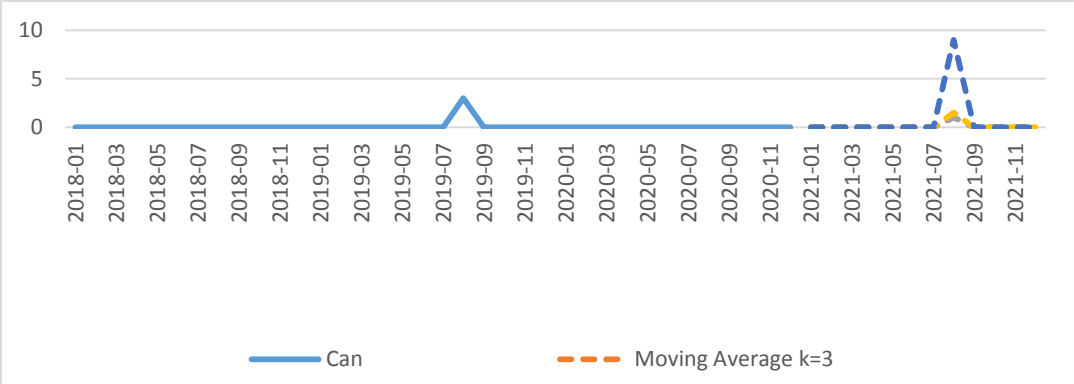

Figure 8 Forecasting techniques in recycling can for Prachaniwet school in year 2021.

6.The forecasting techniques for 4 types of recycling wastes in Sainamtip school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the forecasting line for Sainamtip school moving like forecasting line in Prachaniwet school since has the season effect from semester start (Table 9-12 and Figure 9-12).

Table 9 The prediction of recycling plastic in Sainamtip school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	4.00	4.00	4.00	4.00
Feb 2021	3. 70	4.00	3.00	3.00
Mar 2021	1.33	1.33	1.00	0
Apr 2021	1.33	1.33	1.50	3.99
May 2021	3.33	3.00	4.00	4.00
Jun 2021	3.67	3.50	4.00	4.00
Jul 2021	3.33	3.17	3.49	1.00
Aug 2021	3.67	3.17	4.50	2.00
Sep 2021	3.33	3.00	3.50	0
Oct 2021	4.33	4.33	4.50	6.99
Nov 2021	4.00	3.67	5.00	9.99
Dec 2021	3.67	3.17	5.00	9.99

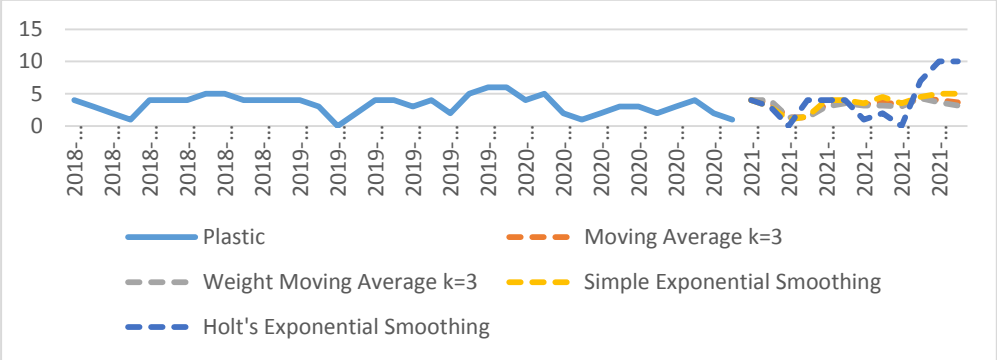

Figure 9 Forecasting techniques in recycling plastic for Sainamtip school in year 2021.

Table 10 The prediction of recycling glass in Sainamtip school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	0	0	0	0
Feb 2021	0	0.67	1.00	5.99
Mar 2021	0	0	0	0
Apr 2021	0	0	0	0
May 2021	0	0	0	0
Jun 2021	0	0	0	0
Jul 2021	0	0.17	0.49	0
Aug 2021	0	0	0	0
Sep 2021	0	0.50	1.50	0
Oct 2021	0	0.67	2.00	0

Nov 2021	0	0.33	1.00	0
Dec 2021	0.67	0.33	1.00	0

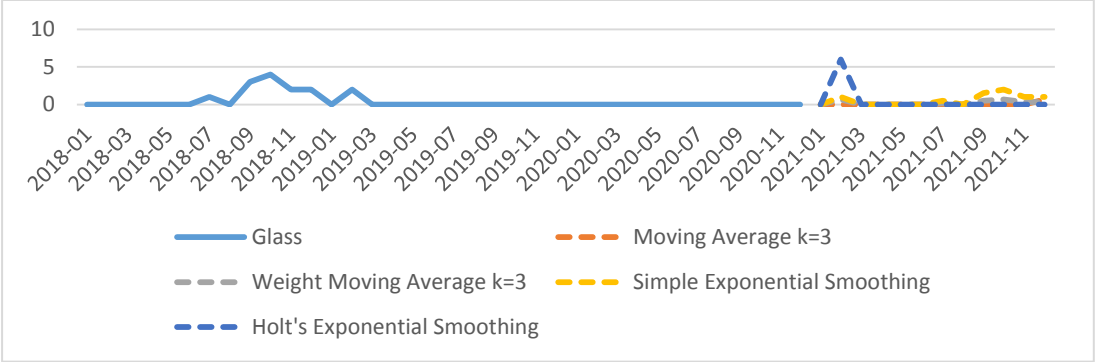

Figure 10 Forecasting techniques in recycling glass for Sainamtip school in year 2021.

Table 11 The prediction of recycling paper in Sainamtip school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	0	0	0	0
Feb 2021	0	0	0	0
Mar 2021	0	0	0	0
Apr 2021	0	0	0	0
May 2021	0	0	0	0
Jun 2021	0	0	0	0
Jul 2021	0	0	0	0
Aug 2021	0	0.67	1.00	5.99
Sep 2021	0	0	0	0
Oct 2021	0	0	0	0
Nov 2021	0	0	0	0
Dec 2021	0	0	0	0

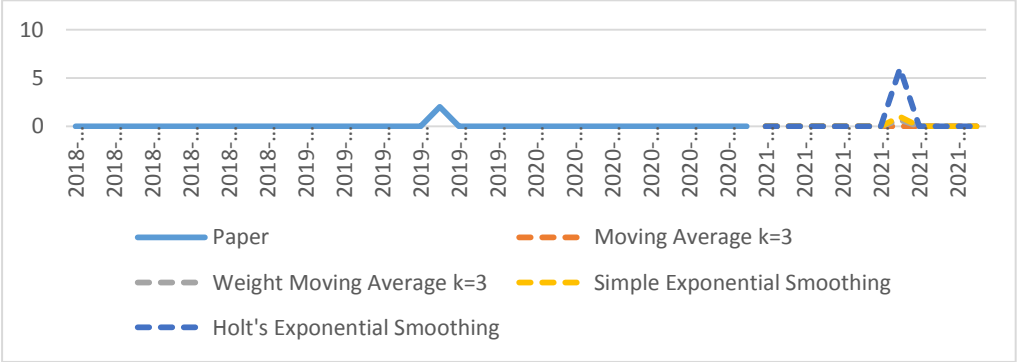

Figure 11 Forecasting techniques in recycling paper for Sainamtip school in year 2021.

Table 12 The prediction of recycling can in Sainamtip school in 2021.

Date	Moving Average k=3	Weight Moving Average k=3	Simple Exponential Smoothing	Holt's Exponential Smoothing
Jan 2021	0	0.67	1.00	5.99
Feb 2021	0	0	0	0
Mar 2021	0	0	0	0
Apr 2021	0	0	0	0
May 2021	0	0	0	0
Jun 2021	0	0	0	0
Jul 2021	0	0	0	0
Aug 2021	0	0	0	0
Sep 2021	0	0.17	0	0
Oct 2021	0	0.33	1.00	0
Nov 2021	0	0	0	0
Dec 2021	0	0	0	0

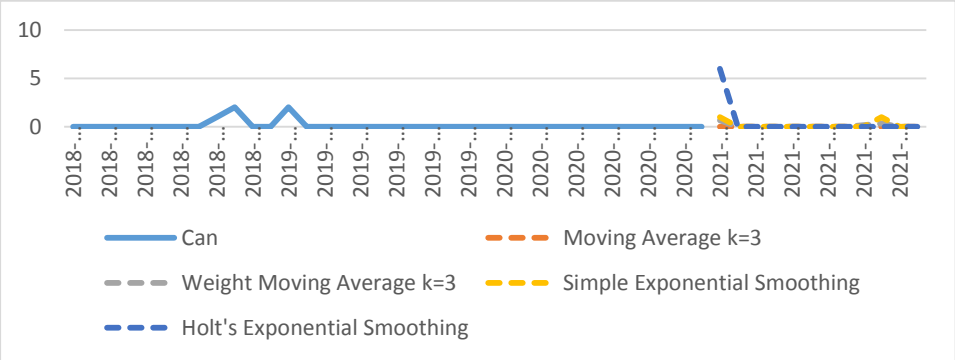

Figure 12 Forecasting techniques in recycling can for Sainamtip school in year 2021.

4.Conclusion

1.Comparison of the recycle waste quatity between Prachaniwet school and Sainamtip school, from 2018 to 2020 through 3 years in range of 6 months for 4 categories with recycling plastic, recycling glass, recycling paper and recycling can .

2. The recycling waste from both Prachaniwet school and Sainamtip school in 4 categories in range of 6 months from 2018 to 2020. The most recycling waste is plastic, which has a seasonal effect due to semester start. The others recycling waste are glass, paper, and can seem to be vanish after September of 2019. Recycle glass appeared in June of 2018 then emerging in September of 2018 then drop in March 2019 which is the closing semester period.

3.The amount of recycling waste that produced from both Prachaniwet school and Sainamtip school 4 categories from 2018 to 2020.Waste plastic is the biggest among recycle waste in these 3 years, about 210 kilograms. Then, recycled glass appears to be 20 kilograms. Recycled paper waste and recycled can waste are 5 kilograms and 8 kilograms, respectively.

4.The comparison in 4 categories between Prachaniwet school and Sainamtip school.Sainamtip school seem to have recycling plastic waste, recycling glass waste, and recycling can waste more than Prachaniwet school. In recycling paper waste, Prachaniwet school seem to have more than Sainamtip school.

5.The 4 forecasting techniques for 4 types of recycling wastes in Prachaniwet school in 2021 Prachaniwet school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the recycling plastic has seasonal effect because the semester starts, the forecasting in 2021 for recycling plastic drop in March and November. And the others 3 recycling wastes lines seem to lay on 0 kilograms and then emerging about 2 months and then drop to 0 kilograms.

6.The forecasting techniques for 4 types of recycling wastes in Sainamtip school in 2021 with Moving average, Weight moving average, Simple exponential smoothing, Holt's exponential smoothing, indicate that the forecasting line for Sainamtip school moving like forecasting line in Prachaniwet school.

7.The research result benefits from The forecasting techniques of this research with the Moving average, the Weight moving average, the Simple exponential smoothing, the Holt's exponential smoothing can be used to prepare for what will happen in the future, gain the valuable in insight, and thee result from prediction methods could decrease cost for the environmental management on the green schools on the recycle waste.

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