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THE ELECTRONIC WASTE MANAGEMENT USING GEOMETRIC CURVE MODEL FOR FORECASTING THE AMOUNT OF ELECTRONIC WASTE, POPULATION AND GROSS DOMESTIC PRODUCT IN THAILAND

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ABSTRACT

The purpose of this research is to study the application of Geometric Curve technique in forecasting the quantity of electronic waste (e-waste), population and Gross Domestic Product (GDP) in Thailand.

We employed the following three equations: 1. for quantity of e-waste forecast model is $Q_n = Q_o(1+r_{average})^{n_F}$*; 2. for population forecast model is* $P_n = P_o(1+r_{average})^{n_F}$*; and 3. for GDP forecast model is* $G_n = G_o(1+r_{average})^{n_F}$**.**

Evaluating using a Geometric Curve model, we achieved the following results: the evaluated quantity of e-waste model accuracy = 0.978133801; evaluated population model accuracy = 0.906364840; and evaluated GDP model accuracy = 0.808724. All models are highly accurate.

Key words: Forecasting, Geometric curve, E-waste, Population, GDP.

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1. INTRODUCTION

Thailand will have an e-waste overflow in the future. According to the UN's Global E-Waste Monitor 2020, global e-waste volumes reached 53.6 million metric tons in 2019, which increased by 21% in just five years. In addition, only 17.4% of it was properly forwarded to the recycling stations. Thailand produces more than 400,000 tons of e-waste per year and recycles only about 7.1% of that. As Thailand's population and GDP increase, it is expected that the quantity of e-waste will also be increased. It will be more difficult to manage e-waste and e-waste volume forecasting is crucial in planning the e-waste management operation including storage, consolidation, material recovery as well as the tools, machines, equipment, personnel, systems and other necessary components.

The higher the quantity of e-waste, population and GDP, the higher the environmental pollution such as air pollution, water pollution, and soil pollution, all of which affect the wellbeing of the population.

One major health concern is the toxic additives and hazardous substances such as mercury, which damage the human brain and coordination system.

Therefore, forecasting the amount of e-waste for next 15 years is very important in order to determine the country's policies and strategies for planning, implementing various projects, including reusing materials and sustainable resources. The forecast is a fundamental information that can be used in the planning, design and management of environmental engineering and inspection for sustainable development of Thailand.

2. REVIEW LITERATURE

2.1. Mathematic Models

There are many mathematic models (Adisak and team, 1998) to forecast the amount in the future such as Time-Series Method : Y = f(t) as below :

(1) Polynomial curves

Liner curve	$y = at+b$	(1-1)
Quadratic curve	$y = at^2+bt+c$	(1-2)

(2) Exponential curves

Liner exponential curve	$y = ab^t$	(2-1)
Quadratic exponential curve	$y = ab^t C^{t2}$	(2-2)
Corrective exponential curve	$y = a-bc^t$	(2-3)

(3)Growth curves

Logistic curve	$y = c/ (1+be^{at})$	(3-1)
Gonbeltz curve	$y = c-ab^{bt}$	(3-2)
High-order curve	$y = at^b$	(3-3)

(4) Geometric curve

Geometric curve $P_n = P_o(1+r_{average})^{n_F}$ (4-1)

Geometric curve is widely used in calculations in the future, especially in population forecast.

P_n = Population in the n^{th} year in the future from the presentn(person)

Po = Current population or the year of the beginning of the calculation (person)

n_F = The time interval to calculate the change from the present or start time of calculation (year)

$r_{average}$ = average population change rate (person/year)

This research will apply the Geometric curve for forecasting the quantity of e-waste, population and GDP in Thailand.

2.2. Geometric Curve Model Performance Measurement

Measuring the performance of a linear regression model using the squared correlation coefficient of determination or the value of R-square (R^2). It is a value used to prove whether the resulting model is suitable, with a value of 0-1, the closer to 1 the better. It is considered that the resulting model is a good forecasting model. R^2 or R-Squared is the most common metric when running model as a statistician. In the formula below, y-hat is a prediction and y-bar is the mean of y. Another name used by statisticians R^2 is Explained Variance to estimate the closeness of the analyzed results to the actual data.

$$R^2 = 1 - \left(\frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2}\right) \quad (5\text{-}1)$$

3. METHODS OF RESEARCH

3.1. To study the input factors of the model using mathematic models by studying the following data set out in Table 1 below: 1. quantity of e-waste according to Thailand's Pollution Control Department, population from Thailand's Ministry of Interior and GDP data from the Bank of Thailand:

Table 1 Data of amount of electronic waste, population, and GDP of Thailand since2008 to 2020.

Year	Quantity of E-waste (tons)	Population (Persons)	GDP (Billion Baht)
2008	322,380	63,389,730	7,710
2009	332,839	63,525,062	7,657
2010	341,989	63,878,267	8,232
2011	350,939	64,076,033	8,302
2012	359,070	64,456,695	8,903
2013	368,314	64,785,909	9,142
2014	376,801	65,724,716	9,232
2015	384,233	65,729,098	9,521
2016	380,605	65,931,550	9,849
2017	393,070	66,188,503	10,260
2018	414,600	66,413,979	10,690
2019	420,000	66,558,935	10,932
2020	428,113	66,186,727	10,265

3.2. Build a forecasting Geometric Curve model by using Excel program.

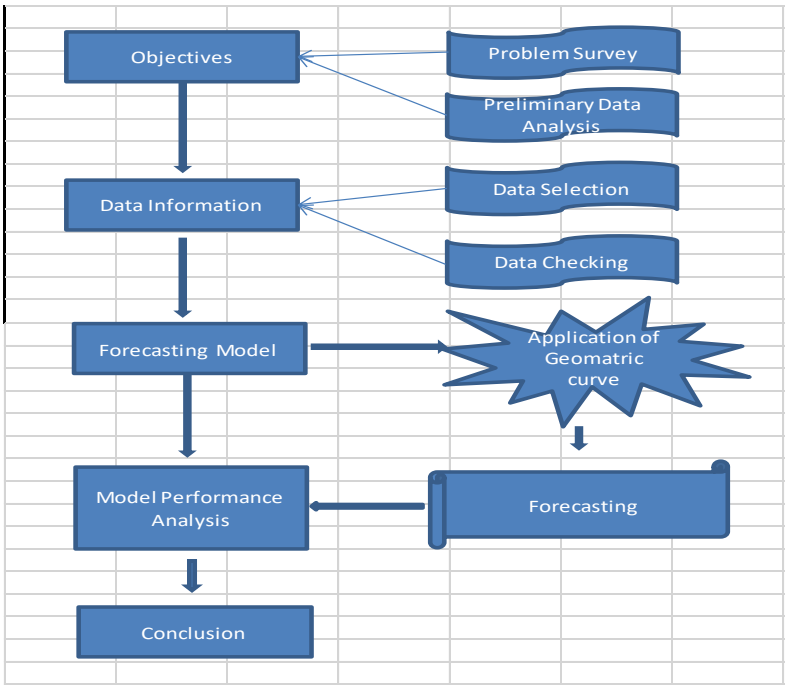

Figure 1 Research Implementation Process for Forecasting model.

4. RESULTS AND DISCUSSION

4.1. E-waste Forecast in Geometric Curve Model

E-waste forecast

Table 2 Data Quantity of electronic waste and forecast.

Year	Quantity of E-waste (tons)	$Q_n = Q_o(1+r_{average})^n{}_F$ (tons)
2008	322,380	322,380
2009	332,839	330,117
2010	341,989	338,040
2011	350,939	346,153
2012	359,070	354,461
2013	368,314	362,968
2014	376,801	371,679
2015	384,233	380,599
2016	380,605	389,734
2017	393,070	399,087
2018	414,600	408,665
2019	420,000	418,473
2020	428,113	428,517
2021		438,801
2022		449,332
2023		460,116
2024		471,159
2025		482,467
2026		494,046
2027		505,903
2028		518,045
2029		530,478
2030		543,209
2031		556,246
2032		569,596
2033		583,266
2034		597,265
2035		611,599

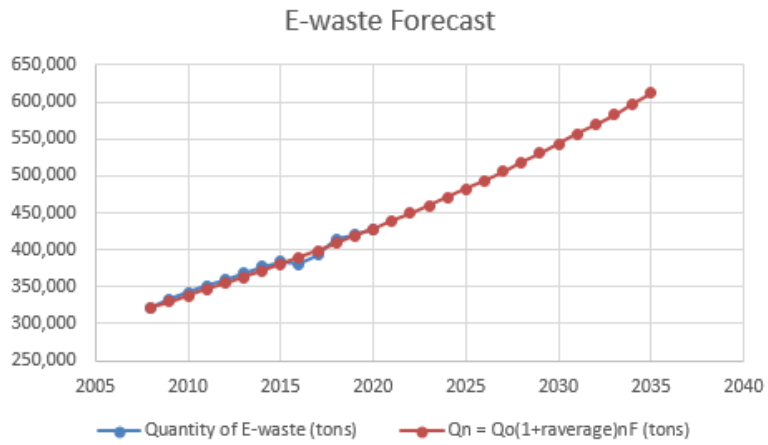

Figure 2 Graph between Quantity of e-waste and forecast.

4.2. Population Forecast in Geometric Curve Model

Population forecast : $P_n = P_o(1+r_{average})^{n_F}$

Table 3 Data of Population and forecast

Year	Population (Persons)	$P_n = P_o(1+r_{average})^{n}F$ (Persons)
2008	63,389,730	63,389,730
2009	63,525,062	63,618,567
2010	63,878,267	63,848,230
2011	64,076,033	64,078,722
2012	64,456,695	64,310,046
2013	64,785,909	64,542,206
2014	65,724,716	64,775,203
2015	65,729,098	65,009,041
2016	65,931,550	65,243,724
2017	66,188,503	65,479,254
2018	66,413,979	65,715,634
2019	66,558,935	65,952,867
2020	66,186,727	66,190,957
2021		66,429,907
2022		66,669,719
2023		66,910,396
2024		67,151,943
2025		67,394,361
2026		67,637,655
2027		67,881,827
2028		68,126,880
2029		68,372,818
2030		68,619,644
2031		68,867,361
2032		69,115,972
2033		69,365,481
2034		69,615,890
2035		69,867,204

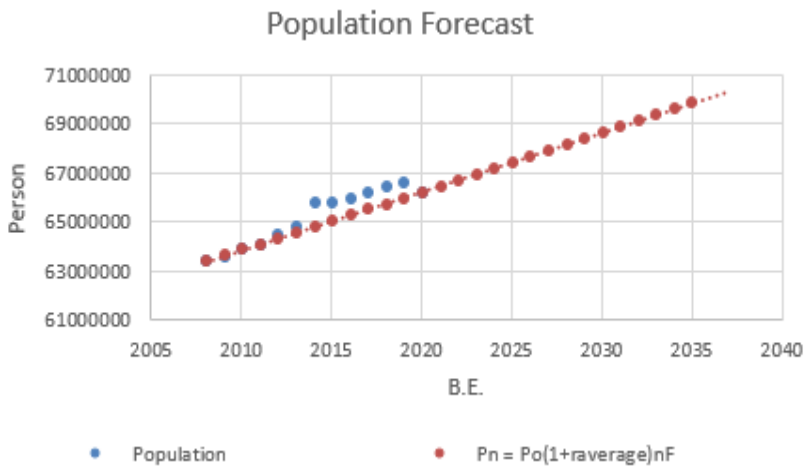

Figure 3 Graph between Population and forecast.

4.3. GDP forcast in Geometric Curve Model

Gross Domestric Product : GDP is one of the indicator to measure the country development.

Table 4 Data of GDP and forecast**.**

Year	GDP (Billion Baht)	$G_n = G_o(1+r_{average})^n{}_F$ (Billion Baht)
2008	7.710	7.710
2009	7.657	7.901
2010	8.232	8.096
2011	8.302	8.296
2012	8.903	8.502
2013	9.142	8.712
2014	9.232	8.927
2015	9.521	9.148
2016	9.849	9.374
2017	10.260	9.606
2018	10.690	9.844
2019	10.932	10.087
2020	10.265	10.337
2021		10.593
2022		10.855
2023		11.123
2024		11.398
2025		11.680
2026		11.969
2027		12.265
2028		12.569
2029		12.879
2030		13.198
2031		13.524
2032		13.859
2033		14.202
2034		14.553
2035		14.913

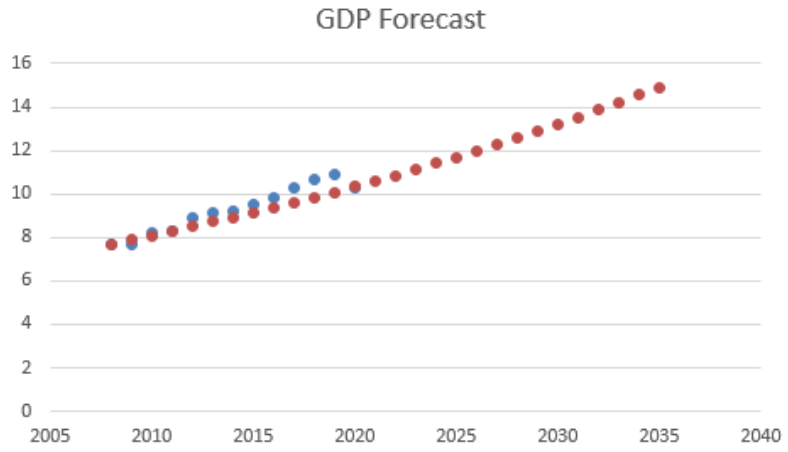

Figure 4 Graph between GDP and forecast.

4.4. Evaluated Quantity of E-waste Forecast in Geometric Curve Model by using R^2

Table 5 Evaluate model : $Q_n = Q_o(1+r_{average})^{n_F}$

n	Y ACTUAL	Y HAT PREDICTION	Y-Y HAT	$(Y-Y\ HAT)^2$	Y BAR	Y-Y BAR	$(Y-Y\ BAR)^2$
1	322,380	322,380	0	0	374,843	52,463	2,752,317,946
2	332,839	330,117	2,722	7,408,631	374,843	42,004	1,764,297,247
3	341,989	338,040	3,949	15,595,147	374,843	32,854	1,079,354,992
4	350,939	346,153	4,786	22,906,856	374,843	23,904	571,379,153
5	359,070	354,461	4,609	21,246,950	374,843	15,773	248,772,971
6	368,314	362,968	5,346	28,583,865	374,843	6,529	42,621,815
7	376,801	371,679	5,122	26,236,578	374,843	1,958	3,835,571
8	384,233	380,599	3,634	13,205,035	374,843	9,390	88,180,767
9	380,605	389,734	9,129	83,329,617	374,843	5,762	33,205,963
10	393,070	399,087	6,017	36,205,611	374,843	18,227	332,240,353
11	414,600	408,665	5,935	35,221,845	374,843	39,757	1,580,655,745
12	420,000	418,473	1,527	2,331,224	374,843	45,157	2,039,196,329
13	428,113	428,517	404	162,829	374,843	53,270	2,837,742,068
SUM Y	4,872,953		SUM 1	292,434,189		SUM 2	13,373,800,919
Y BAR	374,843					SUM1/SUM2	0.021866199
						R^2	**0.978133801**

Evaluated **Quantity of E-waste** model accuracy = 0.978133801 the model is highly accurate.

4.5. Evaluated Population forecast in Geometric Curve Model by using R^2

Table 6 Evaluate model : $P_n = P_o(1+r_{average})^{n_F}$

n	Y ACTUAL	Y HAT PREDICTION	Y-Y HAT	$(Y-Y\ HAT)^2$	Y BAR	Y-Y BAR	$(Y-Y\ BAR)^2$
1	63,389,730	63,389,730	0	0	65,141,939	-1,752,209	3,070,236,379,681
2	63,525,062	63,618,567	-93,505	8,743,171,055	65,141,939	-1,616,877	2,614,291,233,129
3	63,878,267	63,848,230	30,037	902,224,259	65,141,939	-1,263,672	1,596,866,923,584
4	64,076,033	64,078,722	-2,689	7,231,055	65,141,939	-1,065,906	1,136,155,600,836
5	64,456,695	64,310,046	146,649	21,505,856,266	65,141,939	-685,244	469,559,339,536
6	64,785,909	64,542,206	243,703	59,391,388,295	65,141,939	-356,030	126,757,360,900
7	65,724,716	64,775,203	949,513	901,575,169,724	65,141,939	582,777	339,629,031,729
8	65,729,098	65,009,041	720,057	518,481,564,912	65,141,939	587,159	344,755,691,281
9	65,931,550	65,243,724	9,129	83,329,617	65,141,939	789,611	623,485,531,321
10	66,188,503	65,479,254	6,017	36,205,611	65,141,939	1,046,564	1,095,296,206,096
11	66,413,979	65,715,634	5,935	35,221,845	65,141,939	1,272,040	1,618,085,761,600
12	66,558,935	65,952,867	1,527	2,331,224	65,141,939	1,416,996	2,007,877,664,016
13	66,186,727	66,190,957	404	162,829	65,141,939	1,044,788	1,091,581,964,944
SUM Y	846,845,204		SUM 1	1,510,763,856,693		SUM 2	16,134,578,688,653
Y BAR	65,141,939					SUM1/SUM2	0.093635160
						R^2	**0.906364840**

Evaluated model accuracy = 0.906364840 the model is highly accurate.

4.6. Evaluated GDP forcast in Geometric curve Model by using R^2

Table 7 Evaluate model : $G_n = G_o(1+r_{average})^{n_F}$

n	Y ACTUAL	Y HAT PREDICTION	Y-Y HAT	$(Y-Y\ HAT)^2$	Y BAR	Y-Y BAR	$(Y-Y\ BAR)^2$
1	7,710	7,710	0	0	9,284	-1,574	2,478,203
2	7,657	7,901	-244	59,536	9,284	-1,627	2,647,880
3	8,232	8,096	136	18,496	9,284	-1,052	1,107,190
4	8,302	8,296	6	36	9,284	-982	964,777
5	8,903	8,502	401	160,801	9,284	-381	145,337
6	9,142	8,712	430	184,900	9,284	-142	20,230
7	9,232	8,927	305	93,025	9,284	-52	2,728
8	9,521	9,148	373	139,129	9,284	237	56,060
9	9,849	9,374	475	225,625	9,284	565	318,964
10	10,260	9,606	654	427,716	9,284	976	952,126
11	10,690	9,844	846	715,716	9,284	1,406	1,976,187
12	10,932	10,087	845	714,025	9,284	1,648	2,715,143
13	10,265	10,337	-72	5,184	9,284	981	961,908
SUM Y	120,695		SUM 1	2,744,189		SUM 2	14,346,732
Y BAR	9284.2308					SUM1/SUM2	0.19127624
						R^2	**0.808724**

Evaluated model accuracy = 0.808724 which means to test the accuracy of a model or equation with R square where if R square is close to 1. It is considered to have high accuracy. From the test model,

The model is highly accurate.

5. CONCLUSION

Predictive model using Geometric Curve technique, which has the following three equation models:

$Q_n = Q_o(1+r_{average})^{n_F}$ for Quantity of e-waste (tons)

$P_n = P_o(1+r_{average})^{n_F}$ for Population (persons)

$G_n = G_o(1+r_{average})^{n_F}$ for GPD (Billion Baht)

Reliability values with a squared correlation coefficient (Coefficient of determination, R^2): Evaluated Quantity of E-waste model accuracy = 0.978133801, Evaluated Population model accuracy = 0.906364840 , Evaluated GDP model accuracy = 0.808724.

In terms of precision, the mathematic models used to forecast the quantity of e-waste, population and GDP of Thailand have high accuracy.

RECOMMENDATIONS

In this research, while there are other statistical techniques that can be applied, geometric curves have been selected to be used in forecasting of quantity of e-waste, population and GDP of Thailand. It is a fundamental technique for representing the relationship of variables and the strength of technique is its ability to simulate complex systems of data. This is an important feature in forecasting, which relies on these various data and which can be applied in both mathematics and computer science.

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