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# SOLID WASTE GENERATION IN THE PHILIPPINES: A CORRELATIONAL ANALYSIS ON ECONOMIC AND SOCIAL METRICS

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**ABSTRACT:** The Philippines' waste generation continues to rise from $37{\cdot}10^3$ $kg{\cdot}a^{-1}$ in 2012 to $40{\cdot}10^3$ $kg{\cdot}a^{-1}$ in 2016, with a daily waste generation per capita oscillating from 300 to 700 grams for rural and urban areas. The study depicted a five-year correlational analysis on waste generation per capita as against Philippine Economic and Social Metrics for: (1) Average Family Income (2) Average Family Expenditure (3) Population Density and (4) Human Development Index. Both national and regional secondary panel data were analyzed that lead to identifying Average Family Expenditure as an Ecological Footprint (EFA) Indicator with highest correlation on waste generation per capita (WgC). Based on the five-year National Level Analysis, all independent variables exhibited a probability value lower than the significant threshold error value of 0.05. Hence, changes in waste generation per capita for the five year sample size is also recurring prior and beyond the sampling period of 2012 to 2016. Using Regional Level Analysis, an Equation Model was generated in order to predict the degree of changes per unit, stated in gram (with coefficient = 0.319) pertinent to the three remaining EFA Indicators. As depicted in the Equation, for every person increase in population density expressed in per $km^2$, it will generate a positive increases on WgC by 0.0000714; while for every peso (Philippine monetary denomination) increases in family expenditure, has a decreasing effect on WgC by 0.0000009479; and that for every one peso increases in family income, WgC will generate an increase by 0.0000008573.

*Keywords: Ecological footprint indicators, Waste generation per capita, Multi regression analysis*

## 1. INTRODUCTION

The Philippines is at a precarious juncture in its urbanization process and posited for having the second highest average urban density in East Asia and Pacific Region [1]. Like any other developing economy, solid waste management remains a major challenge [2]. The Philippines' waste generation continues to rise from $37{\cdot}10^3$ $kg{\cdot}a^{-1}$ in 2012 to $40{\cdot}10^3$ $kg{\cdot}a^{-1}$ in 2016, with a daily waste generation per capita oscillating from 300 to 700 grams for both rural and urban areas [3]. Unlike developed worlds who's into waste-energy conversion, Philippine Regions must efficiently utilize every landfill, promote wastes avoidance, reduction, re-use, rethink waste recycling and periodically assess waste generation per capita. The result of the waste assessment per region is vital in relation to Republic Act 9003, known as the Ecological Solid Waste Management Act of 2000.

The Philippines has commendable enacted environmental regulatory policy frameworks [4]. But Sta. Romana lamented that policy implementation in the Philippine government agencies, however, remains a challenge [4]. There is an apparent substantial disparity between rhetoric statutes enacted by legislators and real outcomes on Solid Waste Management. There is a need to understand and predict the impact of indicators on national economy's improvement as against final waste generation, globally considered as chaotic human ecological footprint.

### 1.1 Ecological Footprint Accounting Indicators

The study proposed a scientific method to ascertain the degree of significant changes in the four ecological footprint indicators [5] on (a) level of consumption using average family expenditures (b) quality of population quality using Human Development Index (c) Level of Income or average family income and (d) quality of habitat using population density.

The ecological footprint is used to gauge the exerted degree of consumption of human beings on its ecological environment. According to Galli, it can be applied at scales from global to local and gives insight on the ecosystem services to human requirements to sustain changing lifestyle [6]. To quantify sustainable development amidst the escalating environmental degradation is to utilize a resource accounting tool called Ecological Footprint (EFA) [7]. It measures human demand on natural resources and services [8]. Based on Millennium Ecosystem Assessment, EFA can track past human pressure on ecosystem, it requires an analysis of historical data in order to predict [9]. A favorable result occurs when a National Footprint is lesser than the ability of the environment and natural resources to regenerate, favorably, there is what we call biocapacity reservation [9].

Four indicators of Ecological Footprints [5] were applied in the study. The major source of Ecological Footprint is explained by the European Environment Agency as anthropogenic effects, these are processes, objects, materials or those that are derived from human activities as opposed to those occurring in natural environments without human influences [10]. Tools such as Ecological indicators can be used as early warning signal and can quantify anthropogenic effects on the ecosystem brought by the growing level of human and global metabolism [11]. The National Footprint Accounting (NFA) are prevalently used since 1961 [12]. To synthesize further, EFA for Municipal Solid Waste (MSW) provides policy-makers with new insights on how to mitigate territorial footprints and just as important as the policy development and implementation [9].

### 1.2 Average Family Income

Auci and Vignani explained the increase in economy's income at a certain high level has a domino effect, people started to be environmental and may demand imposition of regulatory policies to halt pollution impacts on social and economic activities [4]. In the study the average family income was used as economic metrics. When a systems approach is applied for technology evaluation, the economic dimension of the system life cycle cannot be omitted. The purpose of economic metrics is to provide the quantitative information needed to make a judgment or a decision on the deployment of a new technology in selecting an alternative option [13].

### 1.3 Population Density

Population density is the number of individuals that live in a unit area at a specified time [14]. It is computed by dividing the total population by its land area. When there are a larger number of people living in a smaller amount of space, the area is densely populated while the reversed is called sparsely populated [15]. The effects of population rate on economic development stem on the type of industry classified either as labor intensive or not, human resources is a principal replacement for diminished input in service oriented industries [16]. Eventually, workers or consumers are bound to product consumption of scarce resources and later subject for disposal [16]. The Central Asia, Middle East and Asia-Pacific regions experienced an escalating Ecological Footprint due to population growth of 154% and 465% from 1961 to 2014 generating per capita Footprint equivalent to 126% and 146% respectively [12]. Provinces that have larger urban population and higher economic activities generate greater volume of solid waste [3].

### 1.4 Human Development Index (HDI)

In the study, National progress concerning sustainable development dwelled on comparing the NFA results and explored the degree of relationship of WgC as against the Philippine HDI, as published by United Nation Development Programme (UNDP). HDI is the aggregate of education, longevity, and income into a single metric [12]. The same authors in the study entitled "Ecological Footprint Accounting for Countries: Updates and Results of the National Footprint Accounts, 2012-2018" used HDI as a major indicator of Ecological Footprint. Further, the UNDP defines 0.70 HDI as the threshold for a highly developed economy. As stated previously, bio capacity deficiency on the planet earth is gauged at 1.7 gha per capita in 2014. And they reasonably concluded said deficiency combined with HDI measures globally sustainable development of mankind as a minimum condition set. HDI is a social metrics that measures social sustainability. Social sustainability was defined by Western Australia Council of Social Services as "Social sustainability occurs when the formal and informal processes; systems; structures; and relationships actively support the capacity of current and future generations to create healthy and liveable communities. In addition, socially sustainable communities are equitable, diversely connected, and generally provides a good quality of life [13].

### 1.5 Average Family Expenditure

Average Family Expenditure is another economic metrics as a basis for consumption per capita. Philippine Statistics Authority (PSA) [17] showed that the current average annual family income of Filipino families was approximately 267 thousand pesos in 2015. In comparison, the average annual family expenditure for the same year was 215 thousand pesos. On average, Filipino families have an annual savings of 52 thousand pesos.

## 2. METHODOLOGY AND MATERIALS

Waste assessment is a vital phase of Solid Waste Management and preferably enclosed by macro and/or micro level analysis. Consequently, an assessment called National Footprint Accounting on wastes will be analyzed using multivariate regression analysis for both level of consumption, level of income, quality of population and quality of habitat in terms of population density. These indicators were introduced by Guo et al. (2018) and adapted in the study to establish empirical data that will provide deeper linkages on economic and social metrics as depicted in Figure 1. The result of the study is vital for the program planning of National Solid Waste Management Commission (NSWMC) to forecast the waste generation per Philippine Region based on the foreseeable economic growth, human development and population growth. The Commission shall oversee the implementation of solid waste management plans and prescribe policies to achieve the objectives of the law on "Ecological Solid Waste Management Act of 2000".

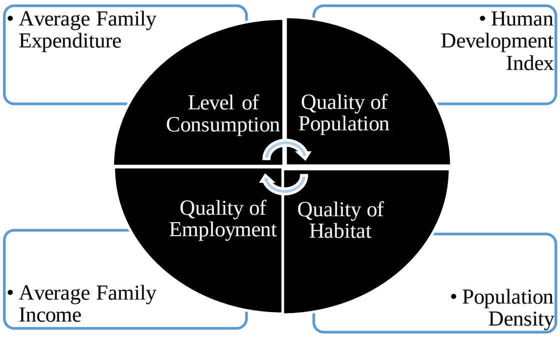


Fig. 1 Conceptual Framework of NFA

The term regression is credited to Francis Galton [18]. Regression analysis allows researchers to quantify how the average of one variable systematically varies according to the levels of another variable. The former variable is often called a dependent variable or outcome variable and the latter an independent variable, predictor variable, or explanatory variable [18]. Regression analysis is a form of predictive modelling technique which investigates the relationship between a dependent (target) and independent variables (predictors). This technique is used for forecasting, time series modelling and finding the causal effect relationship between the variables [19]. It also indicates the strength of impact of multiple independent variables on a dependent variable.

In the study, secondary panel data for national and regional relevant to waste assessment from PSA, UNDP and NSWMC, covering 2012 to 2016 was utilized. Subsequently, the Correlational Analysis generated 85 observations out of the total 17 Philippine Regions within the five-year period. National Ecological Footprint Accounting Data, known as waste generation per capita were processed together with the four EFA indicators using SPSS for Multi Regression Analysis. The dependent variable (presented in ratio scale for a parametric test) pertains to the waste generation per capita per region. The three independent variables classified as interval scale are: (1) Average Family Expenditure (2) Average Family Income (3) Population Density. While the quality of population as the fourth indicator was presented based on parametric variables (ratio scale) using Human Development Index. A reference to adjusted $R^2$ was effected to determine the causal effect relationship between the dependent and independent variables. Further the p-value higher than 0.05 was excluded as independent variable in generating the equation model with interpretation that no significant relationship exist with the dependent variable represented by waste generation per capita. The purpose of the statistical analysis is to generate a Regression Equation Model by transmutation of coefficient values of each independent variables based on the line-intercept.

### 2.1 Regression Equation Model (Regional Level)

$$WgC=0.319+B1*(0.0000714)+B2*(-0.0000009479) + B3*(0.0000008573) \quad (1)$$

**2.2 Research Hypothesis**: There is a significant relationship between WgC and:

(B1) Population Density
(B2) Average Family Expenditure
(B3) Average Family Income
(B4) Human Development Index

## 3. RESULTS AND DISCUSSION

Table 1 presents the panel data for the four independent variables and the dependent variable, waste generation per capita based on the national level.

Table 1 The five-year panel data for National Level

| Year | WgC | ** HDI | *Ave. Family Income | *Ave. Family Exp. | *Population Density |
|---|---|---|---|---|---|
| 2012 | 0.3878 | 0.677 | 182294 | 168471 | 301 |
| 2013 | 0.3879 | 0.685 | 206765 | 173588 | 306 |
| 2014 | 0.3880 | 0.689 | 216824 | 179706 | 311 |
| 2015 | 0.3904 | 0.693 | 227118 | 187294 | 315 |
| 2016 | 0.3912 | 0.696 | 238059 | 195353 | 319 |

Philippine Statistics Authority*
United Nations Development Programme**

The average waste generation per capita between 2012 to 2016 on a nationwide basis is at 389 grams per day which is lesser than the global average of 740 grams per day in 2016 [21]. The Philippine HDI mean is at 0.688, a bit lower in comparison to 0.70 index as the threshold for a highly developed economy [22]. The five year (2012 to 2016) average annual family income was approximately 214 thousand pesos with average annual family expenditure of 181 thousand pesos, giving Filipino families an annual savings of 60 thousand pesos. While the average five-year national population density is at 310 $km^2$ based on a total Philippine land area of 300 000 $km^2$ (refer to Table 2).

Table 2 Descriptive Statistics (National Level)

| | Mean |
|---|---|
| WgC | 0.38906 |
| HDI | 0.68800 |
| Ave. Family Income | 214 212 |
| Ave. Family Expenditure | 180 882 |
| Population Density | 310 |

Table 3 shows that 88% of the variation in waste generation per capita is explained by the variation in Average Family expenditure.

Table 3 Regression Statistics

| | |
|---|---|
| Pearson's Coefficient of Correlation | 0.0000001414 |
| R Square Change | 0.88 |
| Sig. F Change | 0.018 |
| Observations | 5 |

Waste generation per Capita has significant positive correlation with the following independent variables: (a) Average Family Expenditure (r = 0.938, p = 0.009), yielded as the highest with direct correlation on waste generation per capita. An increase in family expenditure will increase wastes generation; (b) followed by Population Density (r = 0.888, p = 0.022) also directly predicting, the larger the number of people in a given land area will escalate waste generation; (c) the same is true with HDI (r = 0.837, p = 0.04), the greater the human development is liken to an economic development, poses greater ecological footprint on wastes; (d) and that positive increases on Average Family Income (r = 0.831, p = 0.041) has also strong and direct impact on waste generation per capita. All independent variables exhibited a probability value of lower than the significant threshold error value of 0.05. Hence, changes in waste generation per capita for the five year sample size is also recurring prior and beyond the period of study (2012 to 2016).

Table 4 Correlations

| | WgC | HDI | Ave. Family Income | Ave. Family Exp. | Population Density |
|---|---|---|---|---|---|
| Pearson Correlation | 1 | 0.84 | 0.831 | 0.938 | 0.888 |
| Sig. (1-tailed) | 0 | 0.04 | 0.041 | 0.009 | 0.022 |
| N | 5 | 5 | 5 | 5 | 5 |

Table 5 shows the statistical analysis for the four independent variables in relation to waste generation per capita for each of the 17 regions in the Philippines. It shows that there is a strong positive correlation (R = 0.933684) between waste generation per capita and the 4 independent variables and 87.1765% of the variation or changes in waste generation per capita is explained by the changes in the 4 independent variables.

Table 5 Regression Statistics (Regional)

| | |
|---|---|
| Multiple R | 0.933684 |
| R Square | 0.871765 |
| Observations | 85 |

The regional weighted waste generation per capita between the periods of 2012 and 2016 is at 368 grams per day which is a bit lower than the national average of 389 grams. HDI per region is not available hence, a reflection of the same five-year national average HDI of 0.688. The regional average annual family income was approximately higher by 13 thousand in comparison per Table 2 (228 less 214 thousand pesos) but with the same average annual family expenditure amounting to 181 thousand pesos. While the average five-year regional population density is at 1 481 $km^2$ with a total Philippine land area of 300 000 $km^2$ (refer to Table 6).

Table 6 Descriptive Statistics (Regional Level)

| | Mean |
|---|---|
| WgC | 0.3680 |
| HDI | .6880 |
| Ave. Family Income | 227 553 |
| Ave. Family Expenditure | 180 882 |
| Population Density | 1 481 |

Table 7 is based on regional panel data and generating a Regression Equation Model, wherein HDI was excluded among the indicators, generating (r = 0.20, p = 0.429) which is above the p-value of 0.05, therefore not a significant factor of waste generation per capita. The result of the causal relationship on the regional level is attributable to lack of regional data for Human Development Indices, see previously presented Eq. (1).

Table 7 Correlations

| | Coefficients | Standard Error | t Stat | Sig. |
|---|---|---|---|---|
| Intercept | 0.319 | 0.00 | 1.525 | 0.131 |
| Population Density | 1.714E-05 | 0.000 | 13.935 | 0.000 |
| Ave. Family Expenditure | -9.479E-07 | 0.004 | -3.070 | 0.003 |
| Ave. Family Income | 8.573E-07 | 0.001 | 3.458 | 0.001 |

After HDI removal having a p-value (greater than the alpha ($p > 0.05$), that for every unit of change on a per gram of waste generation per capita is attributable to the three remaining independent variables classified as fit for the regression equation model; (a) population density (b) average family expenditure and (c) average family income per Table 7.

## 4. CONCLUSIONS

The study depicted a five-year correlational analysis on WgC based on the four ecological footprint indicators (1) Average Family Income (2) Average Family Expenditure (3) Population Density and (4) HDI. Both national and regional secondary panel data were analyzed that lead to identifying Average Family Expenditure as an EFA indicator with a direct and highest correlation on WgC. On the National Level Analysis, for the five-year observation, all independent variables exhibited a p-value lower than the significant threshold error value of 0.05. Hence, changes in waste generation per capita for the five year sample size is also recurring prior and beyond the sampling period of 2012 to 2016.

Based on Regional Level Analysis, the Equation Model was generated in order to predict the degree of changes per unit, stated in gram of WgC (with coefficient = 0.319) in relation to the three remaining Ecological Footprint Accounting Indicators. As depicted in the Equational Model, for every person increase in population density expressed in per $km^2$, it will generate a positive increases on WgC by 0.0000714; while for every peso (Philippine monetary denomination) increases in family expenditure, has a decreasing effect on WgC by 0.0000009479; and for every one peso increases in family income, WgC will generate an increase by 0.0000008573.

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**Appendix A: Regional Secondary Panel Data**

| | | Population | | Average Family | | |
|---|---|---|---|---|---|---|
| Year | Region | Density | HDI | Income | Expenditure | WgC |
| 2012 | 1 | 376.56 | 0.68 | 204000 | 159000 | 0.35 |
| 2012 | 2 | 118.43 | 0.68 | 195000 | 140000 | 0.33 |
| 2012 | 3 | 482.72 | 0.68 | 259000 | 211000 | 0.34 |
| 2012 | 4 | 797.71 | 0.68 | 284000 | 243000 | 0.31 |
| 2012 | 5 | 96.45 | 0.68 | 179000 | 138000 | 0.32 |
| 2012 | 6 | 309.6 | 0.68 | 162000 | 144000 | 0.33 |
| 2012 | 7 | 353.37 | 0.68 | 202000 | 163000 | 0.37 |
| 2012 | 8 | 458.3 | 0.68 | 209000 | 164000 | 0.37 |
| 2012 | 9 | 182.23 | 0.68 | 166000 | 132000 | 0.35 |
| 2012 | 10 | 208.3 | 0.68 | 162000 | 162000 | 0.39 |
| 2012 | 11 | 219.41 | 0.68 | 190000 | 143000 | 0.38 |
| 2012 | 12 | 229.35 | 0.68 | 194000 | 156000 | 0.39 |
| 2012 | 13 | 192.55 | 0.68 | 163000 | 140000 | 0.31 |
| 2012 | 14 | 117.37 | 0.68 | 180000 | 142000 | 0.35 |
| 2012 | 15 | 269.63 | 0.68 | 130000 | 114000 | 0.27 |
| 2012 | 16 | 19981.6 | 0.68 | 379000 | 325000 | 0.69 |
| 2012 | 17 | 92.08 | 0.68 | 257000 | 188000 | 0.37 |
| 2013 | 1 | 380.86 | 0.69 | 215000 | 165000 | 0.35 |
| 2013 | 2 | 119.98 | 0.69 | 208000 | 146000 | 0.33 |
| 2013 | 3 | 491.76 | 0.69 | 272000 | 219000 | 0.34 |
| 2013 | 4 | 819.46 | 0.69 | 293000 | 251000 | 0.31 |
| 2013 | 5 | 97.97 | 0.69 | 193000 | 144000 | 0.32 |
| 2013 | 6 | 313.89 | 0.69 | 170000 | 149000 | 0.34 |
| 2013 | 7 | 357.79 | 0.69 | 210000 | 167000 | 0.37 |
| 2013 | 8 | 465.98 | 0.69 | 218000 | 172000 | 0.37 |
| 2013 | 9 | 184.42 | 0.69 | 176000 | 138000 | 0.35 |
| 2013 | 10 | 211.71 | 0.69 | 171000 | 155000 | 0.39 |
| 2013 | 11 | 223.36 | 0.69 | 200000 | 148000 | 0.38 |
| 2013 | 12 | 233.28 | 0.69 | 211000 | 165000 | 0.39 |
| 2013 | 13 | 196.73 | 0.69 | 171000 | 146000 | 0.31 |
| 2013 | 14 | 119 | 0.69 | 186000 | 147000 | 0.35 |
| 2013 | 15 | 273.46 | 0.69 | 133000 | 113000 | 0.27 |
| 2013 | 16 | 20320.54 | 0.69 | 394000 | 332000 | 0.7 |
| 2013 | 17 | 93.61 | 0.69 | 265000 | 194000 | 0.37 |
| 2014 | 1 | 385.09 | 0.69 | 226000 | 173000 | 0.35 |
| 2014 | 2 | 121.51 | 0.69 | 222000 | 153000 | 0.33 |
| 2014 | 3 | 500.85 | 0.69 | 285000 | 228000 | 0.34 |
| 2014 | 4 | 841.57 | 0.69 | 302000 | 259000 | 0.3 |
| 2014 | 5 | 99.46 | 0.69 | 208000 | 152000 | 0.32 |
| 2014 | 6 | 318.08 | 0.69 | 178000 | 154000 | 0.34 |
| 2014 | 7 | 362.22 | 0.69 | 218000 | 171000 | 0.37 |
| 2014 | 8 | 473.67 | 0.69 | 228000 | 181000 | 0.37 |
| 2014 | 9 | 186.53 | 0.69 | 186000 | 146000 | 0.35 |
| 2014 | 10 | 215.05 | 0.69 | 180000 | 149000 | 0.39 |
| 2014 | 11 | 227.31 | 0.69 | 210000 | 154000 | 0.38 |
| 2014 | 12 | 237.26 | 0.69 | 229000 | 176000 | 0.39 |
| 2014 | 13 | 200.95 | 0.69 | 179000 | 153000 | 0.31 |
| 2014 | 14 | 120.63 | 0.69 | 192000 | 152000 | 0.35 |
| 2014 | 15 | 277.29 | 0.69 | 136000 | 112000 | 0.27 |
| 2014 | 16 | 20657.88 | 0.69 | 409000 | 340000 | 0.7 |
| 2014 | 17 | 95.08 | 0.69 | 273000 | 202000 | 0.37 |
| 2015 | 1 | 386.24 | 0.69 | 238000 | 182000 | 0.36 |
| 2015 | 2 | 122.25 | 0.69 | 237000 | 162000 | 0.34 |
| 2015 | 3 | 509.57 | 0.69 | 299000 | 239000 | 0.34 |
| 2015 | 4 | 854.31 | 0.69 | 312000 | 269000 | 0.3 |
| 2015 | 5 | 100.03 | 0.69 | 222000 | 161000 | 0.32 |
| 2015 | 6 | 319.29 | 0.69 | 187000 | 160000 | 0.34 |
| 2015 | 7 | 427.76 | 0.69 | 226000 | 176000 | 0.38 |
| 2015 | 8 | 390.12 | 0.69 | 239000 | 193000 | 0.37 |
| 2015 | 9 | 190.96 | 0.69 | 197000 | 156000 | 0.35 |
| 2015 | 10 | 212.82 | 0.69 | 190000 | 144000 | 0.4 |
| 2015 | 11 | 228.78 | 0.69 | 221000 | 161000 | 0.38 |
| 2015 | 12 | 240.35 | 0.69 | 247000 | 190000 | 0.39 |
| 2015 | 13 | 201.88 | 0.69 | 188000 | 162000 | 0.31 |
| 2015 | 14 | 120.91 | 0.69 | 198000 | 159000 | 0.36 |
| 2015 | 15 | 301.62 | 0.69 | 139000 | 111000 | 0.25 |
| 2015 | 16 | 20783.77 | 0.69 | 425000 | 349000 | 0.7 |
| 2015 | 17 | 94.1 | 0.69 | 282000 | 210000 | 0.38 |
| 2016 | 1 | 387.39 | 0.7 | 250000 | 192000 | 0.36 |
| 2016 | 2 | 122.99 | 0.7 | 252000 | 171000 | 0.34 |
| 2016 | 3 | 518.43 | 0.7 | 313000 | 251000 | 0.34 |
| 2016 | 4 | 867.23 | 0.7 | 322000 | 279000 | 0.3 |
| 2016 | 5 | 100.6 | 0.7 | 236000 | 171000 | 0.33 |
| 2016 | 6 | 320.5 | 0.7 | 196000 | 166000 | 0.35 |
| 2016 | 7 | 499.18 | 0.7 | 234000 | 181000 | 0.37 |
| 2016 | 8 | 321.29 | 0.7 | 250000 | 205000 | 0.37 |
| 2016 | 9 | 195.47 | 0.7 | 208000 | 167000 | 0.35 |
| 2016 | 10 | 210.59 | 0.7 | 200000 | 138000 | 0.42 |
| 2016 | 11 | 230.24 | 0.7 | 232000 | 169000 | 0.38 |
| 2016 | 12 | 243.5 | 0.7 | 265000 | 205000 | 0.39 |
| 2016 | 13 | 202.81 | 0.7 | 197000 | 171000 | 0.32 |
| 2016 | 14 | 121.19 | 0.7 | 204000 | 166000 | 0.36 |
| 2016 | 15 | 328.02 | 0.7 | 142000 | 110000 | 0.24 |
| 2016 | 16 | 20909.66 | 0.7 | 441000 | 359000 | 0.71 |
| 2016 | 17 | 93.11 | 0.7 | 291000 | 220000 | 0.39 |