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Abstract. Malaysia as an emerging country, increasing population, gross domestic product (GDP) growth and enhanced access to electricity lead to an expanding of demand. The crucial parameters to determine future energy demand and generation projections are GDP, population growth rates and weather implications due to climate change. The study aims to forecast the future trends based on the historical values and also to project the future electricity demand and generation. The electricity demand and generation growth evaluated based on 2 main elements which are population growth and weather parameters (maximum temperature and rainfall). The future trends are forecasted based on the historical values of population and weather parameters. There is 152.9% of population growth in 32 years. The population will keep on developing yet with the lower rate. The GDP trend and the population growth mirrors the pattern of emissions. The findings from Statistical Downscaling Model (SDSM) analysis shows that the rainfall distribution will diminish while the temperature will expand that depict the climate change impact as time passes by. In 2020, the most extreme temperature recorded is 31.7 °C while in 2040, the estimated greatest temperature is 32.3 °C. There will be a 0.6 °C increase in temperature in 20 years. The demand in 2040 will be expanded 50.3% more than demand in 2020. The estimated electricity demand per capita will continue expanding because of the augmentation of the populace and the significance of electricity in daily activities. The pattern shows that electricity demand and generation in Malaysia will be expanding massively year by year.

Keywords: Electricity, Demand, Generation, Gross Domestic Product

Track Name: Human, Social, Economic and Environmental Sustainability

1. Introduction

Worldwide electricity demand will extent about 38700 TWh by 2050 from 25000 TWh in 2017 [1]. There is 54.8% addition of demand in 33 years. Providing the future electricity demand will require an

increment in the power generation capacity. As indicated by [2], world's net electricity generation is projected to increase 69% by 2040, from 21600TWh in 2012 to 25800TWh in 2020 and 36500TWh in 2040. In the emerging countries, population and GDP growth and improved admittance to electricity lead to a growth of demand [1]. The significant employments of electricity are residential, industrial, transportation and commercial consumption [3]. International Energy Agency (IEA) recorded the electricity demand growth in five significant activities which are space cooling (37%), residential appliances (25.5%), lighting (7.8%), heating (12.4%) and other services (17.4%) [4].

According to [5], 2019 started with a weak-to-moderate El Niño event. The average temperature recorded in 2019 was 0.95 °C past the twentieth century average of 13.9 °C, making it the second-warmest year recorded. The five (5) warmest years in the 1880–2019 history happened since 2015, while 9 of the 10 warmest years have noted since 2005. [6] expressed that the last decade has been the warmest at any point recorded where 2016 was the most sweltering year. The pinnacle demand in Malaysia was recorded at 17788 MW in April 2016 because of the El-Nino phenomena [7].

Energy demand for space cooling will triple by 2050. Cooling will lead to top electricity demand, explicitly in hot countries. By 2050, around 2/3 of the world's households might own an air conditioner. Utilizing space cooling appliances like air conditioner and electric fans accounts for about 20% of the world absolute electricity utilized in buildings [8]. As populaces increment, the utilization of climate control systems is gotten normal particularly in the sultrier regions. Rising demand for space cooling is additionally driving monstrous strain on power frameworks in a few nations. Subsequently, the objectives of the study are to estimate the future patterns dependent on the historical values and to project the future electricity demand and generation.

2. Electricity Demand and Generation Scenarios

The electricity created from different sources, for example, hydropower plants, fossil fuels, geothermal systems, solar panels, wind and biofuels including electricity-only plants and combined plants [9]. Energy demand will keep on expanding. Electricity demand is discouraged by the weather condition and economic growth. Due to humid climate, about 40% of Malaysia total energy demand in the commercial sector will be channelled for space cooling [10] while in the cold regions, the electricity demand is for heating because of the utilization of electric heaters and heat pumps [11]. Worldwide electricity demand will prompt a critical development in the electricity demand by 2050. Because of the increment in electricity creation to satisfy future interest, the impending electricity generation blend will be dependent upon spectacular switches around 2050 [12].

In view of [13], the current worldwide populace is 7.8 billion individuals and is expanding by 81 million individuals each year. The most extreme annual growth rate was 2% in the late 1960s yet the pace of increment keeps on declining in the coming years. The total populace will keep on extending in the 21st century, however with a lower rate. It is expected that it will reach 9 billion by 2037 and 10 billion persons in the year 2057. Malaysia population is 0.42% of the total world population and it is estimated to reach 32.7 million in 2020 as compared to 32.5 million in 2019 with an annual growth rate of 0.4% [14].

The high correlation between energy demand and GDP brings to use of GDP as the main factor to determine future energy demand projections. Population growth rates are also a crucial parameter. Besides that, the unpredictable and severe weather implications due to climate change become important issues because it links with energy use. [15] states that the transport sector will lead energy usage in 2040 with 39.6%, trailed by the industry sector with 30.4%.

Rainfall distribution is influenced by topography and the monsoon winds. Malaysia been blessed with abundant rainfall, with normal about 2000-4000 mm every year. Malaysia is influenced by the northeast monsoon (NEM) and southwest monsoon (SWM). NEM begins from November and keeps going till March while SWM blows from late May to September. NEM contributes more rainfall over the country compare to SWM especially in the east coast region during November or December that bring massive floods [16]. Malaysia is situated at the equator and the climate is warm and humid with the mean temperature roughly 20 °C to 32 °C [17]. The warming pattern is at 0.3 °C/decade and the

country will be 2◦C warmer in the following 50 years. Both NEM and SWM essentially show expanding temperature patterns. The higher recurrence of El Niño occasions is the principal justification of the ascent of warming rates in the new decade [18].

3. Methodology

Figure 1 shows the methodology of the study. The electricity demand and generation growth assessed dependent on two (2) main elements which are population growth and weather parameters (maximum temperature and rainfall). The population historical data (1988-2019) extracted from Department of Statistics Malaysia and the population from 2020 to 2040 are projected using linear equation. The historical data for maximum temperature and rainfall (1988-2017) acquired from Malaysia Meteorological Department (MMD), the Department of Irrigation and Drainage (DID) and the Electricity Power Provider. SDSM was utilized in the weather parameters forecasting process in at regular intervals range (2020, 2030 and 2040). Electricity demand and generation historical data (1988-2019) recovered from [19] and forecasted using polynomial equation.

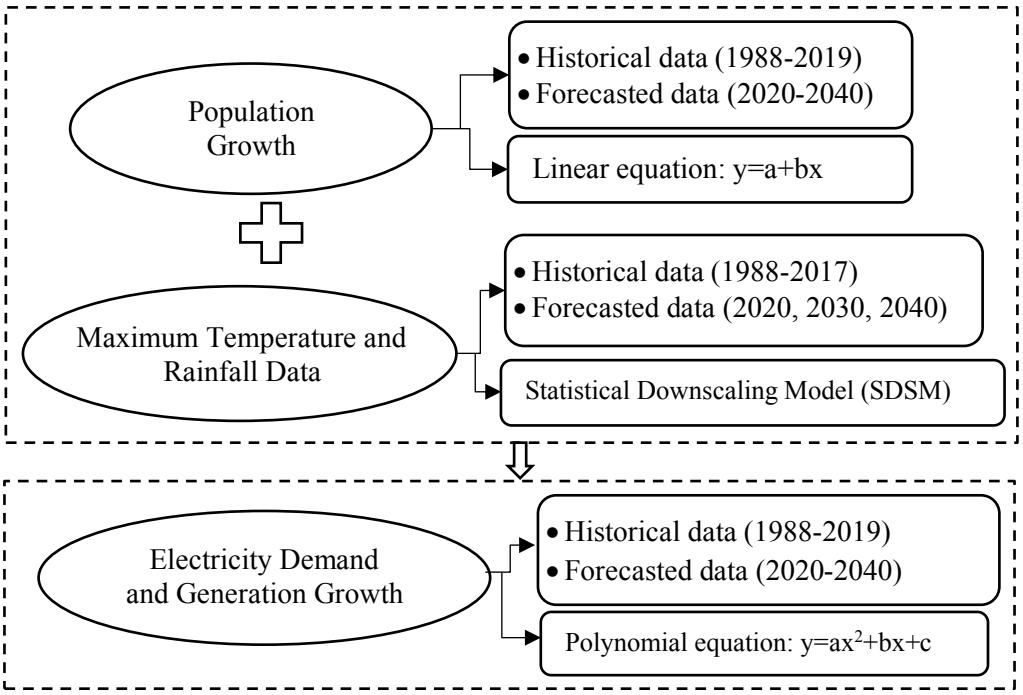

Figure 1. Methodology of the study.

4. Results and Discussions

The findings from the analysis are discussed within three (3) main elements which are population growth, weather parameters (maximum temperature and rainfall) and also electricity demand and generation scenarios. The interrelation between these elements is discussed as well.

Table 1. Malaysia population growth from 1988 to 2040.

Year	Population (million)	Year	Forecasted Population (million)
1988	17	2020	33
1992	19	2024	35
1996	21	2028	37
2000	23	2032	39
2004	25	2036	41
2008	27	2040	43
2012	29		
2016	31		

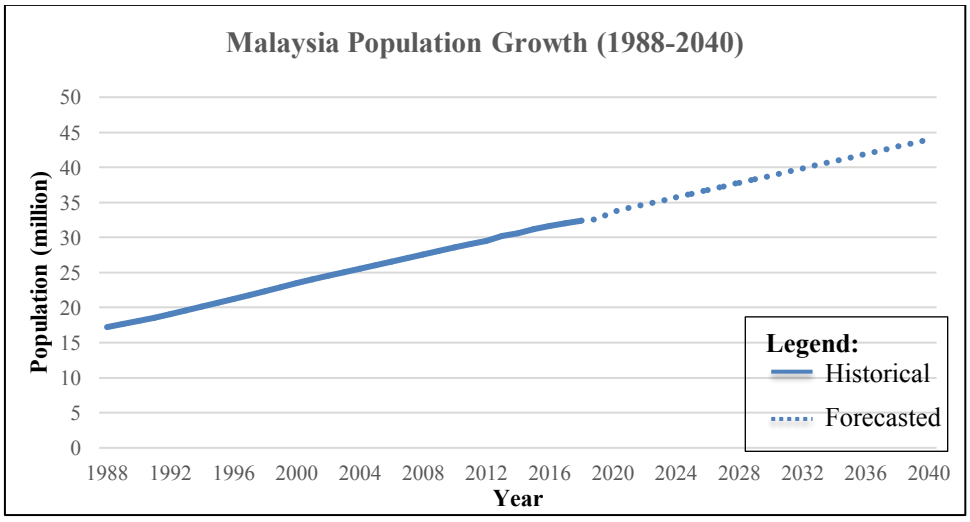

Figure 2. Graph of Malaysia population growth from 1988 to 2040.

There is 152.9% of population growth in 32 years as data in Table 1. Figure 2 clearly shows there is a constant growth from 1988 to 2019. By expecting there will be a linear growth like historical data, the forecasted population is calculated using Eq. 1 and presented in dotted line. The population is projected to increase 30.3% in 2040 compared to 2020.

$$y = 0.5154x + 16.653 \quad \text{(Equation 1)}$$

From the analysis, the population will keep on developing however with the lower rate. The growth rate for the historical data is 0.82 while the value of growth rate for forecasted data is 0.30. This finding in accordance with [13 and 20] where the pace of increment keeps on declining in the coming years and world population growth is projected to flatten in coming decades.

Table 2 recorded the estimated values from the analysis of population and weather parameters (maximum temperature and rainfall) historical data. From the projected population growth data, Malaysia population is 33 million people in 2020 and increment 5 million individuals at regular intervals wherein 2030 and 2040, Malaysia populace will accomplish 38 million and 43 million individuals separately. Figure 3 shows the forecasted population and maximum temperature for 2020, 2030 and 2040. In 2020, the most extreme temperature recorded is 31.7 °C while in 2040, the forecasted maximum temperature is 32.3 °C. There will be 0.6 °C expansion of temperature in 20 years and in accordance with [21] that expressed the temperature may increment by 0.5-1.0 °C during that period. Temperature rise is one of the aspects of climate change and its variances influence economic activities and electricity consumption [22]. As the populace develop and temperature ascend, there will be a critical expansion in electricity use for various activities in space cooling, residential appliances, lighting, water heating, and others as [23] tracked down that over 76% of United States (U.S.) electricity use or over 40% of all

U.S. energy use are utilized for space conditioning and lighting for industrial, commercial and residential buildings. Outrageous temperature occasions result in an expansion in air conditioner utilisation that influences electricity demand also [24]. Space conditioning includes gadgets to either expanding or diminishing air temperature. [25,26] additionally expressed that the pace of energy utilization assessed to increment with economic and population growth due to the usage of modern home appliances, mostly air conditioners and refrigerators.

The GDP pattern and the population growth mirrors the pattern of emissions. Human emissions of carbon dioxide and anthropogenic greenhouse gases have expanded since the pre-industrial era, driven generally by economic and population growth are a primary driver of climate change especially global warming since the mid-twentieth century [6]. Figure 4 shows the findings from SDSM analysis that reflect the climate change effect as time passes by where the rainfall distribution will diminish while the temperature will increase. The positive patterns of temperature increment have been observed since the most recent forty years. The augmentation of the greatest surface temperature is about 0.17 °C to 0.22 °C each decade [26] while a minor diminishing pattern is identified for the rainfall in Peninsular Malaysia and Sabah [21]. Outrageous climate like floods, dry spells, tempests, and heat waves are the effects of climate change [27]. Projection process for rainfall and temperature dependent on Eq. 2 and Eq. 3.

$$P_i^k = \beta_0 + \sum_{j=1}^{n} \beta_j \, X_{ij} + \varepsilon_i \quad \text{(Equation 2)}$$

$$\text{Ui} = \gamma_0 + \sum_{j=1}^{n} \gamma_j \, X_{ij} + \varepsilon_i \quad \text{(Equation 3)}$$

where P_i = amount of total precipitation, k = transformation (fourth root, inverse normal or logarithmic), U_i = daily temperature (T_{Max} and T_{Min}), X_{ij} = selected NCEP/NCAR predictors, β_j and γ_j = regression coefficients estimated for each month using least-squares regression and ε_i = model error [28, 29].

Table 2. The forecasted values from the analysis.

Year	Forecasted values		
	Population (million)	Maximum Temperature (◦C)	Average Rainfall (mm/day)
2020	33	31.7	7.7
2030	38	32.2	6.9
2040	43	32.3	7

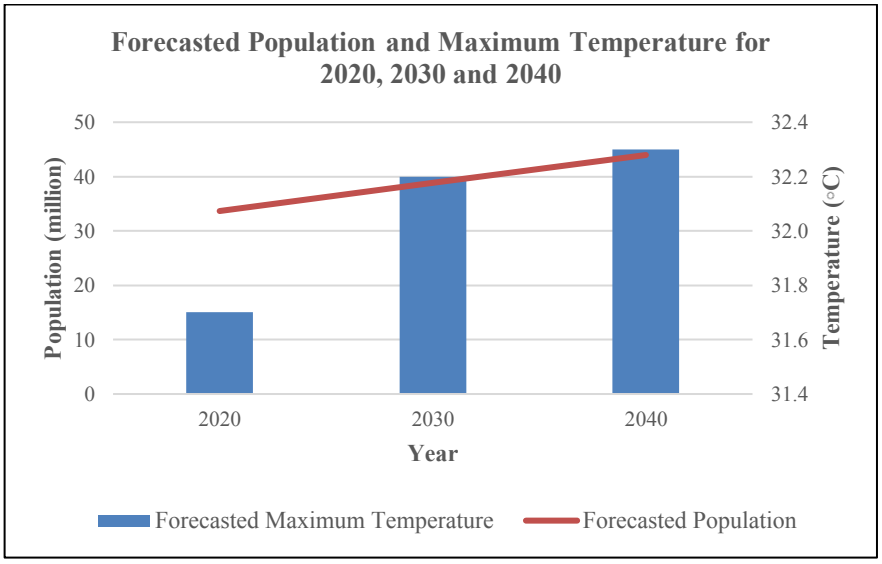

Figure 3. Graph of forecasted population and maximum temperature for 2020, 2030 and 2040.

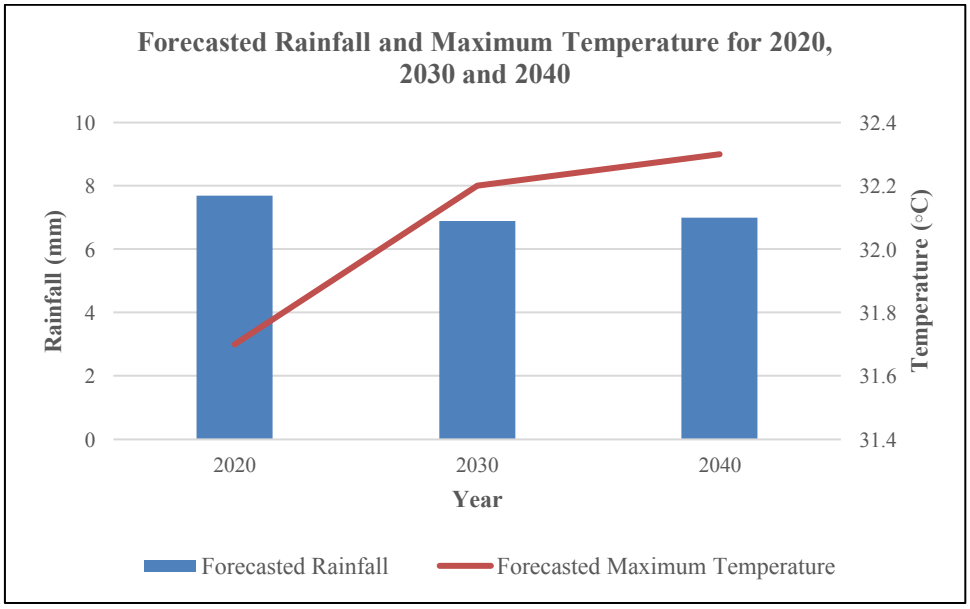

Figure 4. Graph of forecasted rainfall and maximum temperature for 2020, 2030 and 2040.

The electricity demand is essentially reliant upon the climate data [30]. In view of Table 3, electricity demand per capita for 2018 is multiple times greater than in 1988. The demand will be expanded to 7445kWh/individual in 2040 where it is 50.3% more than demand in 2020. The forecasted electricity demand per capita is determined utilizing Eq. 4 and introduced by the dotted line in Figure 5. Expansions in per capita electricity utilization impersonate potential changes in the piece of the economy, for example, shifts to more energy-intensive industries, and changes in service demand, such as growing demand for air conditioning and appliances. The forecasted electricity demand per capita will continue expanding because of the addition of the populace and the significance of electricity in everyday activities as discussed by [31], the expanding electricity consumption is driven by the improvement in GDP and population.

$$y = -0.0368x^2 + 126.48x + 828.45 \quad \text{(Equation 4)}$$

Table 3. Electricity Demand per Capita (kWh/person).

Year	Electricity Demand per capita (kWh/person)	Year	Forecasted Electricity Demand per capita (kWh/person)
1988	940	2020	4955
1992	1352	2024	5453
1996	2068	2028	5951
2000	2603	2032	6449
2004	3022	2036	6947
2008	3367	2040	7445
2012	3943		
2016	4553		

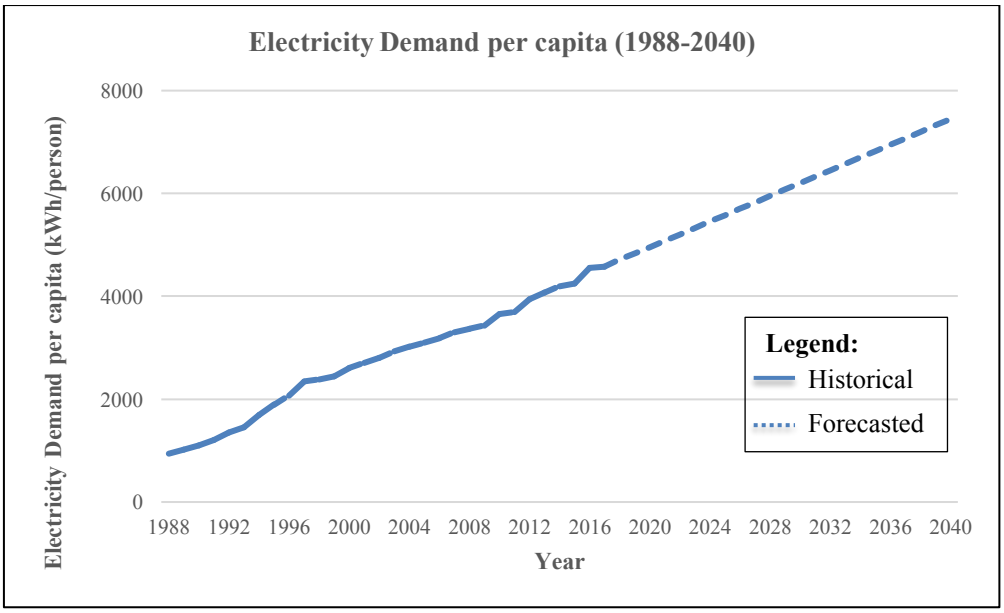

Figure 5. Graph of electricity demand per capita from 1988 to 2040.

High electricity generation prompts high power utilization. Table 4 and Figure 6 shows the values and graph of absolute electricity generation from 1988 to 2040. The anticipated absolute electricity generation are determined utilizing Equation 5. The values show the augmentation as the years progressed. The total electricity generation is relied upon to arrive at 272.8TWh in 2040, almost 60% higher than 2020. Essential energy supply and energy demand developed to pair with the population and economic growth and this pattern is relied upon to proceed [21].

$$y = 0.0071x^2 + 4.6823x + 7.1369 \quad \text{(Equation 5)}$$

Table 4. Total electricity generation from 1988 to 2040.

Year	Total Electricity Generation (TWh)	Year	Forecasted Total Electricity Generation (TWh)
1988	19.4	2020	170.7
1992	29.3	2024	191.1
1996	51.4	2028	211.5
2000	69.3	2032	232.0
2004	82.3	2036	252.4
2008	98.0	2040	272.8
2012	134.5		
2016	156.2		

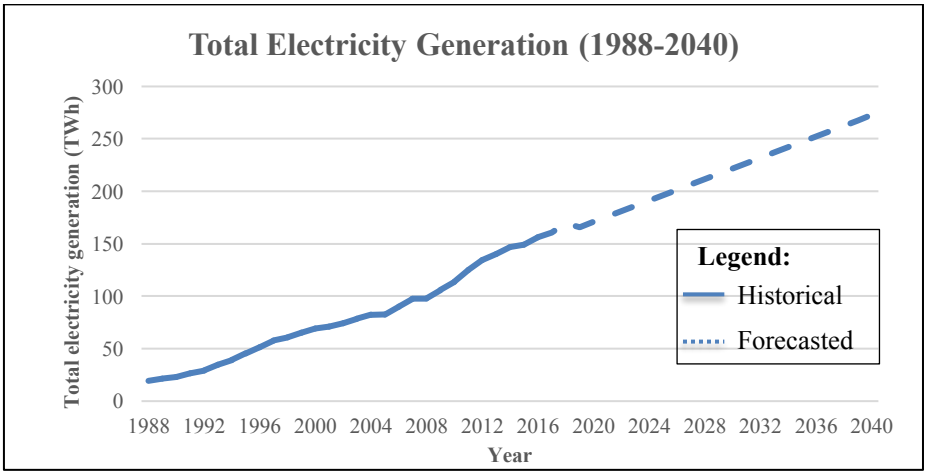

Figure 6. Graph of total electricity generation from 1988 to 2040.

5. Conclusions

The urgent boundaries to decide future energy demand and generation projections are GDP, population growth rates and weather implications due to climate change. The electricity demand and generation development assessed dependent on two (2) primary components which are population growth and weather parameters (maximum temperature and rainfall). In light of the historical values of population and weather parameters, future trends are determined. The population will keep on developing however with the lower rate. The findings from SDSM analysis mirror the climate change impact as time passes by. This tends to the significance of investigating the impacts of climatic variables on electricity demand. Rainfall distribution will diminish while the temperature will increase. The forecasted electricity demand per capita will continue expanding because of the augmentation of the populace. In a conclusion, from the analysis that has been made to crucial parameters in electricity demand and generation in Malaysia, the trending shows that both will be expanding massively year by year.

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Acknowledgment

The authors would like to thank the Ministry of Higher Education for providing financial support under Fundamental research grant No. FRGS/1/2019/TK01/UMP/02/1 (University reference RDU1901141) and Universiti Malaysia Pahang for additional financial support under Internal Research grant RDU1803156, Malaysian Meteorological Department (MMD), and Drainage and Irrigation Department (DID).