NKUA

# TECHNO-ECONOMIC EVALUATION OF TELECOMMUNICATIONS SYSTEMS

ASSIGNMENT PART 2

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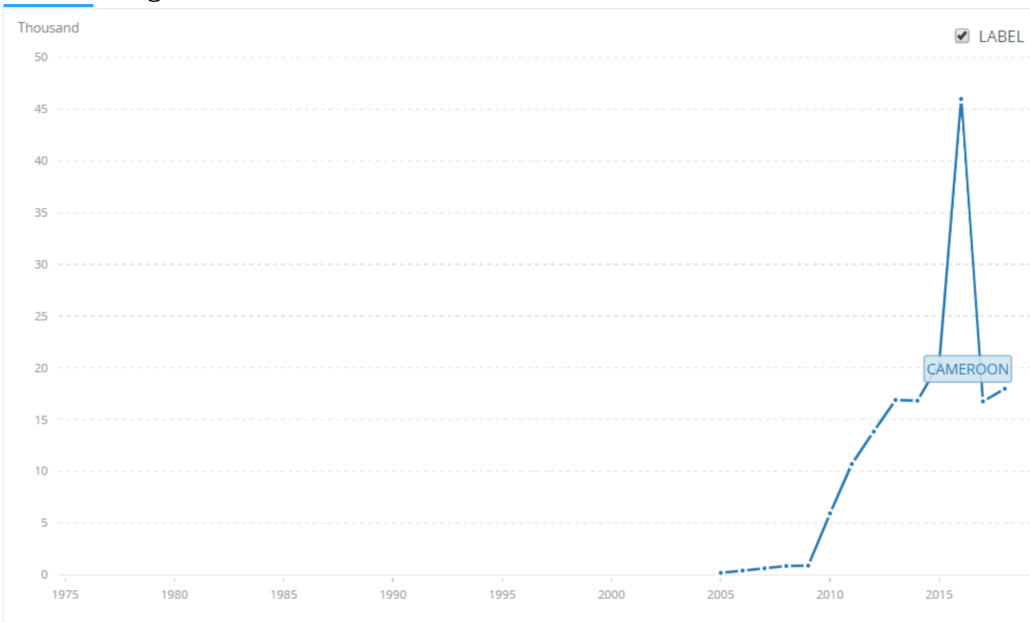
2-5-2020

# Contents

# TELCOM SERVICES UNDER CONSIDERATION

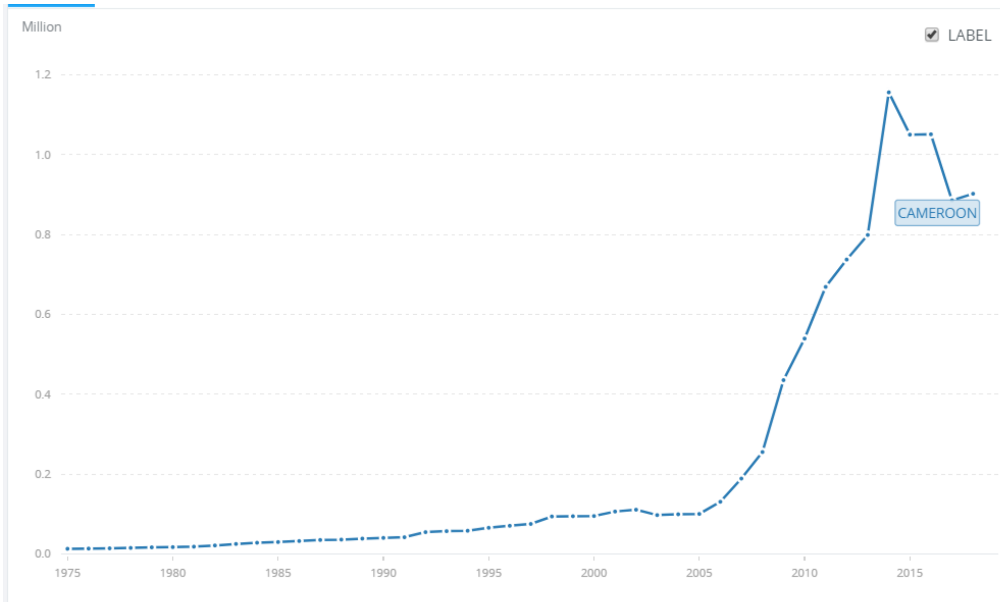
## FIXED BROADBAND SUBSCRIPTIONS

Fixed broadband subscriptions refer to fixed subscriptions to high-speed access to the public Internet (a TCP/IP connection), at downstream speeds equal to, or greater than, 256 kbit/s. This includes cable modem, DSL, fiber-to-the-home/building, other fixed (wired)-broadband subscriptions, satellite broadband and terrestrial fixed wireless broadband. This total is measured irrespective of the method of payment. It excludes subscriptions that have access to data communications (including the Internet) via mobile-cellular networks. It should include fixed WiMAX and any other fixed wireless technologies. It includes both residential subscriptions and subscriptions for organizations.



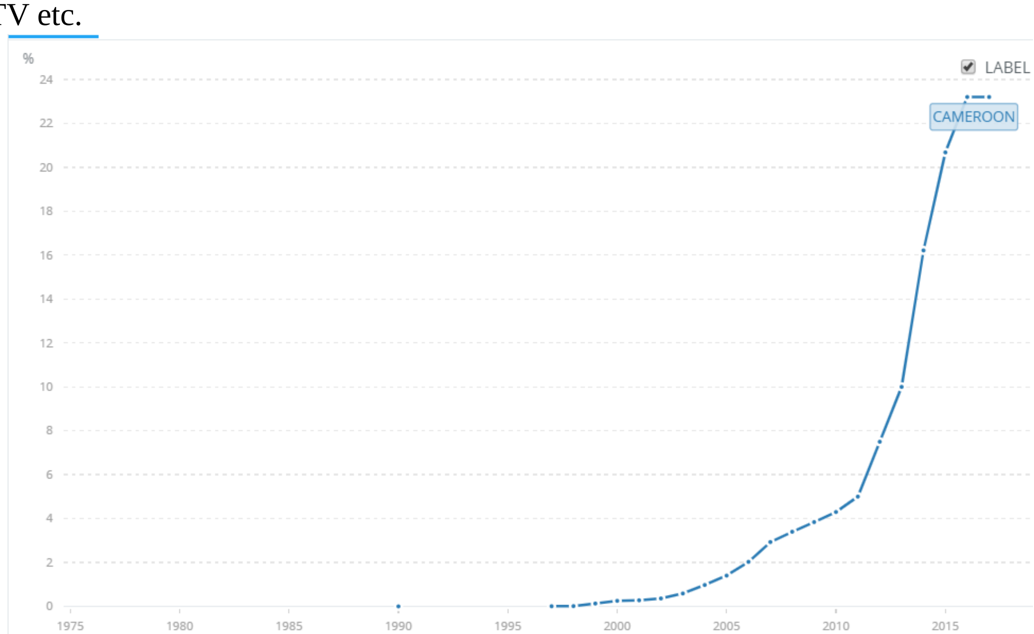

## FIXED TELEPHONE SUBSCRIPTIONS

Fixed telephone subscriptions refer to the sum of active number of analogue fixed telephone lines, voice-over-IP (VoIP) subscriptions, fixed wireless local loop (WLL) subscriptions, ISDN voice-channel equivalents and fixed public payphones.



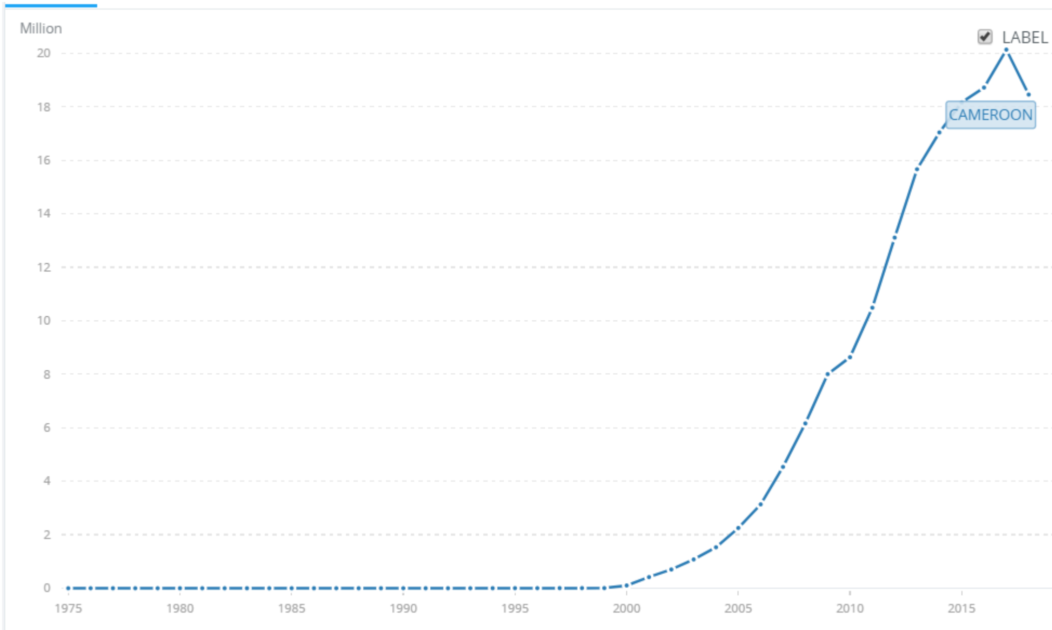

**MOBILE INTERNET SUBSCRIPTIONS (DATA GIVEN IN TERMS OF PERCENTAGES OF POPULATION)**

Internet users are individuals who have used the Internet (from any location) in the last 3 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.



**MOBILE CELLULAR SUBSCRIPTIONS**

Mobile cellular telephone subscriptions are subscriptions to a public mobile telephone service that provide access to the PSTN using cellular technology. The indicator includes (and is split into) the number of postpaid subscriptions, and the number of active prepaid accounts (i.e. that have been used during the last three months). The indicator applies to all mobile cellular subscriptions that offer voice communications. It excludes subscriptions via data cards or USB modems, subscriptions to public mobile data services, private trunked mobile radio, telepoint, radio paging and telemetry services.



# DEMAND MODELING AND FORECASTING

The following models were used in each dataset for demand modelling and forecasting:

- Fisher Pry model
- Gompertz model
- Logistic linear model

## FISHER PRY MODEL

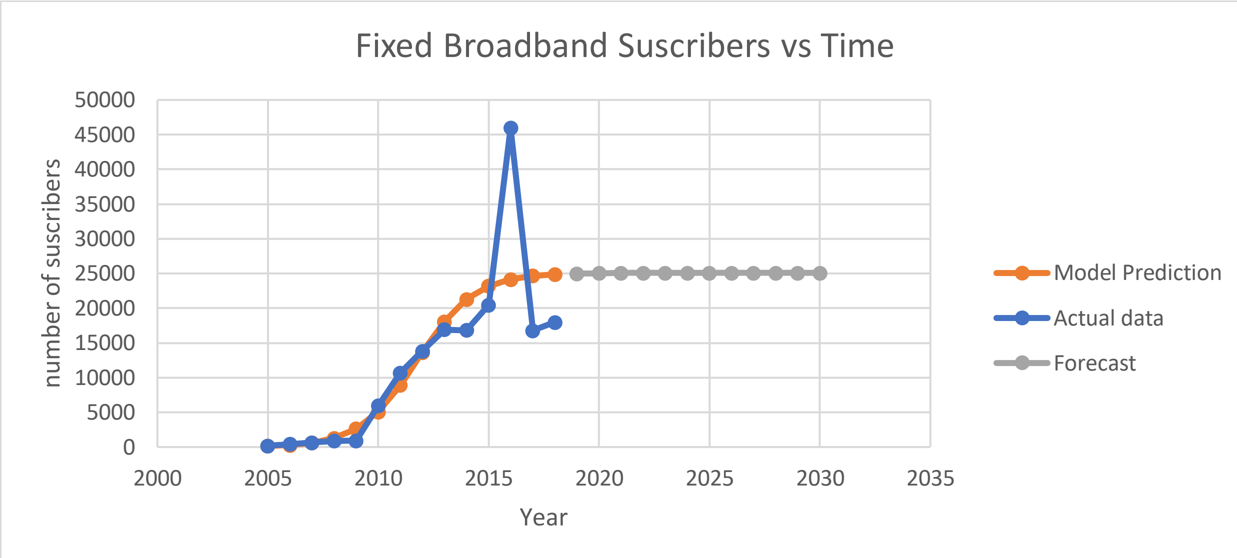
This model is based on the following formula:

$$Y(t) = \frac{S}{1+e^{-b(t-a)}}$$

Where
S = Saturation level
Y(t) = diffusion level at time t
t = time
a = time at which diffusion level reaches 50% of total market
b = technology adoption rate

- The dataset is loaded into MS Excel
- Parameters a,b and S are  estimated using the datafit tool .
- The resulting plots obtained in Excel with corresponding errors is shown below.

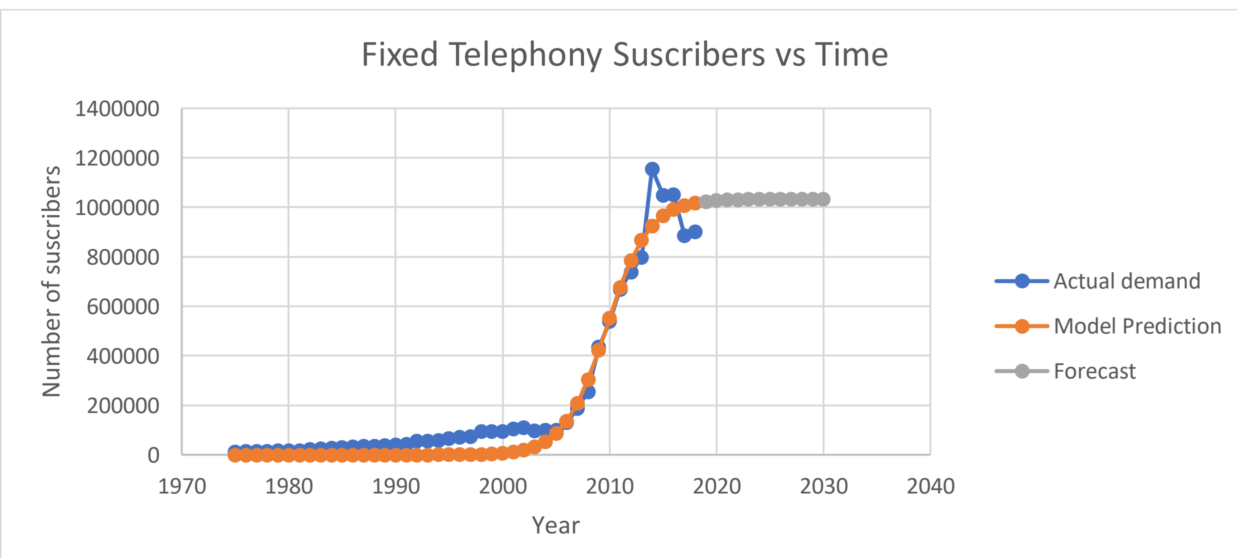
## Fixed Broadband




Error in Prediction

| | |
|---|---|
| **Mean Absolute Error** | **3586.409845** |
| **Mean Squared Error** | **44380032.38** |
| **Mean Ab. % Error** | **37.5325863** |

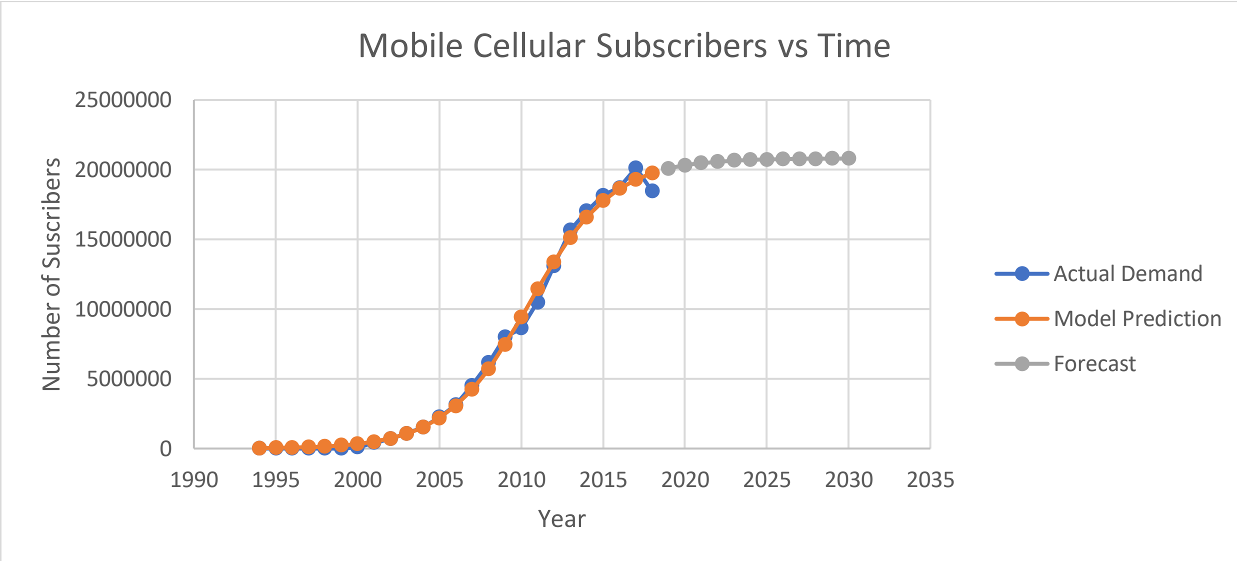
## Fixed Telephony




Errors in prediction

| | |
|---|---|
| **MAE** | **50511.8391** |
| **MSE** | **4228841861** |
| **MAPE** | **67.882505** |

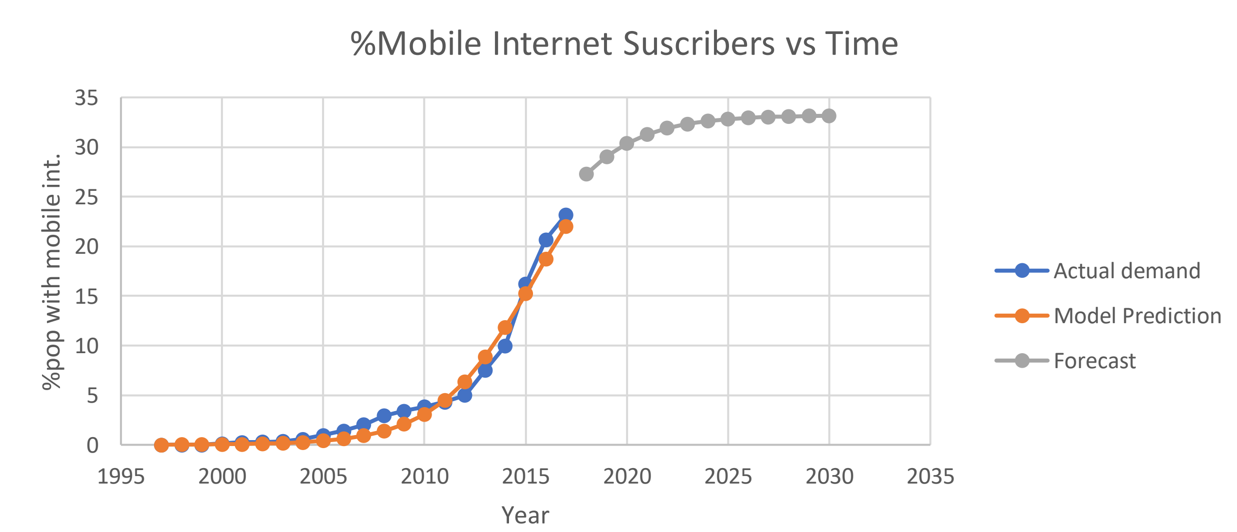
### Mobile Cellular (voice)




Errors in prediction

| | |
|---|---|
| **MAE** | **320659.033** |
| **MSE** | **2.15592E+11** |
| **MAPE** | **603.2438926** |

### Mobile Broadband



Errors in Prediction

| | |
|---|---|
| **MAE** | **0.84008415** |
| **MSE** | **1.11333391** |
| **MAPE** | **49.0314121** |

## GOMPERTZ MODEL

The formula describing this model is the following:

$$Y(t) = S \cdot e^{-e^{-a-bt}}$$

Where:

S = Saturation level

b = defines diffusion rate

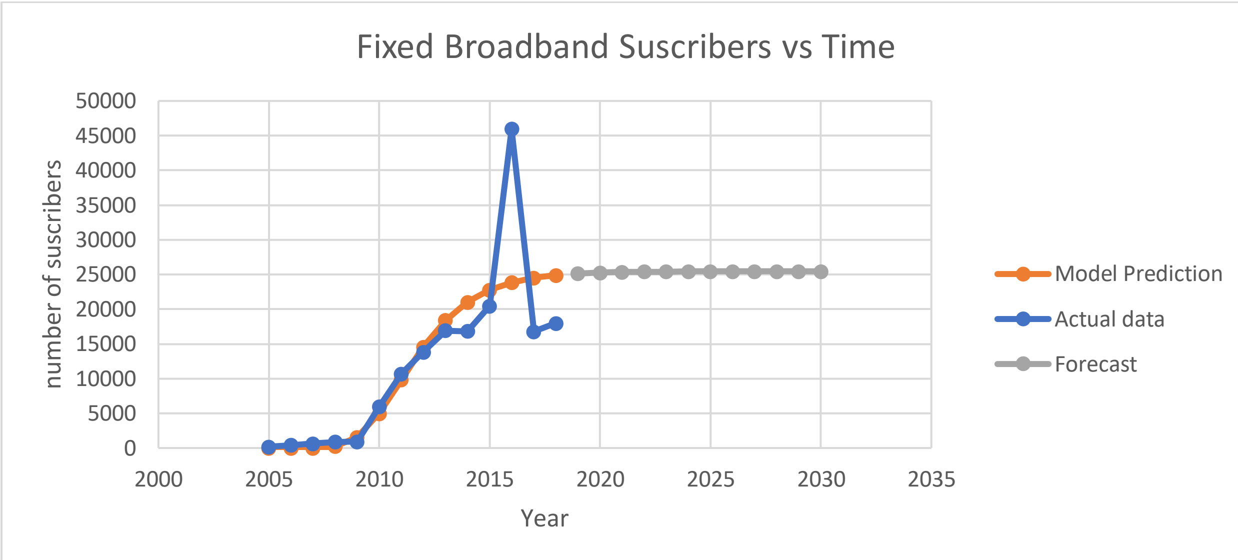
a = defines time when diffusion level reaches 37%

Y(t) = diffusion level at time t.

The same procedure is followed as with the fisher pry model, the only change being the formula by which predictions are made.

The following results are obtained with the Gompertz model.

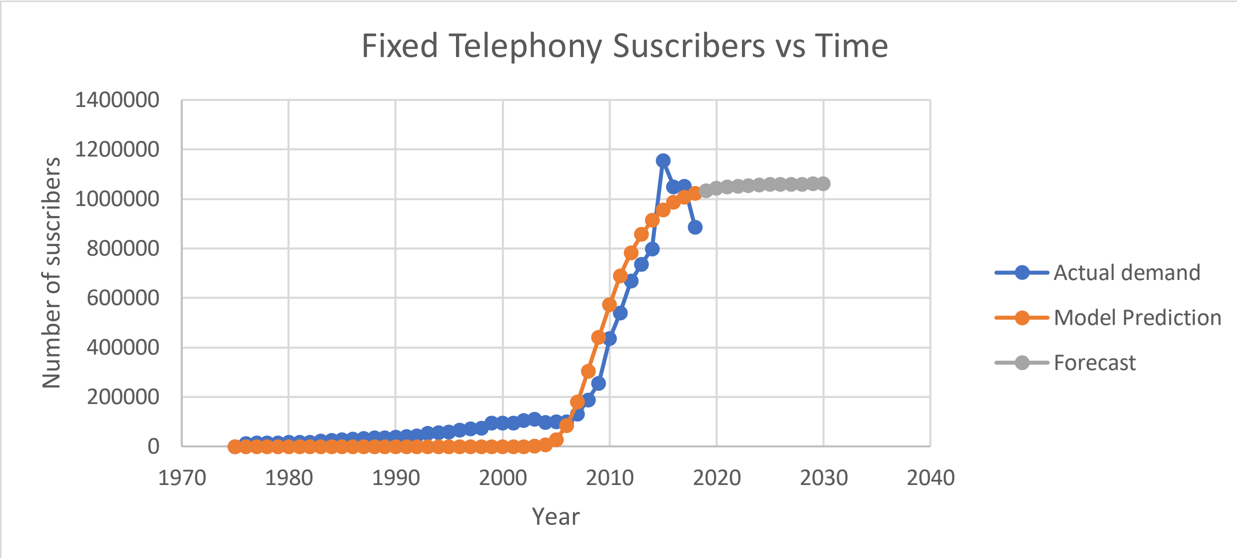
## Fixed Broadband




Errors in Prediction

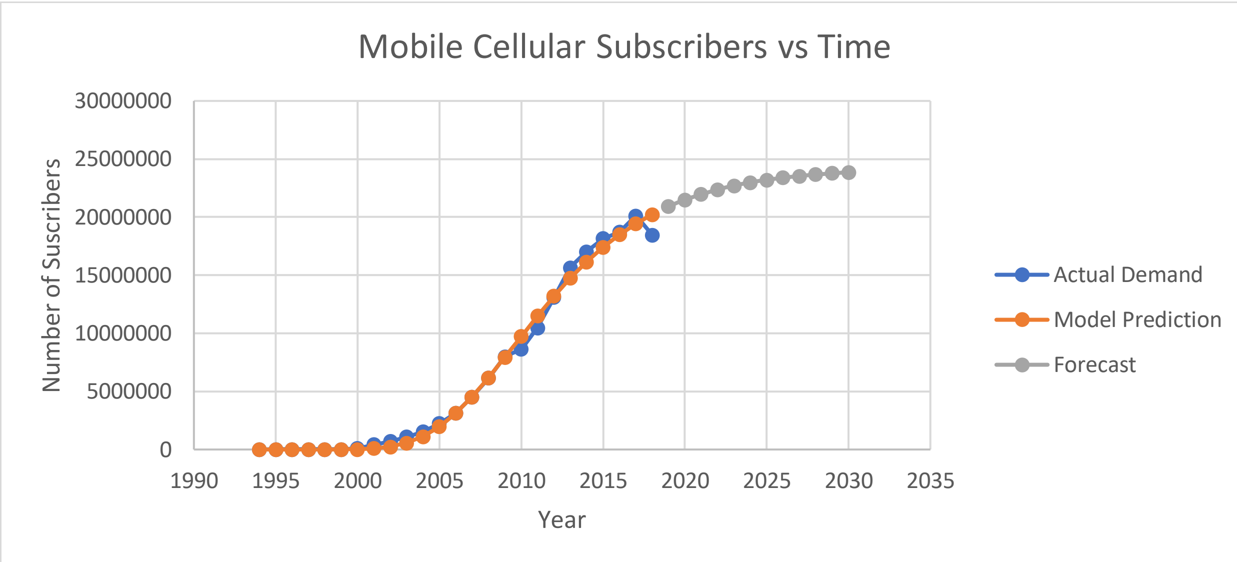
| | |
|---|---|
| **MAE** | **3566.594887** |
| **MSE** | **44723700.64** |
| **MAPE** | **46.81943643** |

### Fixed Telephony



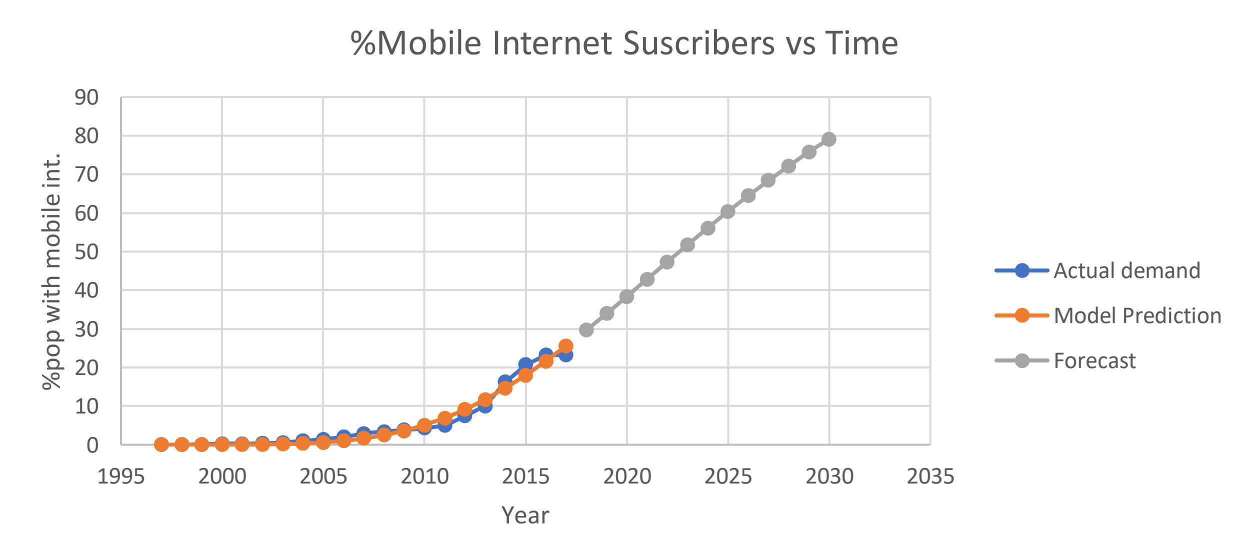

| | |
|---|---|
| **MAE** | **56686.6758** |
| **MSE** | **5099054815** |
| **MAPE** | **72.9849549** |

**Mobile Cellular (voice)**




| | |
|---|---|
| **MAE** | **386514.5373** |
| **MSE** | **3.60705E+11** |
| **MAPE** | **34.45937459** |

**Mobile Internet**




| | |
|---|---|
| **MAE** | **0.96638994** |
| **MSE** | **1.53552424** |
| **MAPE** | **46.1206313** |

## LINEAR LOGISTIC MODEL

The model is based on the following formula:

$$Y(t) = \frac{S}{1+e^{-a-b\cdot t(m,k)}}$$

Where:

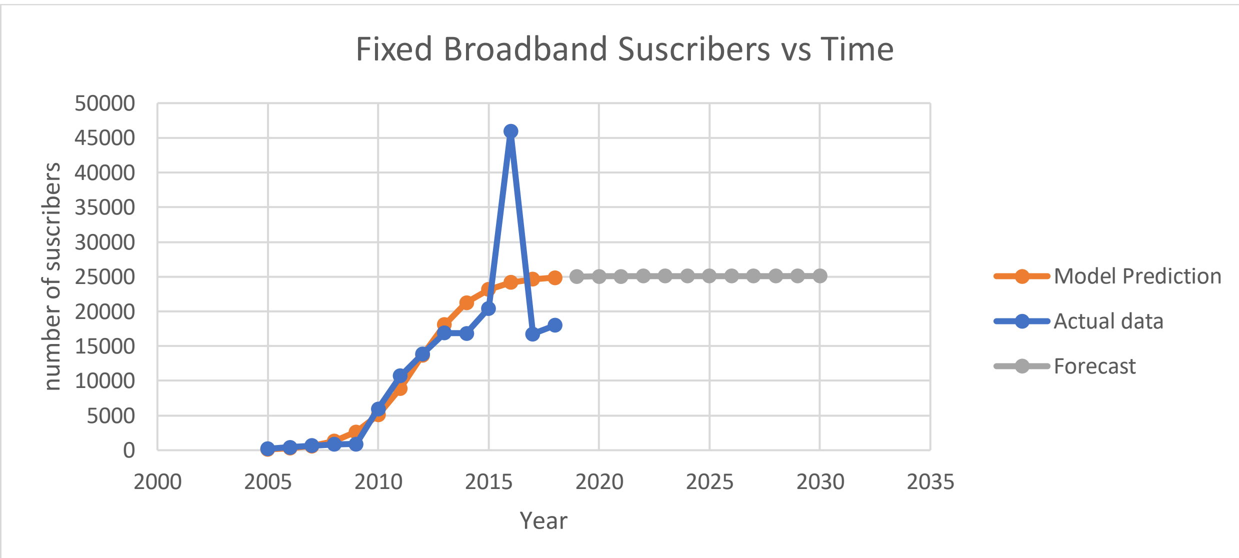
t(m,k) = t

S = saturation level

And a,b = shape parameters.

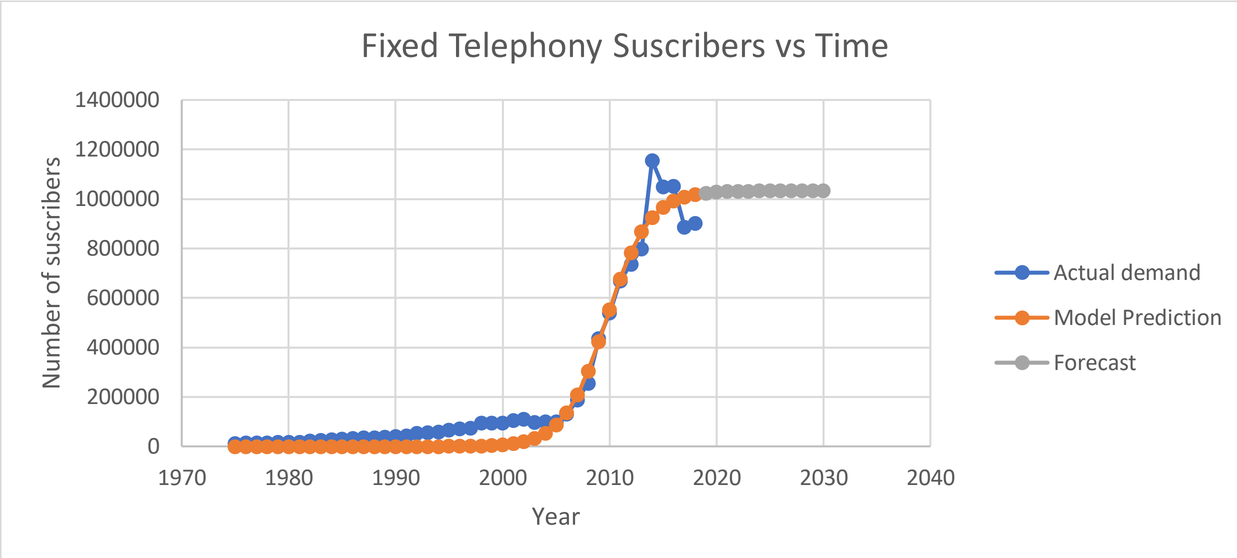
After curve fitting, the following results were obtained:

**Fixed Broadband**



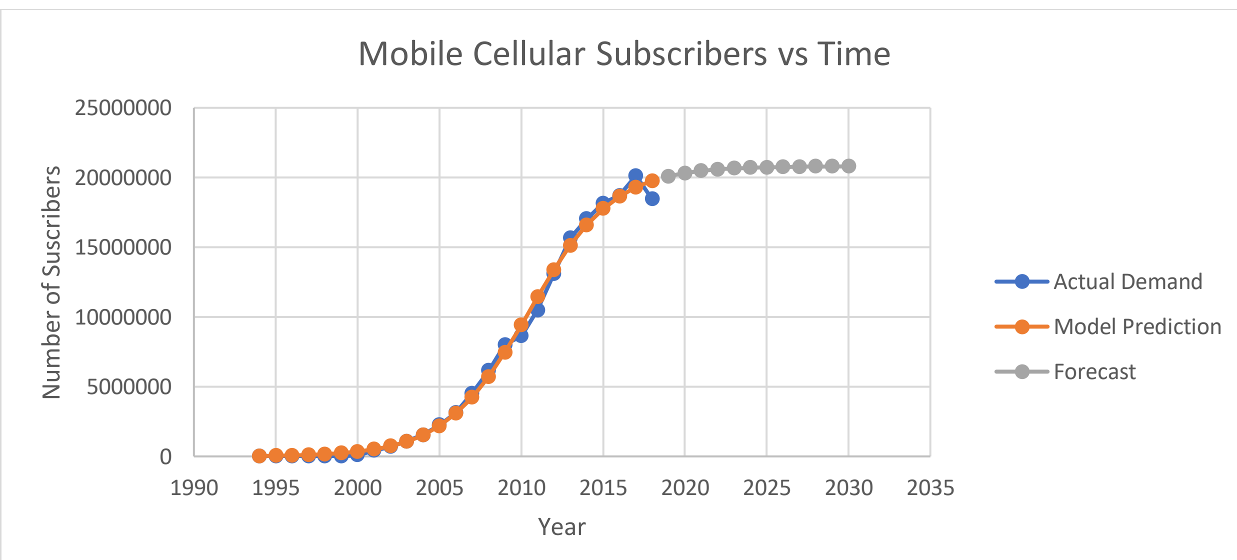

| | |
|---|---|
| **Mean Absolute Error** | **3586.410614** |
| **Mean Squared Error** | **44380032.38** |
| **Mean Ab. % Error** | **37.53261394** |

## Fixed Telephony



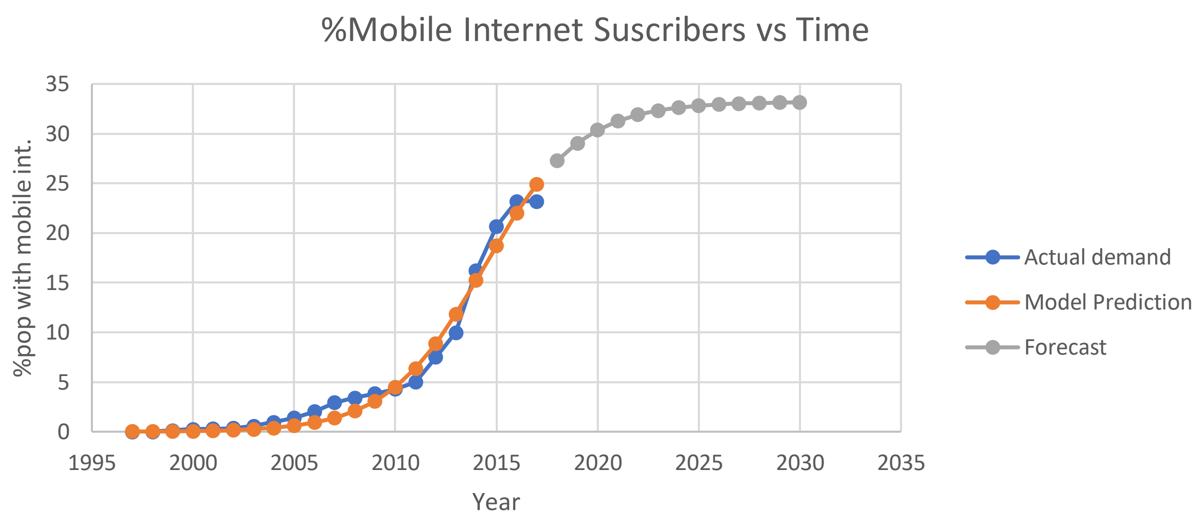

| | |
|---|---|
| **MAE** | **50511.839** |
| **MSE** | **4228841861** |
| **MAPE** | **67.8825048** |

## Mobile Cellular (voice)




| | |
|---|---|
| **MAE** | **320659.0374** |
| **MSE** | **2.15592E+11** |
| **MAPE** | **603.2438508** |

**Mobile Internet users**




| | |
|---|---|
| **MAE** | **0.84008415** |
| **MSE** | **1.11333391** |
| **MAPE** | **49.0314118** |

# COMMENTS ON THE PERFORMANCE OF EACH MODEL

**FIXED BROADBAND DATA**

| | Fisher Pry | Gompertz | Linear Logistic |
|---|---|---|---|
| MAE | **3586.409845** | **3566.594887** | **3586.410614** |
| MSE | **44380032.38** | **44723700.64** | **44380032.38** |
| MAPE | **37.5325863** | **46.81943643** | **37.53261394** |

FIXED TELEPHONY

| | Fisher Pry | Gompertz | Linear Logistic |
|---|---|---|---|
| MAE | **50511.8391** | **56686.6758** | **50511.839** |
| MSE | **4228841861** | **5099054815** | **4228841861** |
| MAPE | **67.882505** | **72.9849549** | **67.8825048** |

MOBILE VOICE

| | Fisher Pry | Gompertz | Linear Logistic |
|---|---|---|---|
| MAE | **320659.033** | **386514.5373** | **320659.0374** |
| MSE | **2.15592E+11** | **3.60705E+11** | **2.15592E+11** |
| MAPE | **603.2438926** | **34.45937459** | **603.2438508** |

MOBILE INTERNET

| | Fisher Pry | Gompertz | Linear Logistic |
|---|---|---|---|
| MAE | **0.84008415** | **0.96638994** | **0.84008415** |
| MSE | **1.11333391** | **1.53552424** | **1.11333391** |
| MAPE | **49.0314121** | **46.1206313** | **49.0314118** |

Looking at the graphs, I would say the fisher pry and linear logistic models outperform the Gompertz model. This could be attributed to the fact that the Gompertz model is best suited for modelling technology change due to depreciation of equipment rather than innovation.

# VOLATILITY MODELING AND RISKMETRICS APPLICATION

General Procedure

- Kolmogorov-Smirnov normality test on the demand data:
  I performed this test on the demand data (as requested by the question) and also on the log changes of the data so as to validate whether or not a GBM model could be made from the data.
  The Kolmogorov-Smirnov normality test can be applied to a specific set of values. The normality criterion stands for values lower than 0,338.

- GBM Parameter modelling
  The demand data is used to compute volatility and drift model parameters. This is done in the following way.
  1. The logarithmic change of the data is computed and the standard deviation of the resulting distribution is the volatility.
  2. The drift is computed from the average of the log changes and the volatility parameter.

- Apply RiskMetrics technique (Monte Carlo Simulation – 10.000 sampling)
  In a bid to estimate future demand dispersion until the years 2025 and 2030.
  The crystal ball plugin in excel was downloaded and used to perform a Monte Carlo simulation with 10,000 trials.
  Using the parameters (drift and volatility) obtained from the GBM modelling alongside the demand for the last observed year, a forecast is made regarding the subsequent behavior of demand.
  The drift parameter is constant mean while the uncertainty factor (computed from the calculated volatility parameter) is stochastic. this models' certain unforeseen changes in the market.
  The calculations are performed 10,000 times using Monte Carlo and a distribution representing future demand dispersions for the years 2025 and 2030 is obtained.
  The results obtained from this procedure carried out on the four different services is shown next.

## RESULTS

### FIXED BROADBAND

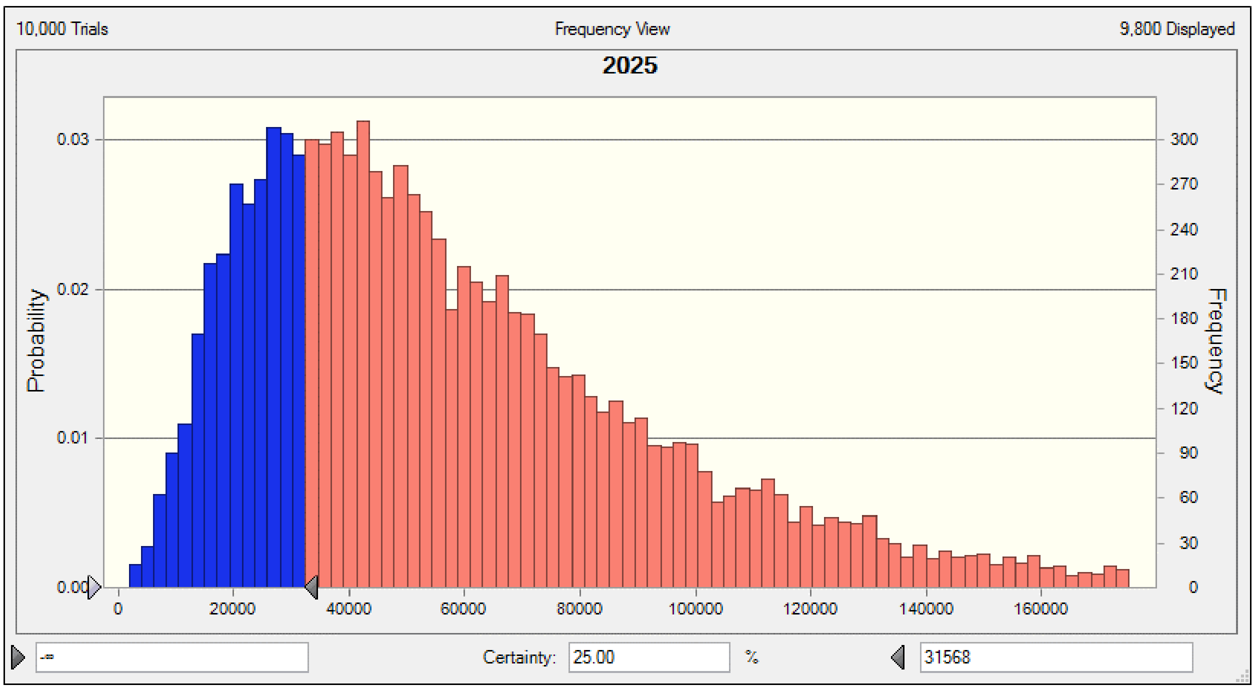
Kolmogorov-Smirnov normality test score on data = 0.178

Kolmogorov-Smirnov normality test score on log data changes = 0.158

Drift = 0.189

Volatility = 0.280

### 2025




### Value At Risk (VAR)

There is a 25% probability that in the year 2025, the number of subscribers would be 31,568 or less.

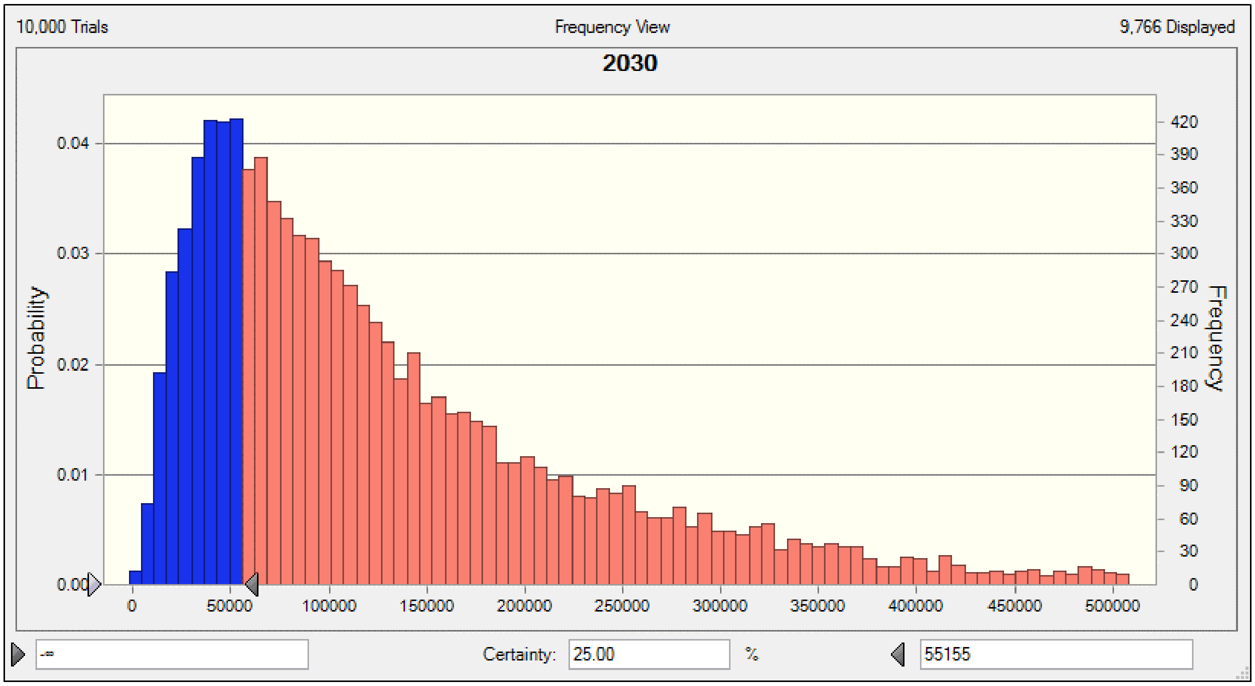
### Dispersion Parameters

Mean 60,338

Median 50,486

Standard Deviation 41,000

## 2030




### Value At Risk (VAR)

There is a 25% probability that in the year 2030, the number of subscribers would be 55,155 or less.

### Dispersion Parameters

Mean 142,380

Median 103,369

Standard Deviation 130,769

### FIXED TELEPHONY(VOICE)

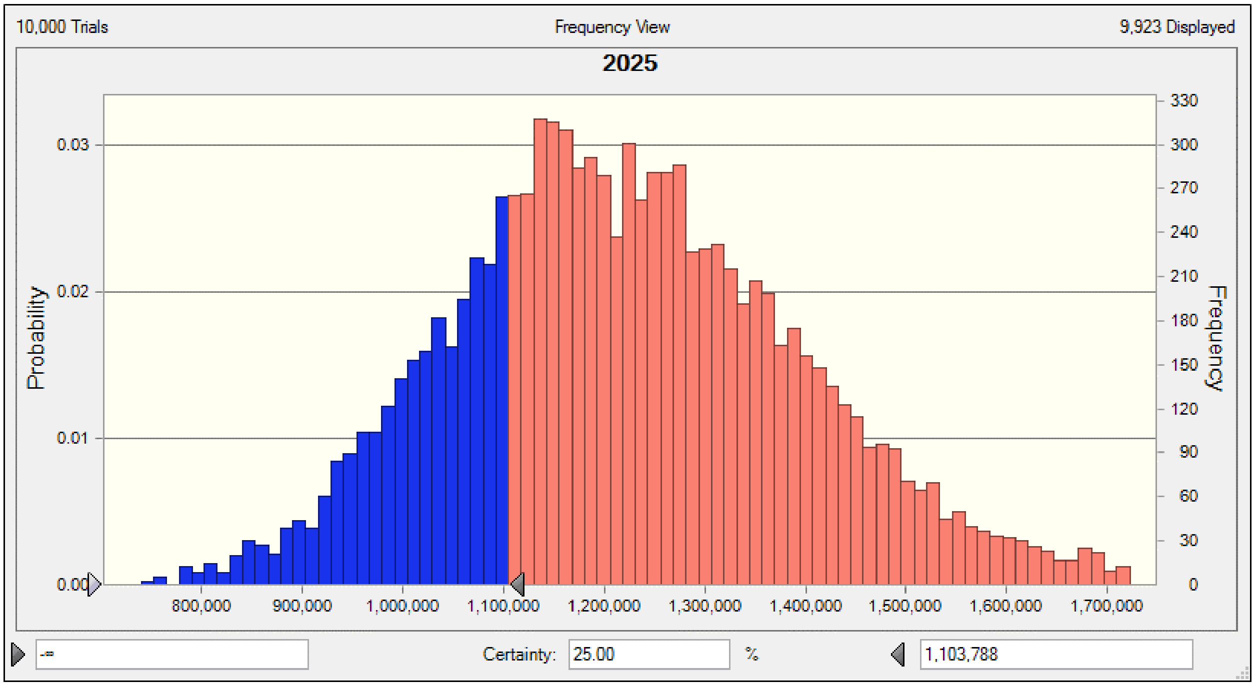
Kolmogorov-Smirnov normality test score = 0.349

Kolmogorov-Smirnov normality test score on log of changes in data = 0.181

Drift = 0.0444

Volatility = 0.0574

**2025**




### Value At Risk (VAR)

There is a 25% probability that in the year 2025, the number of subscribers would 1,103,788 or less.

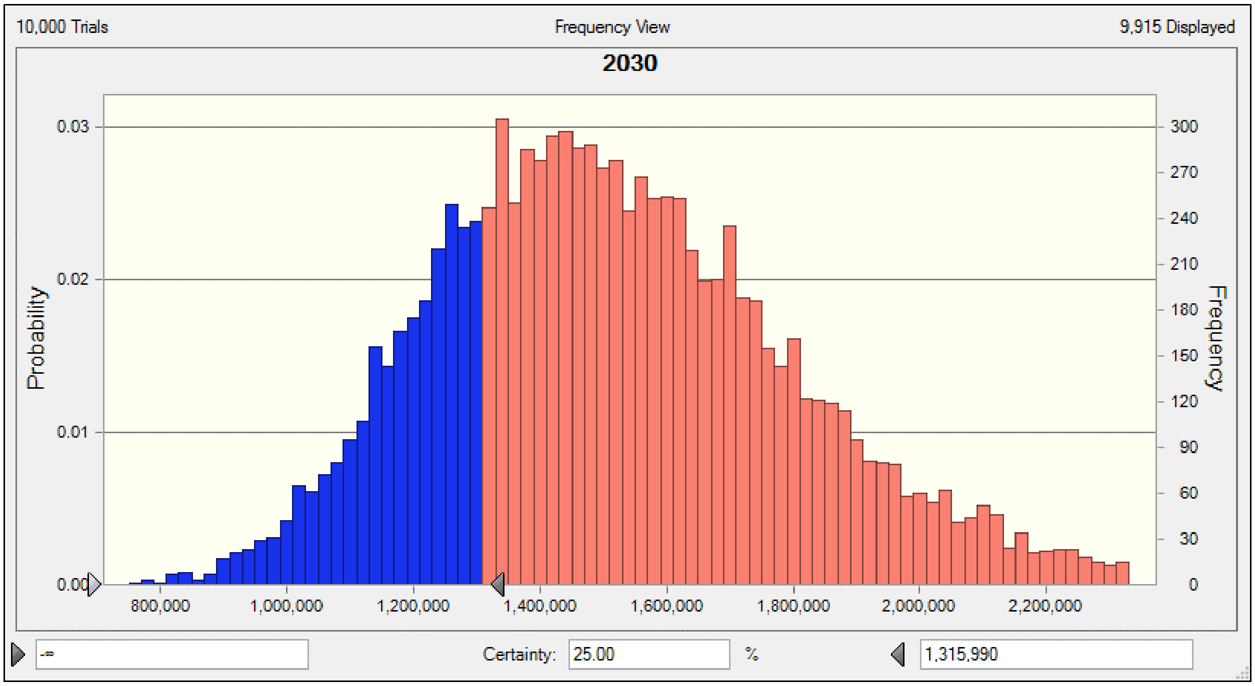
### Dispersion Parameters

Mean 1,224,932

Median 1,213,121

Standard Deviation 177,332

**2030**




**Value At Risk (VAR)**

There is a 25% probability that the number of subscribers in the year 2030 would be 1,315,990 or less

**Dispersion Parameters**

Mean 1,520,362

Median 1,492,962

Standard Deviation 289,627

**MOBILE VOICE**

Kolmogorov-Smirnov normality test score on data = 0.207

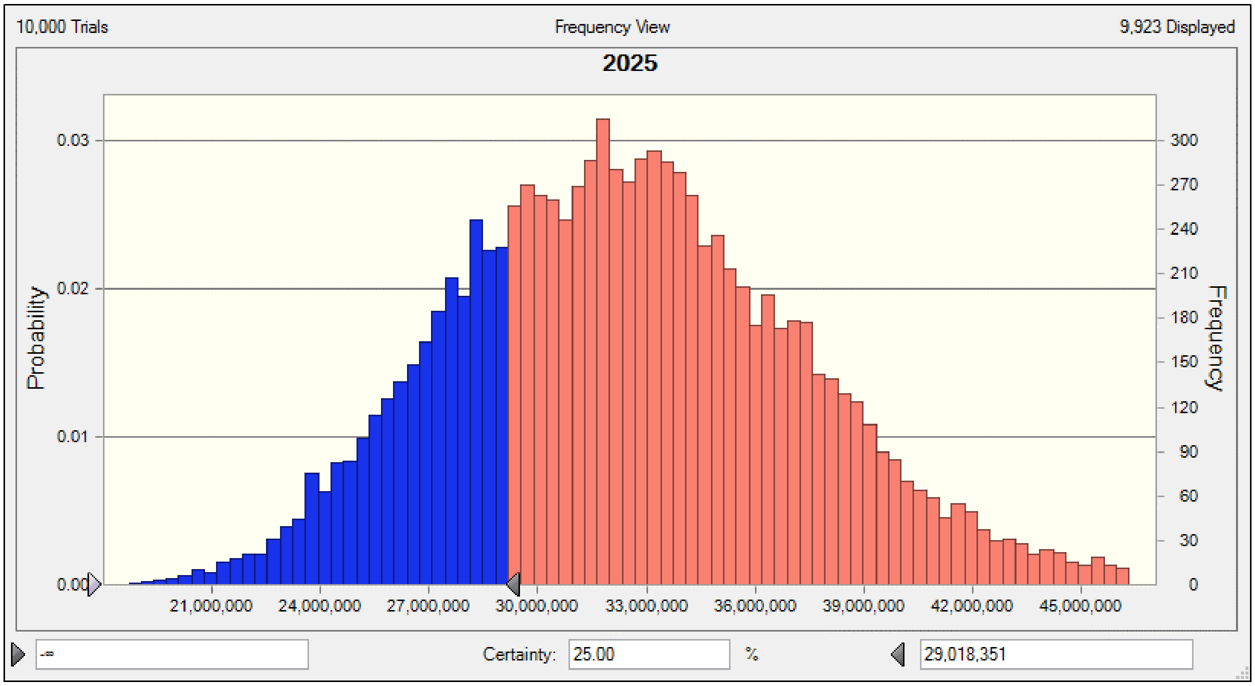
Kolmogorov-Smirnov normality test score on log changes in data= 0.1668

Drift = 0.084232

Volatility = 0.062784

The historical data considered here is in the period 2003 – 2018.

**2025**




**Value At Risk (VAR)**

There is a 25% probability that the number of subscribers in the year 2025 would be 29,018,351 or less.

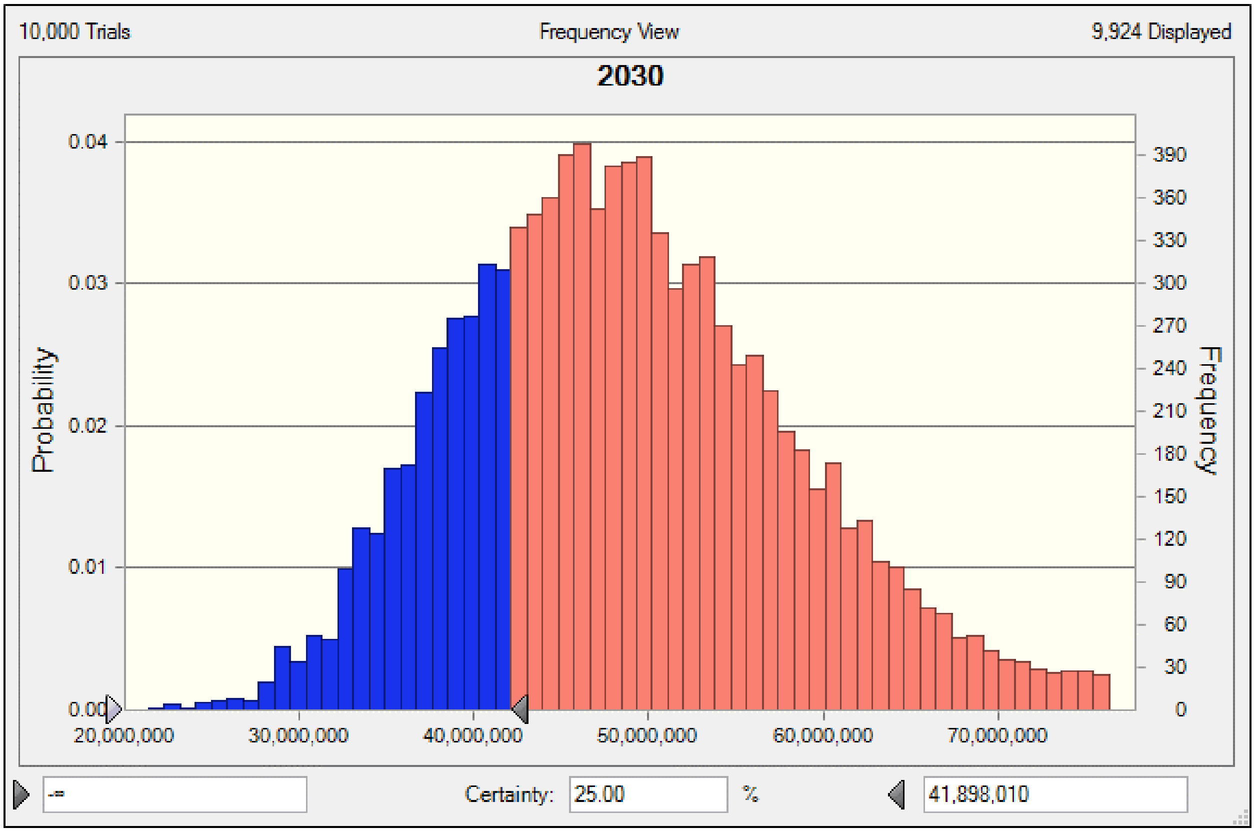
**Dispersion Parameters**

Mean 32,510,576

Median 32,266,801

Standard Deviation 4,934,680

**2030**




## Value At Risk (VAR)

There is a 25% probability that the number of subscribers in the year 2030 would be 41,898,010 or less.

## Dispersion Parameters

Mean 48,891,036

Median 48,023,479

Standard Deviation 9,834,344

**MOBILE BROADBAND**

Kolmogorov-Smirnov normality test score = 0.301

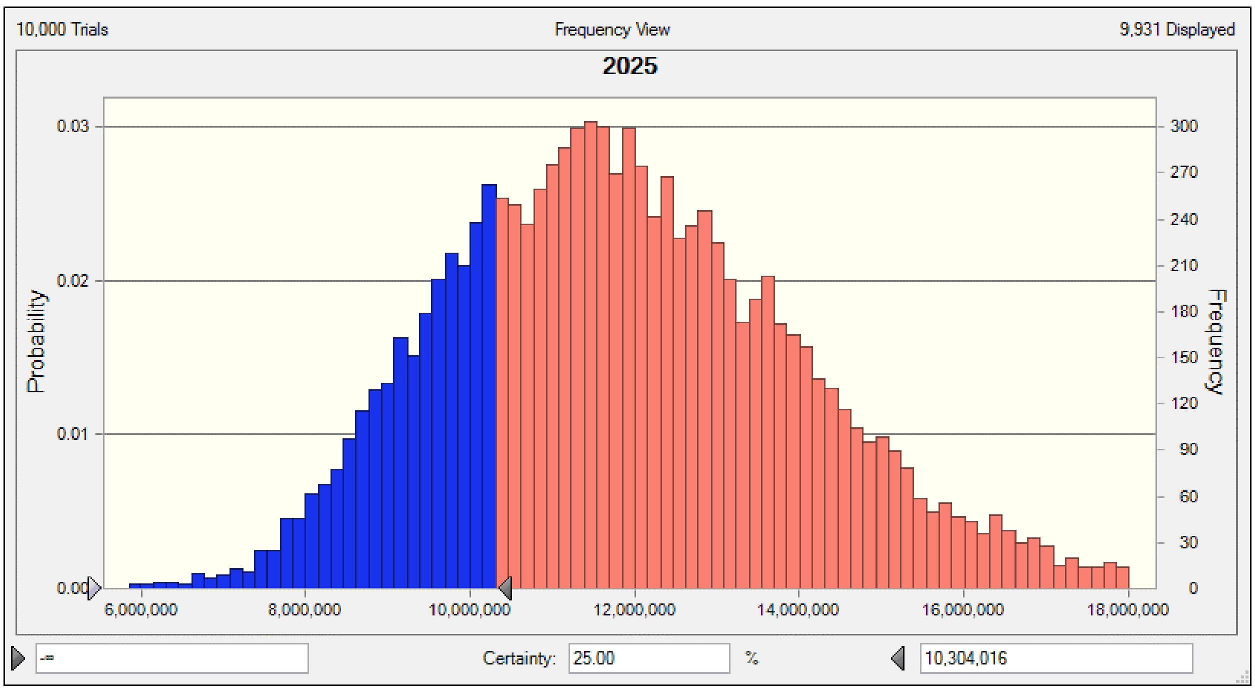
Kolmogorov-Smirnov normality test score on log changes in data= 0.1660

Drift = 0.128332

Volatility = 0.078354

The historical data considered here is in the period 2001-2018.

**2025**




### Value At Risk (VAR)

There is a 25% probability that the number of subscribers in the year 2025 would be 10,304,016 or less.

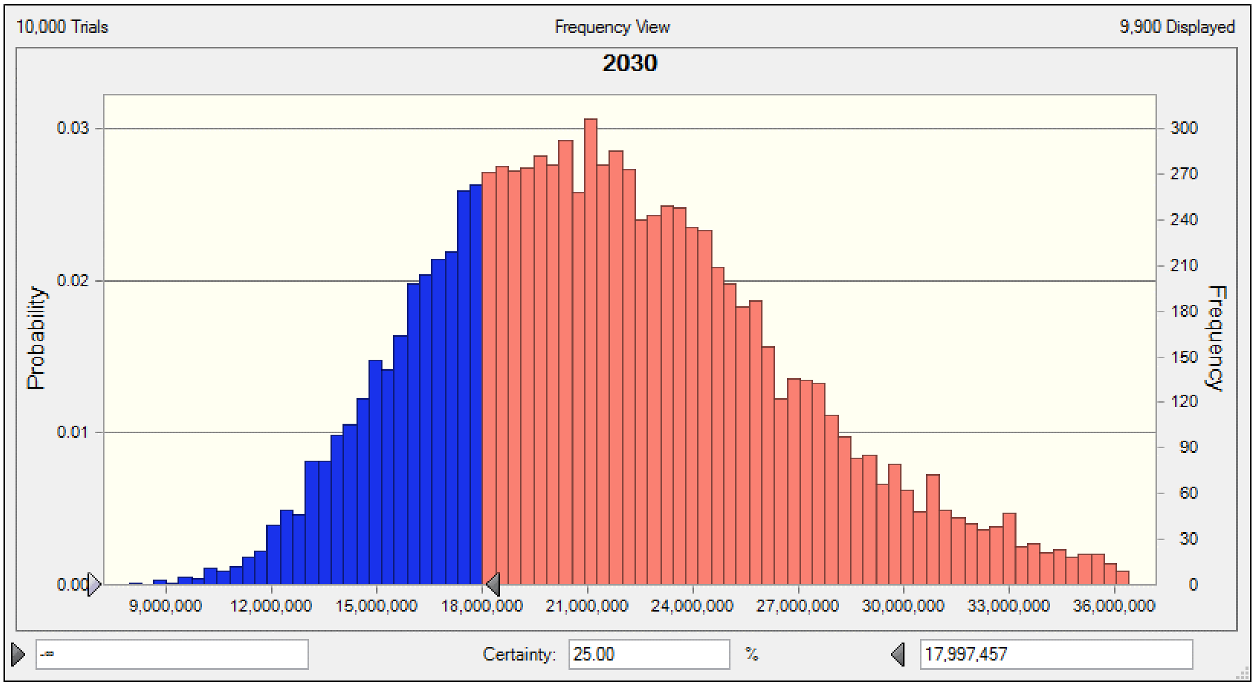
### Dispersion Parameters

Mean 11,884,391

Median 11,712,164

Standard Deviation 2,190,732

**2030**




## Value At Risk (VAR)

There is a 25% probability that the number of subscribers in the year 2030 would be 17,997,457 or less.

## Dispersion Parameters

Mean 21,759,251

Median 21,249,918

Standard Deviation 5,240,877

**COMPARISM BETWEEN GBM/MONTE CARLO AND S-CURVES**

With the S curves discussed earlier, one can only get a single value for particular prediction. For instances, for example in the year 2025, the gompertz model predicts a demand of 1,058,660 telephony subscribers (as shown below) meanwhile with GBM/Monte Carlo, a distribution is observed as follows;

Mean 1,224,932

Median 1,213,121

Standard Deviation 177,332

This means that one can predict with a certain degree of confidence in the forecast. The association of the latter process with statistical parameters is very useful for the decision-making process.

Also, the S curves do not take into account sudden changes in the demand thus prediction are lacking the uncertainty factor which is common in every market. Uncertainty is well represented in the GBM analysis via the uncertainty parameter. This in a sense generates a more realistic prediction of the future demand changes.

In addition, the S-curves do not allow for risk measurement techniques like the VAR. for instance with GBM/monte Carlo, one can make valid statements like "There is a 25% probability that in the year 2025, the number of fixed telephony subscribers would be 1,103,788 or less ". This gives a potential investor in this market an idea of the risk involved.

Despite the drawbacks of S-curves, they remain quite accurate when it comes to long term predictions. My opinion is the predictions on the datasets that span a longer duration are more accurate than those of shorter spans.

Predictions from S-Curves

| | **Fixed Broadband** | **Fixed Telephony** | **Mobile Voice** | **Mobile Internet** |
|---|---|---|---|---|
| **Fisher Pry** | **2025-**25,086<br>**2030-**25,087 | **2025-**1,033,312<br>**2030-**1,033,744 | **2025-** 20,738,149<br>**2030-** 20,799,325 | **2025-** 32.83%<br>**2030-** 33.15% |
| **Gompertz** | **2025-**25,445<br>**2030-**25,457 | **2025-**1,058,660<br>**2030-**1,061,373 | **2025-**23,209,945<br>**2030-**23,864,565 | **2025-**60.36%<br>**2030-**79.14% |
| **Linear Logistic** | **2025-**25,086<br>**2030-**25,087 | **2025-**1,033,312<br>**2030-**1,033,744 | **2025-**20,738,149<br>**2030-**20,799,324 | **2025-**32.83%<br>**2030-**33.15% |