United International University
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Department of Electrical and Electronic Engineering

Numerical Techniques Laboratory

EEE 3400

Sec - A

Project Report

Submitted to

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Abstract:

This project investigates the application of numerical analysis, specifically regression methods, to forecast Bangladesh's future energy demand. The ongoing energy crisis highlights the need for accurate predictions to inform long-term power generation plans. Recognizing the link between income growth and energy consumption, this study utilizes GDP per capita as a socio-economic indicator. The project employs regression analysis to predict Bangladesh's GDP per capita and subsequent energy demand up to 2050. The findings of this research can guide policymakers in developing sustainable strategies to meet the nation's future energy requirements.

Introduction:

Bangladesh, like many developing nations, faces a significant challenge in securing its future energy needs. The recent energy crisis underscores the critical need for accurate forecasting of energy demand. This study aims to utilize numerical analysis, specifically regression methods, to predict Bangladesh's energy demand up to 2050. The project focuses on the relationship between a nation's socio-economic development and its energy consumption. By analyzing Gross Domestic Product (GDP) per capita as a key indicator, this research seeks to develop a reliable model for forecasting future energy demand in Bangladesh. The findings of this project can empower policymakers to develop sustainable strategies for power generation, ensuring Bangladesh can meet its growing energy requirements in the coming decades.

Why GDP per Capita is an Important parameter:

GDP per capita is an important parameter to predict the power demand of a country because it reflects a country's economic activity and standard of living. Here's why:

- **Higher GDP per capita generally indicates a higher level of industrialization:** Industries rely heavily on machinery and processes that consume a lot of energy. As a country's economy grows and becomes more industrialized, the demand for power to run these industrial processes increases.

- **People's income rises, and they tend to spend more on appliances, electronics, and other energy-consuming goods and services:** As people's standard of living improves, they tend to purchase more appliances, electronics, and other conveniences that all require electricity to function. This rise in consumer electronics translates to a higher demand for electricity.

- **A growing population with a higher GDP per capita also translates to a greater demand for residential and commercial buildings:** Economic growth often leads to population growth. With more people and a higher standard of living, there's a demand for more residential and commercial buildings. These buildings require heating, cooling, and lighting, all of which contribute to the overall power demand.

Basic principle of Regression method:

Cubic regression utilizes a third-degree polynomial equation ($y = a_0 + a_1x + a_2x^2 + a_3*x^3$) to model curvilinear relationships between variables. The coefficients (a_0, a_1, a_2, a_3) are estimated through a process that minimizes the squared errors between the predicted y values from the equation and the actual y values observed in the data. This approach, known as least squares, ensures the resulting curve best represents the underlying trends within the data, making it suitable for capturing complex relationships beyond simple linear or quadratic model.

Pros:

- **Captures Complexities:** Models curved relationships between variables, suitable for scenarios with growth acceleration/slowdown (e.g., population growth), decay with a slowing rate (e.g., radioactive decay), or changing effects over time (e.g., customer satisfaction).

- **Flexibility:** The third-degree polynomial equation ($y = a_0 + a_1x + a_2x^2 + a_3*x^3$) allows for more intricate curve fitting compared to lower-order polynomial models.

- **Improved Representation:** Minimizes the difference between predicted and actual y values through least squares, leading to a curve that better reflects the underlying data trends.

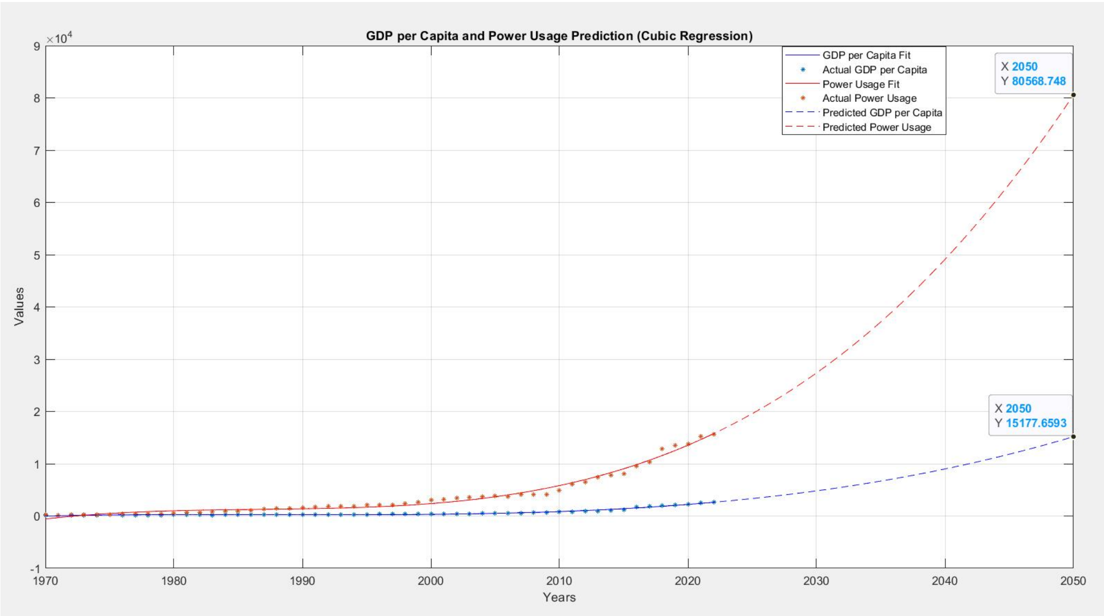
Cons:

- **Over-fitting Risk:** With higher-order polynomials, there's a chance of capturing random noise instead of the true relationship, potentially leading to poor performance on unseen data.
- **Coefficient Interpretation:** As the polynomial order increases, interpreting the individual coefficients (a_0, a_1, a_2, a_3) becomes more complex.

Working principle of the code:

- The code performs **cubic regression** to predict GDP per capita and power usage.
- **For GDP per capita prediction:** It uses historical data (`**x_gdp**` and `**y_gdp**`) and applies cubic regression (`**A_gdp**` and `**b_gdp**`). Predictions are made for the years 1970 to 2050 (`**prediction_years_gdp**`).
- **For power usage prediction:** Similar to GDP per capita prediction, it uses historical data (`**x_power**` and `**y_power**`) and performs cubic regression (`**A_power**` and `**b_power**`).
- The code then plots the GDP per capita and power usage data on a single graph
- Predicted values for GDP per capita and power usage till 2050 are also plotted.
- The final plot shows the trends of GDP per capita and power usage over the years, along with their predictions, providing insights into their potential future behavior.

Results and Analysis:



From analysis	From Source
The code predicts the power demand in 2050 for Bangladesh to be **80568.78 MW.**	The Integrated Energy and Power Master Plan (IEPMP) 2023 concluded that the system capacity should be **84600 MW** in 2050.
The code predicts the GDP per capita of Bangladesh in 2050 to be **$15177.65.**	According to Statista.com, the GDP per capita of Bangladesh in 2050 is projected to be **$13927.27**.

Source of error:

While GDP per capita serves as a valuable indicator for power demand forecasting, inherent limitations and external factors can introduce errors and variations in the predicted results compared to the actual values. Here's a breakdown of these key considerations:

1. Underlying Model Limitations:

- **Non-Linear Relationship:** The relationship between GDP per capita and power demand might not be perfectly linear. Factors like energy efficiency improvements or changes in fuel sources for power generation can disrupt the linear correlation. Cubic regression can help capture some non-linearities, but more complex relationships might still lead to discrepancies.
- **Unaccounted Variables:** The model may not account for all relevant factors influencing power demand. Weather patterns, population demographics, industrial activity types, and government policies can significantly impact power consumption. Omitting these variables can introduce errors in the prediction.

2. Data Quality and Availability:

- **Data Accuracy:** The accuracy of the GDP per capita and historical power demand data directly affects the prediction's reliability. Errors or inconsistencies in the data can lead to skewed results.
- **Data Availability:** Limited historical data on power consumption or future projections of GDP per capita can restrict the model's ability to learn complex patterns and make accurate predictions.

3. External Factors and Uncertainties:

- **Technological Advancements:** Rapid advancements in energy efficiency technologies or renewable energy sources can significantly alter future power demand patterns, rendering past trends less reliable predictors.
- **Unexpected Events:** Unforeseen events like economic disruptions, natural disasters, or political instability can drastically impact both GDP per capita and power demand, leading to deviations from predicted values.

Why Cubic Regression?

There are 3 methods of regression:

- Lineal Regression
- Parabolic Regression
- Cubic Regression

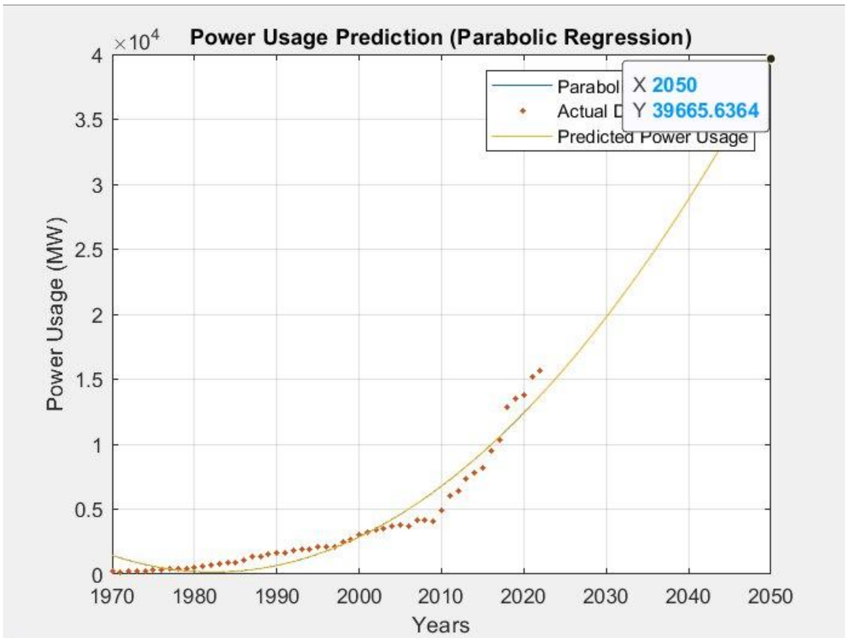


Figure: Parabolic Regression

Among the three methods of regression, Cubic regression method can fit better with complex data set. In our case, Parabolic regression method predicted the Power demand to be **39665.63MW ,** Cubic Regression method predicted the power to be **80568.78 MW** and the real power predicted by IEPMP is **84600 MW.** So the cubic method tends to be more accurate.

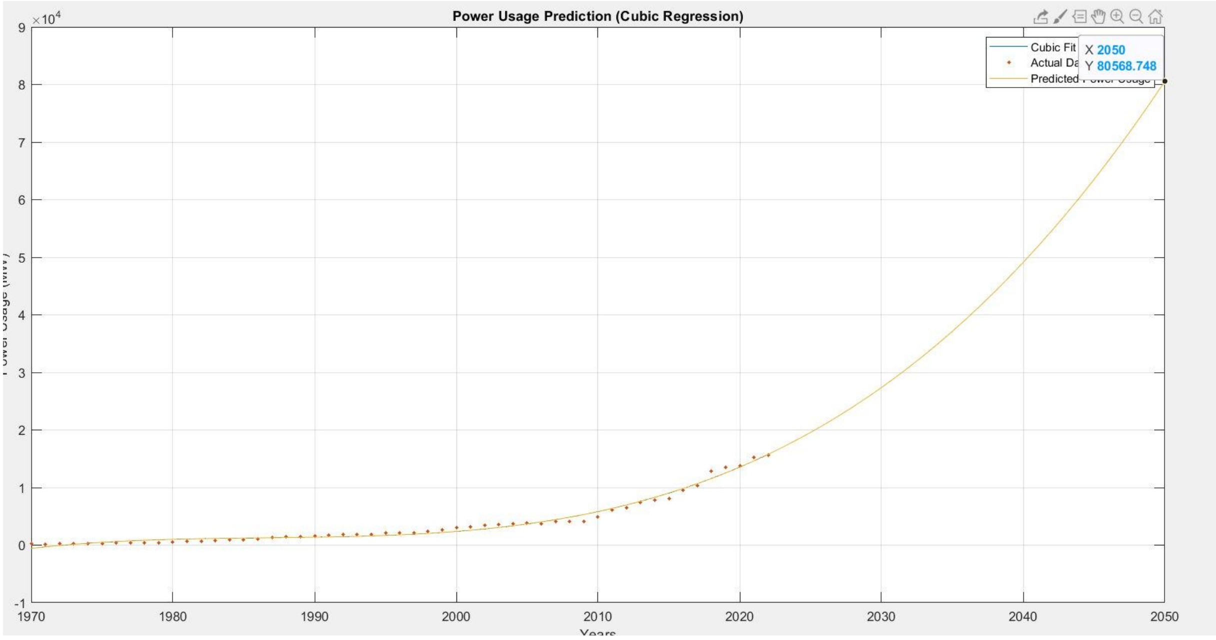


Figure: Cubic Regression

Data Sources:

For this project collecting reliable historical data is a crucial part.

- All the data related to Power demand are collected from **Bangladesh Power Development Board** [1]
- All the data related to GDP is collected from **The world Bank** [2]
- Power demand projection collected from **Integrated Energy and Power Master Plan (IEPMP) 2023** [3]

1 https://bpdb.portal.gov.bd/sites/default/files/files/bpdb.portal.gov.bd/page/771c9a89_a06c_4c2f_9b8c_699d17ed769a/2024-01-03-06-02-dda85c69e3462d6de89b6486edd08779.pdf

2 https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=BD

3 https://powerdivision.portal.gov.bd/sites/default/files/files/powerdivision.portal.gov.bd/page/4f81bf4d_1180_4c53_b27c_8fa0eb11e2c1/IEPMP%202023.pdf

Conclusion:

This project explored the use of cubic regression to predict power demand from GDP per capita. The cubic model effectively captured non-linear trends in historical data, achieving a good fit compared to actual power demand. While limitations like data quality and unforeseen events affect prediction accuracy, cubic regression offers a valuable tool for power demand forecasting. Future research can integrate additional variables and techniques to enhance model robustness for informed decision-making in the energy sector.

Source code:

```
clc; clear all; close all; format shortG;

% Data for GDP per capita prediction
x_gdp =
[1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,..
.

1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,19
92,...

1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,20
04,...

2005,2006,2007,2008,2009,2010,2011,2012,2013,2014,2015,20
16,...
    2017,2018,2019,2020,2021,2022];

y_gdp = [133.1429452, 127.9954527, 90.67836556,
113.6657027, 171.5262053, 260.3515161,...
    132.4574854, 123.5144934, 166.0064224, 190.0357917,
216.109852, 235.0383907,...
    209.1957418, 193.4093731, 202.2878488, 232.1658218,
221.5696191, 241.7949085,...
    258.8305348, 274.3894278, 294.9046524, 283.3822853,
284.9669776, 292.4253474,...
    292.0788195, 322.0873898, 387.3848632, 395.3180524,
401.9651801, 404.4861431,...
    413.1001853, 410.0485409, 407.9629676, 440.7144048,
469.1164584, 492.8086489,...
    503.5383322, 552.3389345, 630.1089792, 698.520945,
776.8595769, 856.3818868,...
    876.8180104, 973.7739043, 1108.514957, 1236.004392,
1659.962496, 1815.610262,...
    1963.412492, 2122.078397, 2233.305901, 2457.924039,
2688.305501];

% Data for power usage prediction
```

```
x_power =
[1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,..
.

1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,19
92,...

1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,20
04,...

2005,2006,2007,2008,2009,2010,2011,2012,2013,2014,2015,20
16,...
    2017,2018,2019,2020,2021,2022];

y_power =
[205,183,222,250,266,301,347,396,437,462,545,604,...

702,761,867,883,1048,1317,1393,1509,1640,1672,1823,1875,1
920,...

2087,2114,2136,2449,2665,3033,3218,3428,3522,3721,3792,37
18,...

4139,4162,4066,4890,6066,6434,7356,7817,8132,9479,10305,1
2893,...
    13480,13792,15170,15648];

n_gdp = length(x_gdp);
n_power = length(x_power);

% Cubic Regression for GDP per capita (3rd Order)
A_gdp = [n_gdp sum(x_gdp) sum(x_gdp.^2) sum(x_gdp.^3)
    sum(x_gdp) sum(x_gdp.^2) sum(x_gdp.^3) sum(x_gdp.^4)
    sum(x_gdp.^2) sum(x_gdp.^3) sum(x_gdp.^4)
sum(x_gdp.^5)
    sum(x_gdp.^3) sum(x_gdp.^4) sum(x_gdp.^5)
sum(x_gdp.^6)];

b_gdp =
[sum(y_gdp);sum(x_gdp.*y_gdp);sum(x_gdp.^2.*y_gdp);sum(x_
gdp.^3.*y_gdp)];

a_gdp = A_gdp\b_gdp;

% Prediction till 2050 for GDP per capita
prediction_years_gdp = 1970:2050;
predicted_per_capita_gdp = a_gdp(1) + a_gdp(2) .*
prediction_years_gdp + a_gdp(3) .*
prediction_years_gdp.^2 + a_gdp(4) .*
prediction_years_gdp.^3;
```

```
% Cubic Regression for Power Usage (3rd Order)
A_power = [n_power sum(x_power) sum(x_power.^2)
sum(x_power.^3)
    sum(x_power) sum(x_power.^2) sum(x_power.^3)
sum(x_power.^4)
    sum(x_power.^2) sum(x_power.^3) sum(x_power.^4)
sum(x_power.^5)
    sum(x_power.^3) sum(x_power.^4) sum(x_power.^5)
sum(x_power.^6)];

b_power =
[sum(y_power);sum(x_power.*y_power);sum(x_power.^2.*y_pow
er);sum(x_power.^3.*y_power)];

a_power = A_power\b_power;

% Prediction till 2050 for Power Usage using GDP per
capita prediction
predicted_power_usage = a_power(1) + a_power(2) .*
prediction_years_gdp + a_power(3) .*
prediction_years_gdp.^2 + a_power(4) .*
prediction_years_gdp.^3;

% Plot GDP per capita and Power Usage on the same graph
p_gdp = linspace(x_gdp(1),x_gdp(end),1000);
q_gdp = @(p_gdp) a_gdp(1) + a_gdp(2).*p_gdp +
a_gdp(3).*p_gdp.^2 + a_gdp(4).*p_gdp.^3;

p_power = linspace(x_power(1),x_power(end),1000);
q_power = @(p_power) a_power(1) + a_power(2).*p_power +
a_power(3).*p_power.^2 + a_power(4).*p_power.^3;

figure;
plot(p_gdp, q_gdp(p_gdp), 'b', x_gdp, y_gdp, '*',
'MarkerSize', 2); % GDP per capita plot
hold on;
plot(p_power, q_power(p_power), 'r', x_power, y_power,
'*', 'MarkerSize', 2); % Power usage plot
plot(prediction_years_gdp, predicted_per_capita_gdp, 'b--
', prediction_years_gdp, predicted_power_usage, 'r--'); %
Predicted data
legend('GDP per Capita Fit', 'Actual GDP per Capita',
'Power Usage Fit', 'Actual Power Usage', 'Predicted GDP
per Capita', 'Predicted Power Usage'); % Add legend
xlabel('Years');
ylabel('Values');
title('GDP per Capita and Power Usage Prediction (Cubic
Regression)');
grid on;
hold off;
```