A Comparative Study of Bali Electricity Demand Forecast

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Abstract - Bali is among other provinces in Indonesia that experiences rapid development, particularly in the tourism sector, the creative industries, and the overall economy. This growth has driven an increasing demand for electricity across various sectors, including residential, industrial, and commercial sectors, as well as public services. To address this issue, electricity demand forecasting in Bali was carried out using an econometric approach for a period of 2025–2033. The projection result then is compared with that stated in the Electricity Supply Business Plan (RUPTL). The findings indicated that, using the proposed method, for an annual economic growth rate of 5.86%, the average annual growth rate of electricity demand is about 7.1%. In comparison, the RUPTL scenario stated that with an average annual economic growth rate of 7.0%, the average annual growth rate of electricity demand is about 7.0%. These results highlight the importance of the applied method in forecasting electricity demand, which are most affected by the economic growth within the region.

***Index Terms*—Econometric, Electricity Demand, Forecasting, RUPTL.**

I. Introduction

Electricity is one of the vital infrastructures that affects the livelihoods of the public, and therefore its provision must ensure adequate availability [1]. As the economy of a region grows, electricity consumption will also continue to increase [2]. This condition needs to be anticipated at an early stage to ensure that electricity supply remains sufficient and affordable. Consequently, long-term electricity demand forecasting is essential to provide an overview of the current and future electricity conditions [3].

Bali is among other provinces in Indonesia that experiences rapid development, particularly in the tourism sector, the creative industries, and the overall economy [4]. This development impacts the growing demand for electricity across various sectors, such as residential, industrial, commercial, and public services. The continuous increase in electricity demand must be anticipated with proper planning, which makes the electricity demand forecast plays an important role in determining the development strategy for the coming years.

This study focused on the electricity demand projection in Bali Province, using an econometric approach based on the historical data of economic growth and elasticity [5]. This approach was chosen because it has been proven that there is a correlation between economic variables and electricity consumption. The projection covers four key indicators: electricity sales, electricity production, the number of customers, and peak load.

The analysis result then was compared with that stated in the Electricity Supply Business Plan (RUPTL). This comparison is aimed to determine the extent to which the results of proposed approach differ from that of PLN plan. Results of this study thus may be used as a complementary input for policymakers in designing an efficient, effective, and sustainable electricity supply in the future.

II. Literature Review

A. PLN Electricity Demand Forecast

In fulfilling electricity demand, the initial stage involves conducting a demand forecast, which forms an integral part of the RUPTL. Accurate estimation of electricity consumption across PLN regional units is essential for effective RUPTL formulation. The process comprises the followings [6]: (a) a top-down approach to define overarching policies and baseline assumptions; (b) a bottom-up approach covering demand forecasting, generation planning, transmission and substation development, distribution planning, and strategies for isolated areas; (c) preparation aligned with the authority of each PLN Business Unit; (d) inter-unit coordination at least twice annually; (e) consolidation by PLN Headquarters; (f) approval from PLN Headquarters; and (g) ratification by the Minister of Energy and Mineral Resources, after which the RUPTL serves as the basis for the Company's Work and Budget Plan (RKAP).

B. Factors Affecting Electricity Demand

According to [2], electricity consumption is projected to increase annually in line with the growing needs of society. This trend is also evident in Bali, driven by the region's economic growth, rising population, and unique geographic and social characteristics. These factors collectively influence Bali's electricity demand, which must be carefully considered in electricity supply planning to align with local conditions and potentials. In more details, the electricity demand in Bali is mainly affected by the following factors:

1) Economic Growth

The growth of Gross Regional Domestic Product (GRDP) is a key factor influencing electricity demand in Bali. Generally, GRDP is divided into three sectors: commercial (business), industrial, and public sectors. In Bali, the commercial sector includes electricity, gas, clean water, construction, trade, as well as transportation and communication, all of which significantly contribute to electricity demand, especially in urban and tourism areas. The public sector comprises services and banking, including non-bank financial institutions, which have grown rapidly in Bali as a center for the creative economy and tourism. Meanwhile, the industrial sector, covering oil and gas and manufacturing activities, although relatively limited, also contributes to electricity demand in specific areas such as Bali's industrial zones.

2) Population Growth

Population growth plays an important role in determining electricity demand in Bali. Although the general growth rate tends to decline and stabilize over time, Bali continues to experience population increases due to urbanization and migration driven by tourism and the creative economy sectors. This leads to increased electricity demand in residential areas and economic centers.

3) Regional Development Planning

Regional development in Bali is strongly influenced by the local economic condition, which directly affects the electricity demand. The provincial and municipal governments in Bali actively formulate policies regarding spatial planning, industrial development, residential areas, and strategic geographical aspects to support tourism and the creative economy sectors. These policies are articulated in regional regulations aimed at sustainable land use and regional development, resulting in a dynamic pattern of electricity demand aligned with ongoing development.

4) Other Factors

Besides the above three main factors, several other factors may also affect the electricity demand in Bali, including the size of consumer buildings, employment levels, family size, and other demographic and social variables. While the influence of these factors is more specific and limited to certain tariff sectors, they still play a role in micro-level electricity demand analysis.

C. Forecasting Method

Various electricity demand forecasting methods include the analytical (end-use) method, econometric method, trend method, and combined method have been widely used [5]. The econometric method is preferred due to its approach based on statistical data and the economic conditions of a region, highlighting the significant role of electricity in driving economic activities. This method requires valid data to represent the relationship between electricity consumption and economic factors, enabling the development of forecasting formulas that reflect actual regional conditions. Therefore, the econometric method is well-suited to produce accurate and relevant electricity demand predictions aligned with local economic dynamics.

D. Key Assumptions

The econometric method can be enhanced by incorporating basic assumptions to ensure that the forecasting results align more closely with actual conditions, based on data indicating that electricity drives economic activities in a region. These assumptions are used to clarify and adjust the forecasting scenarios [5].

1) Energy Elasticity

Energy elasticity measures the relationship between the growth rate of electricity consumption and the economic growth of a region. A lower energy elasticity value indicates better efficiency or more optimal energy use within that area [5], as shown in Equation (1).

$$\text{Energy elasticity} = \frac{\text{Growth in electrical energy consumption}}{\text{Economic growth (GRDP)}} \quad (1)$$

2) Customer Factor

The customer factor represents the correlation between the total number of customers and the economic growth within a specific region. Typically, an increase in economic growth is associated with a corresponding rise in the customer base [5], as formulated in Equation (2).

$$\text{Customer factors} = \frac{\text{Growth in the number of customers}}{\text{Economic growth (GRDP)}} \quad (2)$$

3) Load Factor

Load factor is the ratio between the average load and the peak load, which can be calculated over daily, monthly, or annual intervals. It plays a crucial role in assessing future load characteristics and evaluating the impact of the load on the total system capacity [9]. The load factor is determined using the following formula [10]:

$$Load\ Factor = \frac{\sum kWh\ total\ production\ annually}{\sum kWh\ peak\ load\ x\ 8.760\ hours}\ x\ 100\% \quad (3)$$

The total energy production (in kWh) is the energy produced by all PLN owned plants together with the energy received from interconnection system, and the energy purchased from IPP (if any). Peak Load is the highest load of the system in the period.

E. Econometric Method

The electrical data utilized in this study consist of electricity consumption over the past ten years from the perspective of PLN consumers. The proposed model categorizes customers into four different sectors, which are a) Residential; b) Commercial; c) Industrial; and d) Public. In determining the future electrical energy needs, the following approach are used in the calculation:

1) Number of Customers

Equation (4) is employed to estimate the number of electricity customers in the current year based on the number of customers in the previous year, the customer factor, and economic growth. In other words, the number of electricity customers is projected to increase in line with economic growth and specific customer-related factors [7].

$$Nc = Nc_{-1}(1 + CF\ x\ \frac{gE}{100}) \tag{4}$$

Where:

Nc = Number of Customers
Nc-1 = Number of Customers in the Previous Year
CF = Customer Factor
gE = Total Economic Growth (GRDP)

2) Electricity Sales

The projection of electricity sales in a particular year is calculated based on electricity consumption in the previous year, the rate of economic growth, and the energy elasticity. The demand estimation for the upcoming year thus considering economic changes and the responsiveness of energy consumption to the related growth [7]. The estimated energy sales can be formulated as Equation (5).

$$Pp = E_{t-1}(1 + (g.eE) \tag{5}$$

Where:

Pp = Projected value of electricity sales
E_{t-1} = Electricity consumption in the previous year
g = Economic growth rate based on GRDP
eE = Energy elasticity

3) Electricity Generation

The power plants function as generating electricity to meet overall demand, including the power losses [8]. These losses introduce a degree of uncertainty into the system, thereby complicating the estimation of long-term electricity generation and increasing the complexity of power system design. Furthermore, the network must possess adequate capacity to transmit electricity, including the associated losses, from generators to loads through transmission lines and transformers. Equation (6) expresses the formula for the required generated energy which is covering the electricity consumption as well as energy losses.

$$P_t = P_e(1 + losses) \tag{6}$$

Where:

P_t = Electricity Energy Production
P_e = Electricity Energy Consumption Sales
losses = Transmission and Distribution Losses

III. RESEARCH METHOD

The electricity demand modeling for the 2025–2033 period in this study employs an econometric approach based on energy elasticity, calculated from the period prior to the COVID-19 pandemic to represent the correlation between GRDP growth and electricity consumption. The economic growth rate is derived from the ten-year historical data, excluding anomalous years affected by the pandemic, to avoid distortion in the projection results. The variables include electricity sales, number of customers, annual GRDP, and energy elasticity. The projection results are then compared with the official RUPTL estimation, to identify potential discrepancies and their implications for medium-term energy supply planning in Bali Island.

A. Analysis Data

In this study, the annual GRDP data was categorized based on constant prices by business field. This categorization was carried out to ensure consistency in the format and units of the GRDP data. It also ensures that GRDP data at constant prices by business field can be directly compared with electricity sales data. Refer to Table I, the Bali annual GRDP is divided into 17 categories [4]. These categories are then consolidated into four main sectors: residential, industrial, commercial, and public.

TABLE I
CLASSIFICATION OF ANNUAL GRDP DATA

Sector	Business Field
Residential	Agriculture, Forestry, and Fishing
Industrial	Mining and Quarrying
	Processing Industry
	Electricity and gas procurement
	Water Procurement, Waste Treatment, Waste and Recycling
	Construction
Commercial	Wholesale and Retail Trade, Car and Motorcycle Repair
	Transportation and Warehousing
	Food and Drink Accommodation Providers
	Information and Communication
	Financial Services and Insurance
	Real Estate
	Corporate Services
Public	Government, Defense and Compulsory Social Security Administration
	Educational Services
	Health Services and Social Activities
	Other Services

Table II presents Bali GRDP at 2010 constant market prices for the period of 2014–2024, expressed in billion Rupiah. The GRDP has been classified into four main sectors which are Commercial, Residential, Public and Industrial. The Commercial sector covers market-based service activities, and the Residential sector refers to the residential consumption. Similarly, the public sector represents government and community services, while the Industrial sector includes manufacturing, construction, and other production-based activities. This classification maintains consistency between economic indicators and electricity consumption data, making it easier to identify the correlation between the two data of the similar sectors.

TABLE II
BALI GRDP BASED ON 2010 CONSTANT MARKET PRICES
(MILLION RUPIAHS)

Year	Sector			
	Commercial	Household	Public	Industrial
2014	63,720.36	18,151.21	18,136.37	21,779.61
2015	67,983.74	18,637.35	19,677.08	22,828.40
2016	72,756.03	19,295.70	21,145.42	24,099.28
2017	77,952.17	19,821.71	21,970.04	25,189.37
2018	82,876.40	20,760.22	23,394.05	27,041.99
2019	87,836.97	21,479.55	24,611.44	28,765.41
2020	74,257.85	21,269.19	24,438.25	27,533.64
2021	70,295.71	21,338.45	24,736.95	27,500.56
2022	76,253.74	21,157.30	24,682.61	28,737.14
2023	84,326.60	21,039.32	24,892.64	29,189.11
2024	90,609.51	21,579.83	25,903.97	30,092.73

Table III presents information on the historical data of electricity sales in Bali obtained from the RUPTL. The table shows electricity sales trends in four main sectors, namely Commercial, Residential, Public and Industrial, over the period of 2014–2024. This information is essential for analyzing sectoral consumption patterns and for projecting future electricity demand under different economic growth scenario.

Table IV shows the calculated energy elasticity for each sector. These values indicate the responsiveness of electricity consumption in each sector to changes in economic growth over the period of 2014–2024. Positive elasticity values indicate that electricity consumption increases in line with economic growth, while negative values show a decline in consumption despite economic growth. The negative values observed in several years, particularly from 2020 to 2023, were influenced by the impact of the COVID-19 pandemic, which led to reduced economic activity and electricity consumption across various sectors.

The number of electricity customers in Bali for year 2014 to 2024 can be seen in Table V. The tabel shows a general upward trend in all sectors over the period, with the residential sector consistently having the largest number of customers, followed by commercial, and public sectors. The industrial sector has the lowest number of customers, given that there are not many industries available in Bali Island.

TABLE III
BALI ELECTRICITY SALES (GWH)

Year	Sector			
	Commercial	Household	Public	Industrial
2014	2,058.89	1,846.71	268.98	160.44
2015	2,226.49	1,918.34	281.68	167.67
2016	2,509.86	2,105.02	305.24	178.98
2017	2,526.76	2,058.93	310.10	173.85
2018	2,628.91	2,153.91	332.32	187.52
2019	2,800.13	2,344.57	359.15	202.88
2020	1,971.79	2,434.37	351.45	189.25
2021	1,833.47	2,343.14	347.93	183.47
2022	2,431.11	2,473.52	371.21	194.67
2023	3,033.84	2,738.18	374.89	207.62
2024	3,498.00	3,157.00	432.00	239.00

TABLE IV
ENERGY ELASTICITY

Year	Sector			
	Commercial	Household	Public	Industrial
2014	1.50	2.40	0.92	1.94
2015	1.22	1.45	0.56	0.94
2016	1.81	2.75	1.12	1.21
2017	0.09	-0.80	0.41	-0.63
2018	0.64	0.97	1.11	1.07
2019	1.09	2.55	1.55	1.29
2020	1.91	-3.91	3.05	1.57
2021	1.31	-11.51	-0.82	25.42
2022	3.85	-6.55	-30.46	1.36
2023	2.34	-19.19	1.17	4.23
2024	2.05	5.95	3.75	4.88

TABLE V
NUMBER OF ELECTRICITY CUSTOMERS BY TYPE

Year	Sector			
	Commercial	Household	Public	Industrial
2014	133,126	920,211	35,144	755
2015	168,224	975,075	37,567	802
2016	193,189	1,019,857	40,602	967
2017	202,578	1,081,694	43,400	1,112
2018	200,869	1,144,879	46,214	1,177
2019	204,569	1,212,223	48.727	1,231
2020	213,958	1,263,423	50,223	1,250
2021	222,903	1,303,275	51,824	1,281
2022	232,586	1,343,247	53,392	1,303
2023	246,440	1,398,359	55,368	1,345
2024	225,486	1,468,786	57,898	1,456

B. Projected Modeling

The electricity consumption growth in this study is 5.86%, and was calculated from the average historical economic growth from year 2014 to 2024, excluding the COVID-19 period. This rate is used to calculate sectoral energy elasticity by comparing energy consumption growth with the sectoral GRDP growth. The elasticity calculation uses the historical average prior to the COVID-19 pandemic, yielding an energy elasticity value of 1.2. This value together with the projected GRDP then are used to project the energy consumption growth for the coming years.

IV. RESULTS AND DISCUSSION

A. Number of Customers

The number of customers forecast was estimated using Equation (4), and resulting in a Customer Factor (CF) of 1.8, with the year 2020 (COVID-19 pandemic) excluded from the dataset. This exclusion yields a relatively constant annual customer growth rate of 1.1%, which is lower than the 1.4% as specified in the RUPTL. The discrepancy is most likely due to the differences in the economic growth assumptions used in the analysis. For the forecasting purpose, this study adopts the ten-year historical average of GRDP growth (excluding the anomalous pandemic year). In the other side, RUPTL utilized much longer and more complex historical data, including customer segments model, demand from large-scale projects, electrification initiatives which further contribute to the variation in the forecasting results. Figure 1 shows the projected number of customer forecast from the two different approaches.

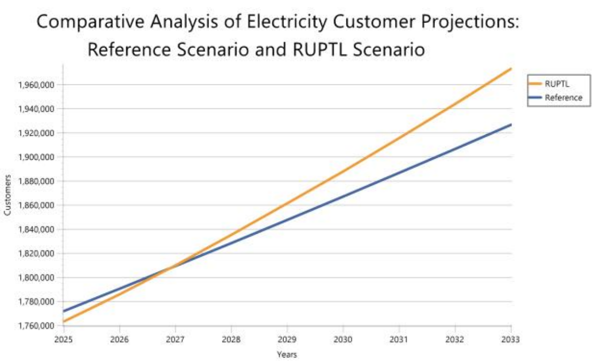

Fig. 1. Comparison of the Electricity Customer Numbers forecast between the proposed scenario and the RUPTL

B. Energy Sales

The forecasting result for electricity sales in Bali and its comparison with the RUPTL is depicted in Figure 2. The proposed scenario used an energy elasticity value of 1.2. The analysis result shows an average electricity sales growth rate of 7.1%, corresponding to an average economic growth rate of 5.86%. The RUPTL in the other hand stated an average electricity sales growth of 7.0%, with an average economic growth of 7.0%.

Although the proposed scenario exhibits a higher average growth rate of electricity sales, the annual forecast of the RUPTL scenario surpass those of the proposed scenario due to a significant surge from 2024 to 2025. This difference can be attributed to additional assumptions embedded in the RUPTL, such as substantial demand arising from new strategic projects (e.g. the development of tourism areas, industrial zones, and electrification programs), which cause a sharp increase in energy sales at the beginning of the simulation period.

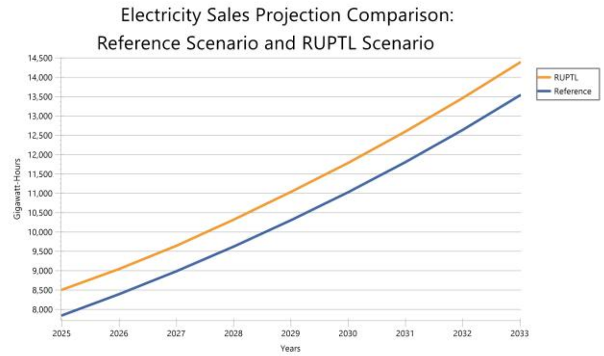

Fig. 2. Comparison of Electricity Sales Projections between the Reference Scenario and the RUPTL Scenario

C. Energy Production

Electrical energy production refers to the total amount of electricity generated from various available sources to meet the required electricity consumption [11]. In the proposed model, the transmission and distribution losses are assumed to be 5.60% in 2024 and then gradually decreases to 5.34% 2033. The transmission and distribution losses in the RUPTL scenario, however, are set to be 5.48% in 2025 and gradually decline to 4.81% in 2033 as presented in Figure 3.

Based on that assumption, the energy production forecast can be determined using Equation (6). The forecasting results indicate that under the proposed scenario, electrical energy production is expected to increase by 8,280 GWh, reaching 14,259 GWh in 2033, with an average growth rate of 7.0%. As a comparison, in the RUPTL model, the electrical energy production is projected to rise by 8,975 GWh to 15,079 GWh, with an average growth rate of 6.9%. The comparison of the two projections is presented in Figure 4.

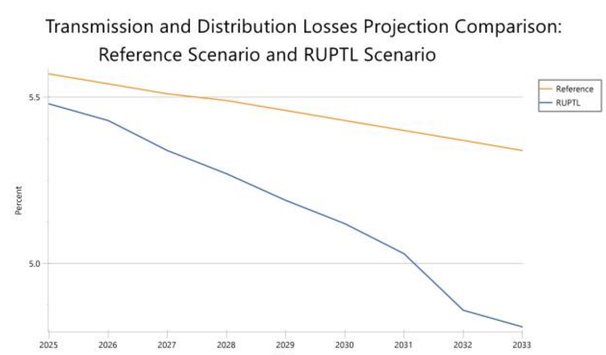

Fig. 3. Comparison of Transmission and Distribution Losses in the Reference Scenario and the RUPTL Scenario

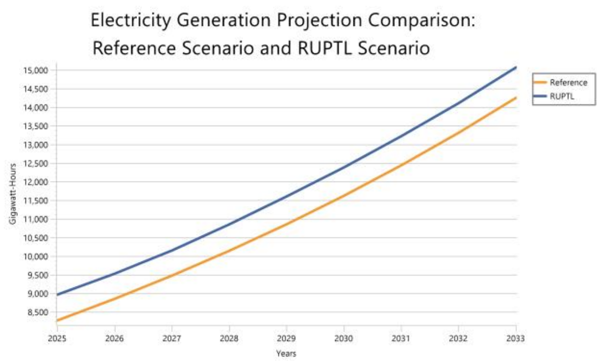

Fig. 4. Comparison of Electricity Generation Projections between the Reference Scenario and the RUPTL Scenario

D. Peak Demand

Figure 5 shows the peak load forecast based on the projected electrical energy demand in Bali. In 2025, the forecasted electricity peak load is about 1,240 MW. In 2033, the electricity peak load is projected to reach about 2,064 MW. As comparison, in RUPTL, the electricity peak load is projected to be 1,296 MW in 2025, and in 2045 it is expected to reach 2,122 MW.

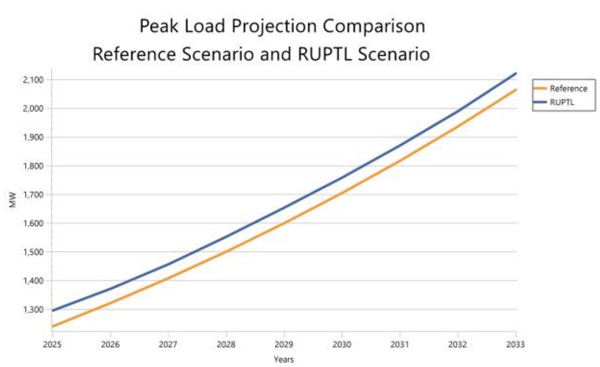

Fig. 5. Comparison of Peak Load Projections between the Reference Scenario and the RUPTL Scenario

TABLE VI
ELECTRICITY DEMAND FORECAST OF THE PROPOSED MODEL

Year	Economic Growth (%)	Sales (GWh)	Generation (GWh)	Peak Load (MW)	Number of Customers
2025	5.86	7,843	8,280	1,241	1,772,068
2026	5.86	8,397	8,862	1,322	1,790,703
2027	5.86	8,990	9,485	1,409	1,809,535
2028	5.86	9,624	10,152	1,501	1,828,564
2029	5.86	10,304	10,866	1,600	1,847,794
2030	5.86	11,031	11,630	1,705	1,867,226
2031	5.86	11,810	12,448	1,818	1,886,862
2032	5.86	12,644	13,323	1,937	1,906,705
2033	5.86	13,536	14,259	2,065	1,926,756
Growth (%)	**5.86**	**7.1**	**7.0**	**6.6**	**1.1**

E. Comparison Summary

The difference in forecasting results between the proposed method and the RUPTL is summarised in Table 6 and 7. In the proposed forecast, an econometric approach considering the correlation between the economic growth and the energy elasticity is used. In this approach, the forecasting results tend to be more moderate than those in the RUPTL.

TABLE VII
ELECTRICITY DEMAND FORECAST OF THE RUPTL

Year	Economic Growth (%)	Sales (GWh)	Generation (GWh)	Peak Load (MW)	Number of Customers
2025	7.7	8,509	8,975	1,296	1,763,379
2026	6.3	9,046	9,537	1,372	1,786,084
2027	6.6	9,646	10,161	1,457	1,810,085
2028	7.0	10,320	10,864	1,553	1,835,502
2029	7.0	11,040	11,613	1,654	1,861,639
2030	6.8	11,788	12,391	1,759	1,888,139
2031	6.9	12,599	13,233	1,871	1,915,673
2032	6.9	13,464	14,118	1,990	1,944,054
2033	6.9	14,387	15,079	2,122	1,973,325
Growth (%)	**7.0**	**7.0**	**6.9**	**6.5**	**1.4**

V. CONCLUSIONS

The proposed approach has successfully determined the energy demand and peak load forecasts for Bali Island. The findings indicated that, using the proposed method, for an annual economic growth rate of 5.86%, the average annual growth rate of electricity demand is about 7.1%. In comparison, the RUPTL scenario stated that with an average annual economic growth rate of 7.0%, the average annual growth rate of electricity demand is about 7.0%. These results highlight the importance of the applied method in forecasting electricity demand, which are most affected by the economic growth within the region.

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