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Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping

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ABSTRACT

Electricity is one of the basic needs and it plays an important role in the community in the social and economic development. It is an essential part of our daily lives as well as electrical energy promotes economic well-being and make social life worthwhile. Most electric cooperative encounters difficulty in monitoring the power consumption in their vicinity due to limited number of field personnel. The researcher observed that there is a need for a study on the prediction of electric consumption for Nueva Vizcaya Electric Cooperative (NUVELCO) to establish the trend of future consumption. This study also serve basis in managerial decision making (DSS) such as; advisory to the staff for power line clearing, household inspection, and additional transformer, additional purchased of energy.

This paper uses two methods, descriptive research and developmental research to analyzed present data. A Correlation Analysis and Linear Regression Analysis is used between temperature and power consumption, precipitation and electric consumption. This statistical tool is used for prediction for analyzing time series data.

The researcher derived power consumption differential equation or models which can be used to determine the growth of the electrical energy consumption. Discriminant Analysis is used in Clustering and classification of a set of observations into subsets in mapping the municipalities of the possible rise and fall of power consumption.

Key words: Clustering and Mapping, Decision Support System, Electricity Consumption Forecasting.

1.INTRODUCTION

The term “electricity” as defined by Webster Comprehensive Dictionary Encyclopedic Edition refers to “fundamental property of matter, associated with atomic particles whose movements, free or controlled, lead to the development of fields of force and the generation of kinetic or potential energy” [1].

Energy can be generated through various technologies: a) fossil fuels like the use of coal, natural gas, and oil; b) renewable energy; c) hydroelectric including wind, geothermal, and solar power; d) nuclear power; and e) other sources like biofuels, and biomass.

Electricity is one of the basic needs and it plays an important role in the community in the social and economic development. It is an essential part of our daily lives and as well as electrical energy promotes economic well-being and make social life worthwhile. Despite the importance of electricity in our daily lives, people tend to take it for granted. People become abusive in consuming electricity.

Electricity has removed darkness from the world and has illuminated every sphere of human activity. Today life without electricity is almost impossible. Modern life has become so modern and so mechanical that even for all small things in daily life we need electricity.

Electric power consumption is affected by diverse factors. One of possible methods to do that is to forecast the electric load accurately and supply power accordingly.

In February 2014 Mindanao experienced an island-wide power outage. This incident had a negative effect in economic development not only in those regions and provinces but the whole island of the Philippines. Cagayan Valley also experienced power outage even with the existence of Magat Dam Power Plant. As early as May 2014, Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) warned of the potential effects of El Niño to the country. The weather bureau initially predicted that El Niño would occur in June 2014. In November 2014, PAGASA adjusted the estimated prediction and announced that there is 65% to 70% chance that El Niño will occur in December six months later than the original announcement [2].

There are two towns in Cagayan during the hotter days that experienced nine hours of brownout due to load shedding schemes of the National Grid Corp. of the Philippines (NGCP), alternately shutting down its transformer as a way of precaution to possible breakdown because of the extreme heat that pushed the transformer on the brink of overheating [3].

Cagayan Valley and Kalinga experienced 12-hour power interruption as announced by National Grid Corp. of the Philippines (NGCP) due to annual maintenance work and testing of the 100-megavolt ampere transformer at the Tuguegarao substation and the commissioning activities of the SN Aboitiz Power Group (SNAP). Dumlao (2014), A 10-hour power outage hit the entire Nueva Vizcaya and the 10 towns of Ifugao province announced by the National Grid Corp. of the Philippines (NGCP) is due to the replacement and relocation of electric posts along the Bayombong-Lagawe line segment and the repair of a power circuit breaker at the Bayombong substation [4].

Due to lack of energy reservation of the country, severe power interruption is one of the problems being encountered in the country. These can lead to the depletion of conventional type of resources. The province of Nueva Vizcaya always experienced power interruption for the past years due to insufficient energy.

With the power outages cited, the researcher observed that there is a need for a study especially on the prediction of electrical energy consumption in order for the Nueva Vizcaya Electric Cooperative (NUVELCO) to be able to establish the trend of future consumption and be prepared to sufficiently supply its member consumers.

2.OBJECTIVE OF THE STUDY

A. *Statement of the Problem*

This study generally aims to develop an Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping specifically seek to determine:

1. What are the problems, issues and challenges encountered in monitoring the electric consumption of barangay and municipalities of Nueva Vizcaya for the past 5 years?

2. Is there a significant relationship between electric power consumption between the following variables:

2.1 Temperature

2.2 Precipitation

3. What regression model is most appropriate in forecasting electrical power consumption in Nueva Vizcaya?

4. What classification and clustering algorithm can be used in the development of the study?

5. What system can be developed in forecasting electrical power consumption in Nueva Vizcaya?

6. What is the extent of compliance of the developed Electric Cooperative Power Consumption Forecasting and Decision Support System using Data Analytics in terms of the overall features and system performance using the ISO 25010 criteria such as:

a. functional suitability
b. performance efficiency
c. compatibility
d. usability
e. reliability
f. security
g. maintainability
h. portability

7. What enhancement can be done to improve the developed system?

B. *Framework of the Study*

The conceptual framework [5] summarizes the theory of what the study achieved and the processes undertaken to come up with an output.

Inputs	Problem	Concept (modules of Intervention)	Users	Outputs
Member Consumer Demographic Data	• There is difficulty in data processing because of clients' massive data;	• Database/Records Management; • Clustering Analysis & GIS	Administrator / Manager - IT Clerk/System Engineer	• Centralized database storage; profile of member-consumers
Consumer Power Consumption	• High power consumption due to high demands of energy in every households	• Analytics using LINEAR REGRESSION	Administrator / Manager - Billing Clerk/Computer Operator	• 5-year historical trend consumption & payments; • 5-year projection on consumption; • Alerts, Reminders, Recommendations
Temperature and Precipitation	• Loss of power due to interruptions caused climatic situations;	• Analytics using Co-relational Analysis; • Descriptive statistics	Administrator / Manager - IT Clerk/ System Engineer	• Forecasted temperature and precipitation; • Graphical trends on temperature & precipitation;
ISO Standard 25010	• Compliance of the developed application in terms of the overall features and system performance	• Basis for performance using descriptive statistics	Billing Clerk/ Computer Operator; IT Clerk/ System Engineer	• Developed application is accepted unconditionally

Figure 1: Conceptual Framework

The study revolves around the interconnecting factors of electricity use, member consumers, and the electricity generation system, and how a decision support system could facilitate an efficient and effective system of delivering excellent services to its member-consumers.

The conceptual framework of the study shows the current situation reflecting the issues in managing an electric cooperative ranging from the difficulty in data processing because clients' massive data; high power consumption, and losses due illegal connections and interruptions caused by climatic situations. With these identified problems, the study looks into interventions that would resolve these problems. The interventions include: Database management; clustering analysis & Discriminant analysis; Analytics using Linear Regression; and descriptive statistics.

It with these models of intervention, the following outputs are achieved: a centralized database storage; profile of member-consumers; a 5-year historical trend of power consumption as well as projection of consumption, alerts and reminders of consumption status using SMS are accessible to member-consumers. Another output is the, forecasted temperature and precipitation using graphical trends.

The Decision Support System of the study give an alert to member consumer on their consumption status; it gives also alert to the Electric Cooperative Authorized Personnel User if there is a high-power consumption and give recommendation if there is a need to add additional transformer or purchased of energy and give recommendation if there is a need of clearing power lines, and checking illegal connections in every household.

The study used a time series and linear regression for modelling and forecasting electric consumption. The study used a Discriminant analysis for classification and clustering model for mapping system. The researcher will use Statistical Package for Social Sciences (SPSS) tools to derive a model to be use in forecasting and clustering. The model derived embedded in the programmed in web-based programming language and other scripting languages.

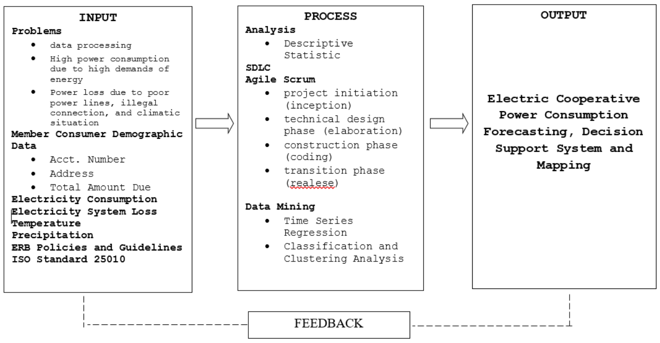

Figure 2: Conceptual Paradigm of the Study

The input box illustrates or shows all possible input variables. The first input are the problems, issues and challenges encountered by the electric cooperative.

The second input are the variables of member consumer's demographic data necessary for the mapping of location in the province and will be used for monitoring monetary collections.

The third input variable in the power consumption of the province for the past five (5) years and these could be used in the monthly projection of the power consumption.

The fourth is the variable for power loss of the province for the past five (5) years and these could be used in the decision making for the Nueva Vizcaya Electric Cooperative especially in the maintenance of the power lines, transformers and other electrical equipment's of NUVELCO.

The fifth and sixth input variables are the temperature and precipitation, these could be used in correlation in the power consumption in a high/low power usage of cooling devices. The seventh inputs are the Energy Regulation Board Policies and Guidelines. Republic Act 9136 An act ordaining reforms in the Electric Power Industry, amending for the purpose certain laws and for other purposes.

The last inputs are the assessment of application system using ISO 20150, to assess the characteristics of the application as assess by the respondents along the following software product quality based from ISO standard 25010 as per functional suitability, usability, reliability, compatibility, security, maintainability, performance efficiency and portability.

The process box illustrates or shows statistical tool like descriptive statistic for the Analysis. System Development Life Cycle is used to meets customer expectations, reaches completion within time and cost evaluations, and works effectively and efficiently.

The Scrum is a framework used primarily for software development projects with the goal of delivering new software capability and manage complex software and product development, using iterative and incremental practices.

Data mining is use for Time Series and Linear Regression for forecasting or predictive analysis in the power consumption. Clustering Analysis using Discriminant Analysis this is used for monitoring or mapping municipalities of the province. Descriptive statistics is also use for presentation of the ISO compliance.

3.METHODOLOGIES

A. *Research Design*

As an initial step, the study looks into the current problems and issues of the electric cooperative on how they resolved their problem in monitoring the electric consumption of the whole province. Based on the observation and findings of the researcher about the problems encountered in monitoring power consumption of each Municipality of the province on Nueva Vizcaya, the researcher identified two weather factors as basis for developing prediction model.

The researcher used two methods such as descriptive research and developmental research. This method enables the researcher to gather, tabulate, organize, treat and analyzed present data collected from the various participants to determine the extent of the compliance of the study as required.

The researcher used data mining to mine gathered data and predict future trends or patterns between variables, and then validated the findings by applying the detected patterns to new subsets of data and integrating database for accessibility and availability of data. In this study the researcher used Classification and Clustering Analysis in classification of a set of observations into subsets called clusters in mapping the location of the possible rise and fall of power consumption.

The Agile Scrum Software Development Methodology was used for software development. It is a lightweight process framework for agile development, and the most widely-used one. Scrum is most often used to manage complex software and product development, using iterative and incremental practices.

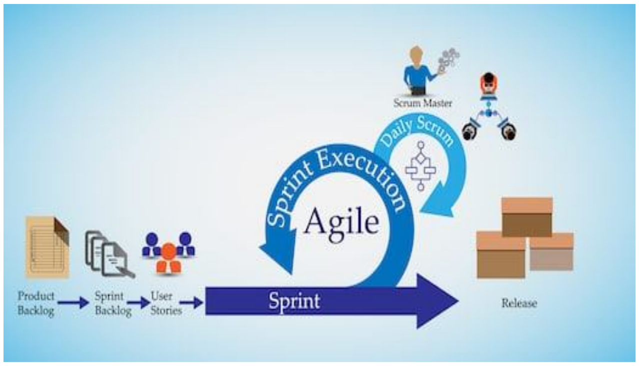

Figure 3: Agile Scrum Framework

Phase1: Project initiation- in the project initiation of the agile software development methodology, the researcher conducted an interview to the personnel of Nueva Vizcaya Electric Cooperative to defines the possible requirement of the end-user (Product Backlog).

Phase 2: Technical Design- in this phase the researcher generated an initial modelling architecture of the system including the platform / framework of the system functionality to meet the end-user requirement.

Phase 3: Construction Phase- in this phase, the researcher developed a Web-Based system application on Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping. This coding stage, the researcher converted the use cases into a software prototype. The researcher used programming and database tools such as PHP, CSS, JavaScript, HTML, Bootstrap and Xampp for Database Server and Web Server.

Phase 4: Transition Phase- is sometimes called a deployment phase, release phase, or hardening sprint in which is conducted after Construction phase. The researcher tested the functionality of the system. Beta testing has done and followed to validate the new system against user expectation to be followed by implementation of the developed web-based application via internet through web-hosting.

B. *Architectural Diagram*

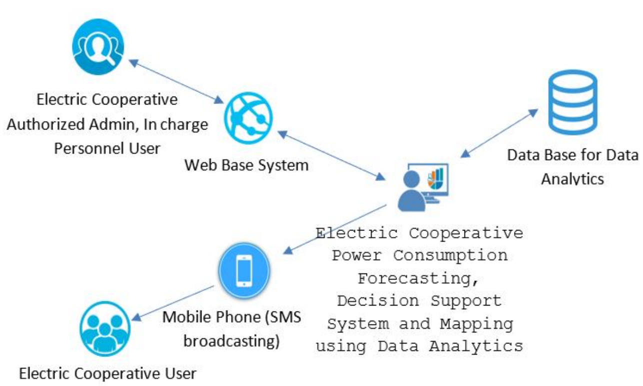

Figure 4: Architectural Diagram

In the development of Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping the Architectural Diagram of the system is implemented.

C. *Participants of the Study*

The participation of users is very important to be able to attain the functionality and realization of the Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping.

The participants of the study are those who served as the sources of data and information are the following:

1. Department Managers- they are responsible in all information and decision making of the cooperative.
2. The Personnel/Staff- who is responsible for collecting the data and information for decision making purposes.
3. Member consumers- are those who will utilize the software in accessing the system to forecast their monthly consumption.
4. I.T. Expert- are those in academe/instruction and are those in industry such as Nueva Vizcaya Electric Cooperative (NUVELCO) I.T. personnel who will evaluate the extent of compliance of the developed system using the ISO 25010.

D. *Instrumentation*

The researcher used the existing data of Nueva Vizcaya Electric Cooperative (NUVELCO)- Gabut, Dupax Del Sur, Nueva Vizcaya to determine the problems encountered in monitoring total monthly electric consumption, in province. On the other hand, temperature readings and precipitation were collected at NVSU-PAGASA Agromet Station, Nueva Vizcaya State University- Bayombong Campus.

The researcher used interview, survey questionnaire method and documentary analysis. The documentary analysis is used to data mine the existing related literature data of Nueva Vizcaya Electric Cooperative (NUVELCO) such as power consumption. Also interview integrated with guide question such as problems, issues and challenges encountered by the cooperative. Lastly, the survey questionnaire was used by the researcher using ISO 25010 to determine the extent of compliance of the developed system.

E. *Data Gathering Procedure*

In data gathering the researcher identified three participants to gather data; the Department managers; personnel/staff; I.T. experts.

The researcher requested the participants in the event that they were willing to be interviewed and well prepared to reply and provide necessary information to the best of their understanding and experience. In the interview, the researcher explained: first is the purpose of the research; second is that the interview is voluntary; third is confidentiality of records and information; fourth is that there is no monetary equivalent for the interview, and last it the right to refuse or withdraw at any time they like. The researcher asked the participants to sign an Informed Consent indicating the above concerns. All collected data were subjected to data treatment.

F. *Data Analysis*

The data collected was tabulated, analyzed, interpreted and treated to fit in the analysis of the study. The researcher used Time Series Analysis as a tool to forecast climatic data. A

Correlation Analysis and Linear Regression Analysis is used between temperature and power consumption, precipitation and electric consumption. This statistical tool is used for prediction and most effective approaches for analyzing time series data. The researcher derived a power consumption differential equation or models using linear regression which is used to determine the growth of the electrical energy consumption of Nueva Vizcaya.

This study also makes used of the Discriminant Analysis to perform clustering of the locations like; municipality in the province of Nueva Vizcaya that is statistically significant the peaks and valleys around the mean in terms of power consumption.

The data collected from the user during the implementation of the System Application was tabulated, analyzed and interpreted using descriptive statistics such as weighted means was used to assess the application functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, portability along with the standards of ISO 25010.

4.RESULTS AND DISCUSSION

1. The problems, issues and challenges encountered in monitoring Electric Consumption.

A. Non-normal Power Consumption

It is important to check power consumers that might be giving problems, such as power consumption deviation from the normality that could indicate that the hardware or devices for monitoring power consumption such as power meters might be malfunctioning.

B. Difficulty in Restoring Damaged/Broken Power Meters

Based on the interview conducted by the researcher, another problem, issues and challenges encountered by the cooperative is when there is a calamity or act of God like typhoon, it is very hard for the cooperative to restore damage/broken power meters specially in remote areas of the province of Nueva Vizcaya.

C. Inadequate Manpower for Meter Reading Consumption

Another is the lack of manpower in reading of meters of power consumers for the entire province. Lastly the cooperative has no existing system in forecasting power consumption within the province of Nueva Vizcaya.

2. Significant relationship between electric power consumption between Temperature and Precipitation

Table 1: Test for Significant Relationship Between Consumption and Climatic Variables

Variables Correlated	Pearson r Coefficient	P-Value	Remarks
Consumption and Precipitation	0.52	<0.01	Significant
Consumption and Temperature	0.78	<0.01	Significant

2.1 *Temperature*

Temperature is significantly related to electric power consumption. This statement is based on the r - value of 0.78 with probability value of <0.01. The r- value of 0.78 suggests that temperature and electric power consumption are strongly related to each other. The result further implies that the temperature in every municipality has strong and direct effect to the electric power consumption in the locality. The higher the temperature in the locality, a high tendency that the home owners will use electric appliances which later will lead to increase electric consumption. Conversely, the lower the temperature in the locality, a high tendency that the homeowners will not use (some) electric appliances which will lead to decrease in electric power consumption.

2.2 *Precipitation*

Precipitation is significantly related to electric power consumption. This statement is based on the r - value of 0.52 with probability value of <0.01. The r- value of 0.52 suggests that precipitation and electric power consumption are moderately related to each other. The result further implies that the precipitation level in every municipality has moderate direct association with electric power consumption in the locality. The higher the amount of precipitation in the locality, a moderately – high tendency that the homeowners will use electric appliances which later will lead to increase in electric consumption. Conversely, the lower the amount of precipitation in the locality, a moderate tendency that the homeowners will not use (some) electric appliances will lead to decrease in electric power consumption.

3. Prediction Model

Table 2: Regression Model to Predict Electric Power Consumption

Model		Unstandardized Coefficients		Standardized Coefficients	t-test value	P-value
		B	Std. Error	Beta		
1	(Constant)	477481.386	982038.702		.486	0.629
	TEMP.	387472.360	44687.837	.680	8.671	<0.001
	PRECIPITATION	125383.399	32753.168	.300	3.828	<0.001
R^2=.687						

The regression model that could predict electric power consumption (C) in Nueva Vizcaya is presented by C = Temp * 387472.360 + Preci * 125383.399 + 477481.386; where: Temp is the average temperature in Nueva Vizcaya over 30 days readings prior to the target date of forecast, Preci is the average precipitation in Nueva Vizcaya over 30 days readings prior to the target date of forecast.

Temperature has higher contribution to electrical power consumption than that of precipitation. This statement is based on the comparison of the Standardized Beta values of B = 0.68 for Temperature and B = 0.30 for Precipitation. It could be inferred from the model that possibly there will be high electric power consumption during summer season especially when there is small amount of precipitation in the locality; also, there will be lesser electric power consumption during the cold season where no precipitation is expected is occur.

The r2 value of 0.687 suggests that the electric power consumption could be associated to Temperature and precipitation level in the community as the electric power consumption is determined by these two climatic factors.

4. Classification and Clustering

Among the <number of variables> variables considered in the study, only five (5) variables could discriminate the municipalities in term of electric power consumptions and could be used to classify the municipalities into cluster 1 (below the electric power allotment of the locality), cluster 2 (within the electric power allotment of the locality), and cluster 3 (exceeded the electric power allotment of the locality).

The variables which have positive impact to locality's total electric consumption are the electric consumption of consumers tagged as Life Liner (Con_LL), consumers tagged as Non-Life Liner (Con-NLL) and the level of precipitation (Preci) in the locality. On the other hand, the amount allotted by the cooperative as lifeline to each municipality (lifeline) and the recorded temperature (Temp) were noted to have negative effect on the locality's total electric consumption.

The clustering of municipalities based on their electric consumption could be based on the Discriminant index using Canonical Discriminant coefficients and the identified group centroids.

Table 3: Canonical Discriminant Coefficients

Variables	Function
Con_LL	.000340
Con_NLL	.000919
Lifeline	-.000017
TEMP	-.020017
PRECI	.004776
(Constant)	-1.705457

The Discriminant Index (Di):

Di = Con_LL*0.000340 + Con_NLL*0.000919 – Lifeline*0.000017 – Temp*0.020017 + Preci*0.004776 – 1.705457

Table 4: Group Centroids

Cluster / Group	Range
1	1.032 - below
2	1.033 - 4.749
3	4.75 - above

The Group Centroids (G):

If the computed Di of certain municipality is within the G range of 1.033 – 4.749, the said municipality is grouped or clustered as Cluster 2, if the Di is lower than 1.033 it belongs to cluster 1, and if D1 is higher than or equal to 4.75, it is classified as cluster 3.

Table 5: Clustering Power

Clustering Power (prediction)		
Pred - Actual	Total (p-a)	%
1-1	624	0.756364
1-2	0	0
1-3	0	0
2-1	22	0.026667
2-2	62	0.075152
2-3	3	0.003636
3-1	0	0
3-2	9	0.010909
3-3	105	0.127273
Total cases	825	
	Correctly	0.958788
Classified	Incorrectly	0.041212

The Clustering Power

In the simulated cases of municipalities along the identified discriminators over the monthly data for 5 years, the computed Di and G were determined and were classified. Out of 825 cases, 791 cases or 95.88% were correctly classified; 624 cases are in cluster 1 in the actual and correctly predicted as cluster 1, 62 cases are in cluster 2 and correctly predicted in cluster 2, and 105 cases are in cluster 3 and correctly predicted in cluster.

5. Electric Cooperative Consumption Forecasting, Decision Support System and Mapping

Based on the significant weather predictors relative to the occurrence of the rise and fall of power consumption the researcher found out that the developed system that utilizes the derived prediction models is a Web-based Decision Support System because of the following advantages. First, it can predict the power consumption of the whole province of Nueva Vizcaya as well as per municipality that supports decision-making activities of managerial personnel by providing updated data on the possible occurrences of power consumption based on the weather particularly concerning temperature and precipitation using predictive models. Second, it eases data storage and retrieval of data and information. Lastly, it reduces a geographical and technological barrier; for the personnel in providing real-time data and information on the power consumption with in the province with much ease.

6. Electric Cooperative Consumption Forecasting, Decision Support System and Mapping ISO 25010 compliance

Table 6: Summary of the extent of compliance of the developed system to ISO25010.

ISO 25010 CRITERIA	CATEGORY MEAN	Qualitative Description
1. Functional Suitability	4.65	Very Great Extent
2. Performance Efficiency	4.60	Very Great Extent
3. Compatibility	4.57	Very Great Extent
4. Usability	4.56	Very Great Extent
5. Reliability	4.46	Very Great Extent
6. Security	4.70	Very Great Extent
7. Maintainability	4.60	Very Great Extent
8. Portability	4.73	Very Great Extent
Mean	4.61	Very Great Extent

The summary of compliance to ISO 25010 reflects the mean and corresponding qualitative description of the developed system. The developed system using the ISO 25010 quality criteria is compliant to a "Very Great Extent" concerning functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

7. Enhancement of Developed System

The study focused on the use of internet technology. Nueva Vizcaya Electric Cooperative (NUVELCO) will provide data and information to personnel in charge of the developed system (web admin). One particular input to enhance the system is the development of a mobile application to allow access to information with the use of smart phones. In addition, another enhancement to the developed system is to enable the system to process and train a dataset.

5.CONCLUSION

The Electric Cooperative Power Consumption Forecasting, Decision Support System and Mapping is an easy-to-adopt intrusion tool in providing data and information on the occurrences of the rise and fall of power consumption in the province or locality to the Managers, personnel or staff of Nueva Vizcaya Electric Cooperative (NUVELCO). When the system is further improved, and more data sets are used to update the accuracy of the regression or prediction models constantly improved, the developed system has a strong probable to significantly benefited the cooperative specially in their decision making for the next period of time.

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