Mathematical and Statistical Modelling in Solving Industrial Problems - A University Industrial Collaborative Research

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Abstract

Successful business requires good management, decision making and planning process. Strong bridges are required to connect theory (the university) and practice (industry), and many problems must be solved before mathematical models or methods can be used efficiently and effectively in management situations. Application issues are rather under explored and this has been highlighted in many papers publication and it is virtually impossible to work with real organisations without realising that the gap between the development of mathematical models and their application is huge. In this paper, we present case studies on modelling of palm oil yield and forecasting of electricity demand where collaboration between university and industry may be carried out. Here we did not explore the technical aspects of demand forecasting but rather to highlight the need for benchmarking the forecasting practices when conducting forecast of electricity demand. This applies to to the application of mathematical model for predicting palm oil yeild.

Keywords: Forecasting, Extrapolation method, Genetic Algorithms, Energy, Industrial Partnership.

Introduction

It is a great pleasure to be invited to present an invited paper to speak at this prestigious Annual Fundamental Science Seminar 2006. I wish to thank the Director of Institute Ibnu Sina for the opportunity given to me to share my experience in R&D in the field of Mathematics and Statistics. Much of the joy of mathematical and statistical research is the joy of producing solid result and there is a great satisfaction in building good mathematical and statistical tools for other people to use. The essential factor which keeps the scientific enterprise healthy is a shared respect for each others ability to produce and produce quality goods. It is not my intention to give a lecture in detail the technicalities of mathematical and statistical modelling for solving industrial problems but just to share my experience in collaborative work with several industries in solving industrial problems.

Malaysian government is encouraging more research on alternative energy sources. Research grants has been set by the government and found that only a small percentage of the research findings has been turned into a useable product. It is an issue that must be looked at in many aspects as not to make decisions that may hinder the progress and the expansion of research activities in this country. The government has been encouraging research conducted by industries to solve industrial problems but due to the lack of researches and expertise, this idea may not at all viable. It is therefore necessary for the authority to recognize the balance between research and research for the purpose of commercialization. Mathematical and statistical modelling on its own has no commercial value but it has the ability to solve complex real life problems within industries and organizations.

In achieving the status of a developing nation, Malaysia's development highly dependent on the ability to produce and increase in its production. Energy is recognized as one of the prime agent in the increase of productivity and a significant factor in economic development. There has been a strong relationship between the availability of energy, economic activity and improvements in standards of living and overall social well-being.

Research in industries has been recognized as a variable in measuring the status of a developed nation. Here, we share a few industrial problems and demonstrate the need for mathematical and statistical modelling and the collaborative effort between researches and the industries. Areas of collaborations between the department and industries include in the modelling of bus routes, maximizing profit in tickets collection, modelling of production schedule of Proton assembly line, modelling of palm oil yield and electricity demand forecast.

Forecast of electricity for major electricity producers requires an accurate forecast as it becomes a forecast of energy demand for the country with data based on the standard format recommended in the energy sectors. A five years total monthly energy generated data in kWh unit is available for making future prediction. In making forecast, accuracy is the primary criteria in selecting among forecasting techniques.

In the oil palm industry, modelling plays an important role in understanding various issues. It is used in decision making and the advance in computer technology has created new opportunity for the study of modelling. Modelling can be categorized into statistical and heuristic modelling. Statistical modelling is defined as the analysis of the relationship between multiple measurements made on groups of subjects or objects, and the model usually contains systematic elements and random effects. As a mathematical aspect, statistical modelling can be defined as a set of probability distributions on the sample space. Modelling involves the appropriate application of statistical analysis techniques with certain assumptions on hypothesis testing, data interpretation, and applicable conclusion.

Statistical analysis requires careful selection of analytical techniques, verification of assumptions and verification of the data. In conducting statistical analysis, it is normal to begin with the descriptive statistics, graphs, and relationship plots of the data to evaluate the legitimacy of the data, identify possible outliers and assumption violations, and form preliminary ideas on variable relationships for modelling.

Another widely used for solving complex problem approach is the heuristics models. The heuristic approach is defined as pertaining to the use of general knowledge based on experimentation, evaluating possible answers or solutions, or trial-and-error methods relating to solving problems by experience rather than theory. Heuristic is also the problem-solving procedure that involves conceiving a hypothetical answer to a problem at the outset of an inquiry for purposes of giving guidance or direction to the inquiry. One of the heuristic approaches is the neural network model, which is based on the rules of thumb and widely used in various fields. A very important feature of neural networks is their adaptive nature where 'learning by example' replaces 'programming' in solving problems. This feature renders these computational models very appealing in application domains, where one has little or incomplete understanding of the problem to be solved, but where training data or examples are available.

The developments of models for agriculture are normally divided into three steps. The first step is to develop a preliminary model, which is inadequate. This preliminary model does not have to be a good model but it acts as a basis. This leads to further research, to develop a comprehensive model incorporating all the processes that appear to be important. Such a model is valuable for research, but far too complex for everyday use. To overcome this, a set of summary models is produced, each containing enough detail to answer limited questions. For example, there might be a summary model to predict the response to fertilisers on different soil types. Another model might be used to predict cyclic variation in yield. Modelling helps to make predictions more accurate. There is no doubt that modelling will maintain its importance in oil palm research as the problems set more complex and difficult. This organization of this paper is as follows. Section 2 covers some aspects of decision making and the importance of mathematical and statistical models in the process. A brief discussion of our experience in modelling at Tenaga Nasional Berhad (TNB) and Malaysia Palm Oil Board (MPOB) is given in section 3. The results of the study depends on the successful collaboration between the industries and the university and this is discussed in section 4 followed by the conclusion and the summary on the component of a successful partnership in research.

Mathematical and Statistical Modelling in Decision Making

Today, we have a large mass of descriptive data, from both field and laboratory, that show how human problem solving and decision making actually take place in a wide variety of situations. A number of theories have been constructed to account for these data, and while these theories certainly do not yet constitute a single coherent whole, there is much in common among them. In one way or another, they incorporate the notions of bounded rationality: the need to search for decision alternatives, the replacement of optimization by targets and satisficing goals, and mechanisms of learning and adaptation. In this section we are interested in developing tools to assist the decision making and one such tool is the modelling. Prediction model is about modelling future behavior pattern of events of units and it is a science of a much closer approximation to what is actually going on.

Development of new mathematical models for decision making and their practical application developed in the university environment will enable managers (the decision makers) to use in making better decisions. Forecasting for example is essential for decision-making. The growing importance of the forecasting function within companies or organisations is reflected in an increased level of commitment in term of money, hiring of operational researchers and statisticians (Berenson, M. L and Levine, D. M. (1999). There are several factors that have caused the importance of this function to increase namely

- The increasing complexity of organisations and their environments which makes decision making more difficult to consider all factors relating to the future development of the organisation into account.
- Organisations have moved towards more systematic decision making that involves explicit justification for individual actions and formalised forecasting is one way forward.
- Further development of forecasting methods and their practical application has enable managers (the decision makers) to understand and use these techniques.

With particular reference to the last point, it is evident that knowledge of forecasting is only useful if *applied* to an organisation's decision making and planning process. Strong bridges are required to connect theory (the university) and practice (industry), and many problems must be solved before forecasting methods can be used efficiently and effectively in management situations. Application issues are rather under explored and this has been highlighted in many papers publication and it is virtually impossible to work with real organisations without realising that the gap between the development of forecasting techniques and their application is huge. Against this background, the aim of this paper is to draw and on the experience on forecasting practices by one major energy provider and the higher institutions which will provide an up to date overview of empirical studies on forecasting; develop framework within which an organisation and benefit.

Modelling Experience at TNB

On collaborative research to develop forecasting models for electricity energy generated does not have a specific MOU or MOA but just an agreement between two units within the departments. This project began with our participation in the Integrated Resource Planning (IRP) project initiated By Pusat Tenaga Malaysia (PTM), a collaborative project to develop Malaysian Energy Model. This has lead to a proposal to develop methods for forecasting Malaysian Electricity, which can be used to complement the forecast of the overall Malaysian Energy Demand.

Management Support
Forecasting is one of the functions in the organization of TNB and decision making at operational level is one of the common problems. The need for forecasting models that evaluate the electric consumption with the highest level of accuracy is underlined by the black-outs that recently took place in Malaysia. Because of the sudden heat wave that invested the whole country from the first days of January, an intensive utilization of heating, ventilating and air conditioning systems provoked an unforeseen load peak that brought the national power grid to the point of collapse. On January 13th, 2005 a national electric load of 13 000 MW was recorded, to be the highest value ever registered in Malaysia. Since then, TNB has highlighted the need to strengthen the team of forecasters and has recognized the important function of forecasting.

For a forecasting function to succeed, it needs the support of the upper management, because it needs resources to start it and resources to maintain it, which only the upper management can provide. Resources here mean the need to buy forecasting software or system, to acquire syndicated data, storage facilities and tools for analyzing the data.

Furthermore, for a forecasting function to work efficiently in TNB, it needs collaboration from various stakeholders, both internal and external. The internal stakeholder may be the support from each power plant, information from each state, support from the transmission unit and others. The external stakeholder may be the customers, weather department, the IPPs, government agencies and others. All these information have a bearing on the forecast. Besides these, forecasters needs correct and prompt input from operators at power stations. Without the blessing of the upper management of TNB, nothing would be forthcoming. It is fortunate that the upper management in TNB recognizes the need for forecasting function.

Forecasting Process
A Forecasting process provides a mechanism for soliciting participation from individuals who have knowledge of future events and compiling it into a consistent format to develop a forecast. The forecasting process concentrates defining how information will be gathered and reconciled into a consistent picture of the future. In cases where a statistical forecast is used the process will also define how much weight should be given to the mathematical models versus input from participants to develop the final consensus forecast.

Others may define forecasting process as the process how it deals with issues related to developing a forecast. It describes the issues such as what kind of data is needed to prepare forecasts? From where does it come? Where the forecasting function should resides? What level of details in forecasts is needed?

For forecasting function to work smoothly and efficiently, we need collaboration among different function in TNB. Forecast cannot be prepared in isolation. The forecasters need inputs from various functions such as the weather department, power plant operators, information on types of holidays. They need all relevant information to prepare forecasts as well as to overlay judgment over statistically generated forecast. At TNB, the forecaster is normally the head of forecasting units and for the forecast to be implemented; he has to present it to a group of forecaster from other units before any final figure is identified.

At TNB, they have adopted a one-number forecast philosophy, with that every decision on the operation will be based on that number. It is quite impossible for the operator to operate the power plant with more than one figure of forecast. However, for a long term forecast or in organization where different functions have been all along preparing their own forecast, it won't be easy for them to give it up.

Methods used for forecast
The TNB forecasting methodology has evolved from a pure judgmental approach to a statistical/judgmental approach method since 1970. Early 1980's represents the pioneer attempts at using time series analysis, regression analysis and income elasticity approaches to demand forecasting. Late 1980 have witnessed the introduction of several methods, namely the sectoral trend analysis and end-use method to complement the adopted approaches. Most of the approaches have been retained till today and are still used in the load forecasting study. Various forecasting approaches adopted are time series analysis, regression analysis, sectoral trend analysis and income elasticity approach (Long Term Forecast Report 1994-2000, TNB).

Forecast Accuracy
Making accurate forecast has been the dream and desire of almost all forecasters but we all know that forecasts are almost always wrong. We can only hope is to minimize the error. The question arise is how much. Why one make such an error in their forecast? A forecast is better than no forecast. In TNB, a certain amount of error can be tolerated as the errors indicate the amount of electricity generated or not generated. This is called acceptable error, which varies from short term forecast to long term forecast.

Issues of Forecasting

Development of new forecasting methods and their practical application developed in the university environment will enable managers (the decision makers) to use in making better forecast. TNB conducted the short, medium and long term electricity demand forecast which will then be used by other units within the organization and by other IPPs. The information on the electricity demand is recorded on line to the central control station. For a short term forecast, TNB requires forecasts of electricity lead demand of 24 hours ahead. It is not our intention in this to explore the technical aspects of demand forecasting but rather to highlight the need for benchmarking the forecasting practices when conducting forecast of electricity demand. The upper management does recognize the need for the function of forecasting and this is supported by the recent establishment of forecasting units in TNB.

A forecasting exercise is usually carried out in order to provide an aid to decision-making and in planning the future. Typically all such exercises work on the premise that if we can predict what the future will be like we can modify our behavior now to be in a better position, than we otherwise would have been, when the future arrives. We therefore engaged ourselves in modelling the future pattern of demand for electricity.

Forecasting is the estimation of the value of a variable (or set of variables) at some future point in time. Applications for forecasting at TNB include:

- *inventory control/production planning* - forecasting the demand for a product enables us to control the stock of raw materials such as the petroleum, gas and coal as source of energy and finished goods, plan the production schedule, etc
- *investment policy* - forecasting financial information such as interest rates, exchange rates, share prices, the price of gold, etc. This is an area in which no one has yet developed a reliable (consistently accurate) forecasting technique particularly in relation to the electricity demand.
- *economic policy* - forecasting economic information such as the growth in the economy, GDP, unemployment, the inflation rate, etc is vital both to government and TNB in planning for the future demand of electricity.

Many of the above applications are common in many industries and organizations. Each organisation has its own administrative or operational structure and different set of organizational structure requires different level of forecasting practices. In understanding the status of organization structure among industries and forecasting practices, a small study was conducted the findings will be described in the next section. Electricity demand forecast is of considerable interest to electric power utility as it is recognized a function in the planning and management of the company. Forecasting of the total electricity demand or the total system load is necessary in daily scheduling of power plants. The daily forecast is needed to consider the economics of starting up and shutting off various electricity power plants. Each power plant may be generated using different fuel and some may require longer time to start while others may be turned on instantaneously such as the hydro power system.

There are many factors involved in the successful operation of a power system. The power system is expected to have power instantaneously and continuously available to meet customer's demand. It also expected that the voltage supplied to the customers will be maintained at nominal rate. Other operating consideration are that the public and employees should not be placed in hazard by operations of the system and at the same time proper operating procedures must be observed to avoid damage to equipment and to other facilities of the system. All of these requirements must be achieved simultaneously and it is also expected that the production and distribution of power will be accomplished at minimum cost. In addition to meeting the reliability and economic requirements, consideration must also be given to planning for future installations. In planning for daily and future load demand forecasting plays a very important role in the electricity industries.

Thus, accurate load forecasting is a crucial issue for the resource planning and the management of electric power generation utilities. Forecasting is one of the functions in the organization of TNB and accurate forecast is very important. The three time scales load forecast that are normally used at TNB are the short term load forecast (STLF) that covers a period of half an hour to 24 hours. This is important for the daily operation of the system. The people who forecast electricity load demand for the next half hour or day are skilled individuals who, over the years, have developed special expertise. They normally use both their expertise and mathematical/statistical models to make their decision on the load. Having models to assist them in solving the problems, it means they have more time to spend on their other duties, such as ensuring that data gathering are accurate and arrive on time.

The medium term load demand covers a period between 24 hours up to one year and this is essential for TNB is term of scheduling the supply of fuel and maintenance operations. The long term load demand forecasting predicts the requirements of electricity for more than a year up to 20 years. This is essential for capital assignment and infrastructure plans drawn upon long-term forecast. Currently, the projections of long-term electricity demand for Peninsular Malaysia are carried out by the Generation Planning and Load Forecast Unit, Grid Systems Management Division, TNB. This unit is involved in both generation planning activities and demand forecasting i.e. demand and supply studies.

Organizations forecast so that they can plan and help shape their future. Forecasting is crucial input for planning in almost all companies as it provides estimation of some future event or condition which is outside an organization's control. This becomes a basis for managerial planning. In our survey on usage of forecasting in electronics industries in Malaysia, 79% of the respondents indicate that the forecasting was important for their company's success (Zuhaimy *et.al*, 2002).

For TNB, the main resource of income is from the generation unit and efficient management of these units means running them at a minimum cost to satisfy the requirements of customers. To achieve this purpose, the starting-up and the shutting-down the generation units should be performed according to schedule upon the decision forwarded by the forecast units (Zuhaimy and Jamaluddin,2004). The scheduling process is also known as unit commitment. If the generating system is able to meet customers demand both during normal and emergency conditions, the system is said to be a secure. If not, the system is said to be insecure and this is not allowed at TNB. Thus, it has developed the policy of producing above the demand rate by more than 25%.

If the forecast is inaccurate, the generation will be either above or below the mead demand rate. If the forecast is under-estimate, extra electricity must be generated immediately upon demand and may trigger tripping. If over-estimate, it could cost the company money for generating excess electricity. It is therefore essential for the forecasting unit to develop forecast with as small an error as possible.

Modelling Experience at MPOB

Malaysian Palm Oil Board (MPOB) is a government agency established to be directly involved in the development of palm oil industry in Malaysia. It has extensive research work on the palm oil industry which enables MPOB to enhance the production of oil palm in this country. We are interested in modelling oil palm yield.

The Model

The problem in modelling oil palm yield growth is that it does not follow a linear model. It normally follows a nonlinear growth curve. In modelling a nonlinear curve, the complexity of the problem increases with the increase in the number of independent variables. This causes the model to be more inaccurate. The function of a growth curve has a sigmoid form, ideally its origin is at (0,0), a point of inflection occurring early in the adolescent stage and either approaching a maximum value, an asymptote or peaking and falling in the senescent stage. Normally, oil palm can be harvested after three years of planting. The oil palm yield will increase vigorously until the tenth year of planting. The yield will then increase at a low increment until the twenty-fifth year. From our exploratory study on modelling practices, little work has been reported on modelling the oil palm yield growth.

Other Approaches

In most cases, researchers focused their study on the effect of environmental factors, such as evapotranspiration, moisture and rainfall to the oil palm growth. Chen et. al. (2003) conducted a study on the effect of climate change to fresh fruit bunches (FFB) yield, and found that climate change has significantly affected oil palm yield.

The most popular method used in the oil palm industry is multiple linear regression. This model is used to investigate the causal effect of the independent variables to the dependent variable. The literature shows that the foliar nutrient composition can be used as an indicator to estimate the oil palm yield. Nevertheless the foliar nutrient composition is also dependent on several factors, such as climate, soil nutrients, fertilisers, pest and diseases, but little had been done on modelling these factors. This study explores the possibility of improving the model but in particular, in improving the level of accuracy it can produce.

The response surface analysis is the technique used to model the relationship between the response variable and treatment factors. The factor variables are sometimes called independent variables and are subject to the control by the experimenter. In particular, response surface analysis also emphasises on finding a particular treatment combination, which causes the maximum or minimum response. For example, in the oil palm industry there is a relationship between the response variable (oil palm yield) and the four fertiliser treatments, namely nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg). The expected yield can be described as a continuous function of the application rate factor. A continuous second-degree-function is often a sufficient description of the expected yield over the range of factor levels applied (Verdooren 2003). If the fertiliser application rates are greater or smaller than the optimum application rate it may result in reduced yields. Fertilisers are wasted if the amount applied is more than the optimum rate. The advantage of this technique is that the effects of treatment combinations that have not been carried out in the experiment may still be estimated.

The use of analysis for the quadratic response function or response surface analysis is necessary to obtain the optimum level of fertiliser requirements. In response surface analysis, the eigenvalues will determine whether the solution gives a maximum, minimum or saddle point of the response curve. From our exploratory study on the use of response surface analysis, there is no solution if the stationary point is a saddle. This study will propose to use ridge analysis as an alternative solution to overcome the saddle point problem.

The University-Industry Partnerships

Motivation to develop university-industry research collaboration varies according to the needs of both parties involved. We cannot really give the real reason or reasons for establishing university-industry partnership without a proper study on the subject. It would only be appropriate for us to identify factor that may foster good relationship and provide some ideas for developing and maintaining successful partnership. However, there seems to have common factors that prompt the creation of alliances which includes:

- *Sharing of experts* – this is due to the recognition from both parties that partnerships of some kinds will enable the gathering of experts from both university and industry to solve complex problems, develop new methods and create new and innovative products. UTM on these factors would provide its expertise in term of modelling, methodologies and ideas while the industries would share their practical experience and the real issues relevant to forecasting practices.
- *Prestige* - Association with established university or large or international companies may impart a sense of quality and prestige to both parties. Approaches such as that carried out by UTM linking it with established national and international institutions will bring improvement in public opinion for both parties.
- *Human Resource Development* – The rapid changes in technology have promoted the creation of partnership between UTM and industry to ensure that the workforce posses the most current knowledge and information. This will enable both parties to maintaining technical skills, educational needs prompting the development of training programs in technical and non-technical areas.

Financial Gain – Alliances are often created to pooled resources and share the financial costs of certain projects. This is particularly true in R&D that involved sophisticated and expansive capital investment in instruments or lab facilities.

Components of Successful Partnership

The goal of partnerships between university and industry should be to establish an effective working relationship that benefits both parties. Successful partnerships should observe some of the points below:

- *Acknowledgement of differences* – As with any relationship, identifying differences add to or detract from the partnership enable both parties to work with the differences rather than against them and this include respect from differences and a higher level of trust.
- *Communication* – Open communication between partners is imperative for a successful relationship. Components such as defining terms and policies may prevent problems later. Additionally, clearly define the roles and expectations of the partnership will encourage a successful relationship.
- *Flexibility* – Successful partnership between university and industry tend to be flexible and willing to evaluate progress on a regular basis in order to gauge how partnership is working and make some kind of adjustment to ensure success for both parties.
- *Clear Goal* – Both university and industry should have clearly defined goals and expectations with both parties in agreement.

MOU and MOA – This is an important element to any successful initiative. An agreement arranged at the CEO level will ensure support from high-level management.

Conclusion

While abundant demand for collaborative research between university and industry for mathematics and statistics, it is important that mathematicians and statisticians recognized the need to solve many industrial problems. University, particularly the mathematicians and statisticians must expose their knowledge to new challenges to assist them and the industries. Capacity building among mathematicians will enable them to develop initiatives in solving problems from the Small and Medium Industries (SMI) or simple real life problems. Mathematicians must show their ability through modelling in improving services, maximizing profits and improve quality and much more. The potential for research between university and industry is more in the recently announced in the 9th Malaysian Plans.

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