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FORECASTING METHOD SELECTION FOR CAPACITY PLANNING IN SERVICE SYSTEMS

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ABSTRACT: *Although service firms tend to estimate the number of customers in a sensitive manner, the structure of the service is changeable on a large scale. Under these circumstances, choosing the most suitable forecasting method is a quite important decision. In this paper, a rule-based Expert Forecasting Method Selector (EFMS) was built by using PROLOG to capture the skill and aimed to act as an advisor for choosing appropriate method. EFMS was designed based on specific criteria to cover both qualitative and quantitative methods that may be applied to service systems. The EFMS also provides users fundamental info about forecasting methods and a chance of making calculation related to the selected method.*

KEYWORDS: *Expert Systems, Forecasting Methods, PROLOG, Service Systems.*

SERVİS SİSTEMLERİNDE KAPASİTE PLANLAMASI İÇİN EN UYGUN TALEP TAHMİN YÖNTEMİNİN SEÇİLMESİ

ÖZET: *Servis işletmeleri müşteri sayılarının tahmininde olabildiğince hassas davranma eğiliminde olmalarına rağmen, ürün karması ve servis sistemlerinin yapısı değişkenlik gösterir. Bu şartlar altında en uygun tahmin yöntemini seçmek önemli bir karardır. Bu makalede, uygun yöntem seçiminde bir danışman olarak hizmet edebilecek kural tabanlı bir uzman sistem (EFMS), PROLOG kullanılarak tasarlanmıştır. EFMS, servis sistemlerinde kullanılabilen niteliksel ve niceliksel yöntemleri kapsayacak ölçütler baz alınarak oluşturulmuştur. Aynı zamanda EFMS, kullanıcılara seçilen yöntem hakkında bilgi sunmakta ve yönteme ilişkin hesaplamalara olanak sağlamaktadır.*

ANAHTAR KELİMELER: *Uzman Sistemler, Talep Tahmin Yöntemleri, PROLOG, Servis Sistemleri.*

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I. INTRODUCTION

Expert Systems are computerized advisory programs that attempt to imitate or substitute the reasoning process and knowledge of experts in solving specific types of problems [1].

There is a great potential for expert system (ES) applications in a forecasting process. NOSTRADAMUS that helps a non-expert to select an appropriate forecasting method for a specific complex problem by considering criteria such as user preferences, situational factors, data patterns and characteristics, item (product) characteristics and type of forecast sought [2]. Kwong and Cheng [3] developed a knowledge-based system called Forecasting Model Selection Consultation System (FMSCS). Collopy and Armstrong developed a model selection knowledge-based system by manually eliciting production rules from human experts in forecasting and ended up with considerably accurate forecasts [4]. Lo [5] describes an ES for decision making of demand forecasting methods selection. Arinze's article [6] was the first to use rule-based induction as a mean of automatically extracting rules about method selection from the characteristics or features of time series data. Later, Arinze et al. [4] considered possible advantages of hybrid forecasting methods to the overall accuracy of model selection. Kandil et al. developed a knowledge-based expert system for the implementation of long-term forecasting strategies [7, 8].

In service systems, demand forecasting and capacity planning related to demand are very important issues. In comparing manufacturing and service firms, manufacturers tend to use more quantitative techniques and are more satisfied with the forecasting process. On the other hand, service firms tend to use subjective forecasting much more than manufacturers. Because of the different methods each uses, service firms also reported that their forecast process is more cumbersome than manufacturers'. Additionally, service firms are less satisfied with the forecast.

Service forecasting requires, in many cases, forecasts of hour-to-hour and day-to-day activities as well as aggregate forecasts, whereas in manufacturing, weekly, monthly and aggregate forecasts are more common. This means that in services, very short range forecasts must be made very frequently [9]. Generating a forecast that is accurate, cheap, and understandable by management depends on appropriate method selection.

A rule-based EFMS is devised by using PROLOG in order for the service firms to find solutions to the problems mentioned above and to choose the appropriate methods for continuously changing factors. The knowledge base of the EFMS, which is composed of three main parts (Knowledge-base, Inference Engine Mechanism, and User Interface), involves selection rules related to qualitative and quantitative methods which can be used to solve the problems faced in daily life easily by the users. The inference engine mechanism uses the most important factors such as time horizon, technical sophistication, cost, data availability, variability and consistency of data, detail and accuracy, turning points and form to interpret rules. EFMS will also be helpful for users to get detailed information about suitable method and to make calculations depending on the characteristics of method.

After a brief discussion about demand forecasting methods, the structure of EFMS is introduced in detail. This paper is supported with a case study so as to show the capability of the method. Finally, the advantages of EFMS are discussed and conclusions are presented.

II. CHOOSING A FORECASTING METHOD

Before a forecasting method can be exercised, one has to select the appropriate method that can make the best use of available data to achieve the required purpose. Choosing an appropriate method among various forecasting methods available requires many considerations on both internal and external factors of the firm. As proposed by Georgoff and Murdick [10], the most essential factors considered for developing EFMS are explained as follows:

Time horizon. Most managers want to extend the results of forecasting as far into the future as possible. However, selection of an approprite method may be more confusing in a long period. An extended time horizon increases the complexity, cost and time required to develop the forecast results.

Urgency. The time needed to produce a forecast can be broken down into development and execution time. Development time includes gathering and entering of the data, modification of programs to the firm's specific requirements and start-up of the system. On the other hand, the time to produce a forecast by a particular method is called as execution time.

Frequency. Sometimes, frequent updates may be needed for the results of forecast. Accommodating frequent updates is an important feature for a method.

Technical sophistication. Experiences show that computer and mathematical skills can be integrated into many methods but high-level quantitative skills and computer capabilities are required for some methods.

Cost. The cost of any method is generally more important during the installation and development phases. Installation and development cost usually exceeds the cost of generating and updating forecasts.

Data availability. Before choosing a method, the forecaster must consider the extensiveness, currency and accuracy of the available data. More and detailed data tend to improve accuracy.

Variability and consistency of data. If significant changes occur in the firm's structure or its environment, the manager must look at the kind of stable relationships assumed among independent variables appeared in the model. If the forecast covers long term or the firm expects a substantial change in a vital relationship, the forecaster should either make judgment or use a quantitative method.

Amount of detail necessary. While aggregate forecasts are easy to prepare, the manager may need specific information (e.g. individual product classes, time periods, geographic areas etc.) to determine quotas or allocate resources. Sometimes a method that can accurately predict individual components and then combine the results into an overall picture may be desired. Otherwise, the forecaster can use one method to provide an overall picture and then use past patterns or market factors to determine the component forecasts.

Accuracy. Sometimes a high-level accuracy may be critical. Also it must be remembered that accuracy alone is not the most important criterion. The forecaster may wish to forgo some accuracy in favor of a method that signals turning points or provides good supplemental information.

Turning points. Because turning points represent periods of exceptional opportunity or caution, a manager may want to analyze whether a method anticipates fundamental shifts. Some methods give false turn signals, so the forecaster must keep in mind not only a method's ability to anticipate changes but also its propensity to give erroneous information.

Form. Whereas some methods make point estimation, the others presents the forecasting results as an interval. It is always advisable to use a method that provides some kind of mean or central value and a range of possible outcomes. If even remotely accurate, such information helps the manager to determine more explicitly risk exposure, expected outcomes and possible distributions.

Forecasting methods can be classified into two main categories [13]: Qualitative and quantitative methods. Qualitative methods use qualitative information such as executive experiences, expert opinion, special events and records of comparable products, and may or may not take the past into consideration. Generally, no historical product demand data is required to conduct qualitative forecasting methods. There are two divisions belonging to the qualitative type; judgment and counting methods. On the other hand, quantitative methods use quantitative historical data and find the estimates mathematically. There are two divisions belonging to the quantitative type: causal method and time series analysis [14].

III. DESCRIPTION OF EFMS

EFMS is developed to aid users in selecting the most suitable forecasting method for service systems. It is explained regarding to the stages proposed by Wilson and Keating [13]: identification and selection, design and system development, implementation and maintenance.

III. 1. PROBLEM IDENTIFICATION AND SELECTION

The importance of ES usage in selecting the most suitable method for service forecasting is taken into consideration at problem identification and selection stage.

Because of being a specific and limited field, method selection problem can well suit for applying expert systems that the domain of application is well defined and sufficiently narrowly bounded so that the successful coding of relevant knowledge is likely. In practice, an expert interprets and assesses the applicability of all methods one by one from basic principles. The task of selecting the best forecasting method with prior considerations among the various influencing factors is a typical management problem suitable for employing the heuristic problem solving model-ES [5].

ES that allows non-experts to draw out qualified decisions can widely assist the businessmen of different management levels who do not possess adequate forecasting knowledge. In addition, many computer programming packages of quantitative forecasting methods are available. Thus, with ES as the consultation tools to perform the judgmental tasks, business people can be well-equipped to generate desirable forecasts on their own even without the help of an expert forecaster. Another advantage of building such an ES is the development versatility to provide easy updating and expanding of the system knowledge so as to cope with the new findings of forecasting methods or ideas concerned.

III. 2. DESIGN AND DEVELOPMENT

EFMS is designed to help users for not only selecting the most suitable method, but also getting detailed information about the selected method and making some calculations by using Minitab. PROLOG is used to build EFMS. It is specially designed and relatively easy to use programming language for expert systems. PROLOG, an expressible language, also requires less computer memory, and mathematical background of users [14]. The EFMS uses “If-then” rules to specify a set of conditions and a conclusion-action follows those conditions. The knowledge-base consists of 22 rules and 17 conditions in terms of questions and facts. For the foundation of the questions prepared as a base to choose the suitable method, it is benefited from the forecaster’s chart proposed by Georgoff and Murdick [10]. The questions are prepared according to the time (span, urgency, frequency), resource requirements (mathematical sophistication, computational background, financial requirements), input (antecedent, variability, internal consistency, external consistency, external stability) and output (detail, accuracy, capability for reflecting direction changes, capability for detecting direction changes, form) factors.

The methods within the scope of the EFMS are given below in terms of qualitative and quantitative methods:

Qualitative Methods. Extrapolation, Sales Force Composite, Jury of Executive Opinion, Scenario Methods, Delphi, Historical Analogy, Consumer Market Survey, Industrial Market Survey and Market Testing.

Quantitative Methods. Moving averages, Exponential Smoothing, Holt’s and Winter’s Method, Adaptive Filtering, Decomposition, Box-Jenkins method, Linear Regression, Input-Output Models and Econometric Models. Hierarchical structure which provides the suitable method selection is exemplified for quantitative methods in Figure.1.

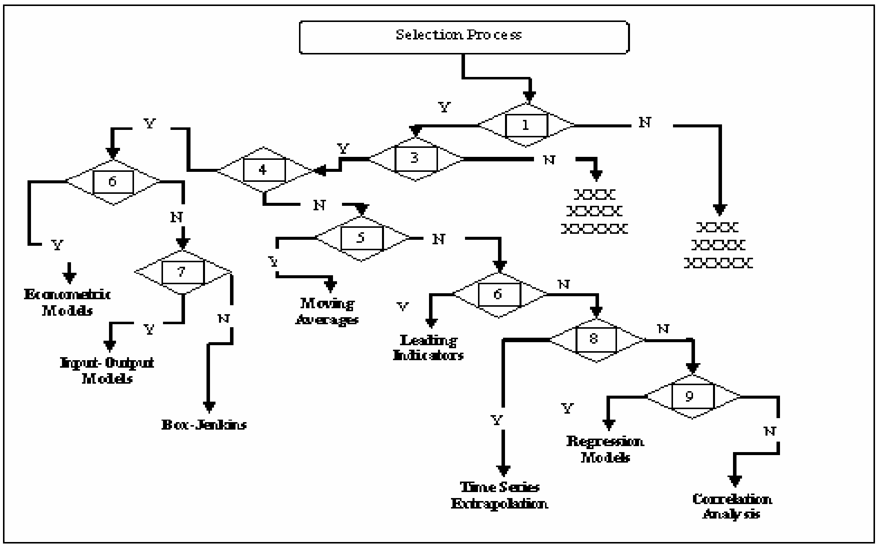

Figure 1. The partial structure of the inference engine mechanism representing quantitative methods (selection of Econometric Models).

The organization of the rules and conditions in the knowledge base of EFMS is expressed in Figure 2.

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Rule(1,"method","Econometric Models",[1,3,4,6])
 Cond(1,"Data are in a quantitative structure")
 Cond(2,"Data are in a qualitative structure")
 Cond(3,"Long-term forecasting is necessary")
 Cond(4,"High-level mathematical and technical background is required")
 Cond(5,"Results should be prepared rapidly")
 Cond(6,"Results are sensitive to significant environmental changes")
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Figure 2. The rules and conditions for Econometric Models.

If the answers of questions #1, 3, 4, 6 are ‘yes’ and #2, 5 are ‘no’, respectively, then the first rule will be applied. When the questions are properly answered, the most suitable method for the user’s expectations appears on the screen. If the answer of the user for a specific question is not in the knowledge base, a warning message is presented on the screen to guide the user either recheck the answers or update the knowledge base.

III. 3. IMPLEMENTATION AND MAINTAINANCE

EFMS has several options to allow users to consult, load, erase and edit the knowledge base, offer help for building the knowledge base, and exit. After loading the knowledge base, the user may start searching for the most suitable forecasting method by selecting the consultation option. When this option is selected, the user will be prompted to answer related questions which are prepared to provide the appropriate method based on the answers.

In order to explain the structure of EFMS, an example regarding to the given rule in the previous section is prepared and depicted in Figure 3. The answers for the questions may be either yes, no, or why. The user may type the first letter of each answer type. It is clear that the answer of a question is “y” or “n”. But sometimes the user may not be sure how to answer a question and/or may want to know why answering that question is necessary. Why option is included into the system for this situation. The user who wants to take fundamental information about the selected method can press any key to go to Microsoft Word environment. Detailed information related to the method and useful information related to the syntax and commands of Minitab can be found in a text file. Minitab is statistical software that is used for calculations to make forecast.

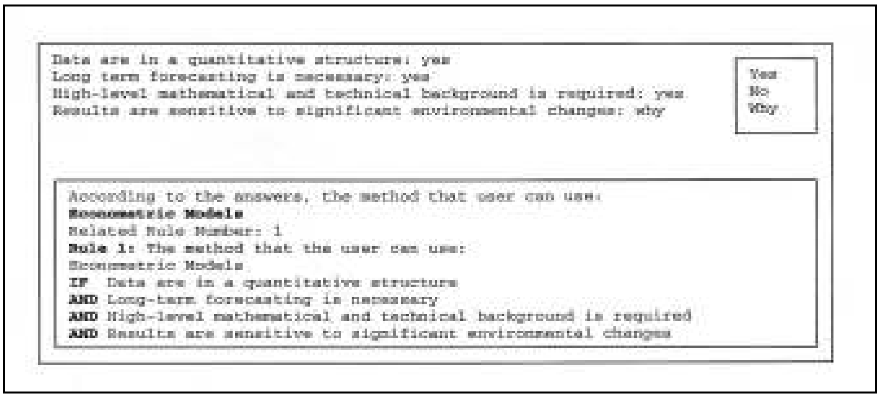

Figure 3. Consultation process in the EFMS.

After giving extra information about selected method, EFMS offers an option to the user whether he/she wants to make calculations. All of the calculations are made by means of Minitab. In Minitab environment the user may either open a worksheet and enter new data into the appropriate column(s), load a worksheet contains data or copy the data stored as excel file to Minitab.

IV. A CASE STUDY

A firm producing refrigerator aims to launch its products to the market with zero defects. The complaints of the customers about the products are transmitted to services and after the problems are solved, the complaints are put into the computer system which will only be seen by the authorities. By this way, the guarantee period is set again with regards to the service failure rates (SFR). Although 4-year data of appearance control defect rate (X_1), electricity control defect rate (X_2), gas leakage control defect rate (X_3), quality index (X_4), receiving inspection control reject rate (X_5), receiving inspection control conditional acceptance rate (X_6) and scrap rate (X_7) which are thought to cause SFR are kept on a monthly base, these factors are not taken into consideration. The SFR are compared to the previous ones and predictions are made by using naive extrapolation, moving average and exponential smoothing methods so there appears a big difference between the estimated SFR and the SFR that occur. Therefore, the most suitable forecasting method to estimate the SFR for a type of refrigerator is selected by using EFMS. In the base of the answers to the questions of the EFMS, the forecasting method suitable for the type of data, data structure, the need and expectations of the service firm is the regression model. The screen occurring with the operation of the EFMS is shown in Figure 4.

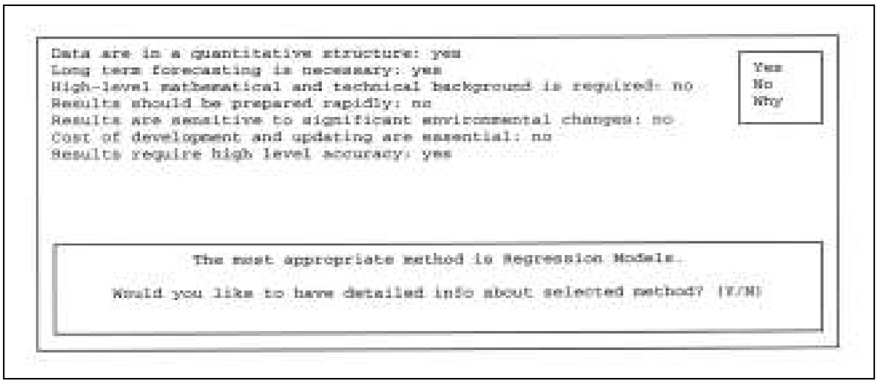

Figure 4. Method selection process for the case study.

The variables needed to be in the regression model with the best subsets analysis are determined as X_1, X_5, X_6 and X_7. Among the linear and nonlinear models obtained by using these variables, a model is selected with standard error of 0.1008 and R^2 of 69.1%.

When we search the previous expert method selectors in literature, none of them is designed to test validity and reliability but Tommy Lo [5] proposes that programming packages of quantitative forecasting techniques can be connected to the ES so as to assess the performance of the artificial advisor directly. In this study, Minitab is connected to the ES to measure the performance. When the SFR of the firm are examined, several time series techniques contains seasonality, cycles and random variations and some causal methods like econometric models are inappropriate to forecast. On the other hand, some suitable methods for the SFR such as naive extrapolation (NE), moving avarages (MA) and exponential smothing (EXPS) are used for the comparative study. The SFR obtained via the regression model are compared to the actual SFR (ASFR) and estimated SFR (ESFR) by using Mean Absolute Deviation (MAD) and Mean Squared Error (MSE) performance measures for the last 4 months and given in Table.1. According to the performance measures, it is seen that the most suitable method is regression models and this fact validates the result of EFMS for this case. It is also possible to support the validity of EFMS by the other case studies.

Table 1. The Comparison of the estimated service failure rates for the case study.

Period	**ASFR**	**ESFR** (Regression M.)	**ESFR** (NE)	**ESFR** (MA-two period)	**ESFR** (EXPS/α=0.4)
1	0.37	0.45	0.51	0.515	0.514
2	0.39	0.49	0.51	0.513	0.512
3	0.51	0.54	0.51	0.514	0.513
4	0.46	0.46	0.51	0.514	0.513
MAD		0.0525	0.0780	0.0815	0.0805
MSE		0.0043	0.0092	0.0098	0.0096

V. CONCLUSIONS

The main purpose of EFMS is to help service firms which are less satisfied with the forecast because of having tendency to use qualitative forecasting methods much more than manufacturers. The EFMS is designed to select an appropriate method between qualitative and quantitative methods with prior considerations among the various influencing factors such as time horizon, technical sophistication, cost, data structure, and amount of detail necessary and so on. For this reason, the knowledge base of EFMS contains both qualitative and quantitative methods in contrast to previous studies that usually use time series methods only.

When the expert forecasting method selectors are compared, it is shown that EFMS helps users not only to select the most appropriate method but also to get detailed information. Additionally, it allows users to make some calculations related to the selected method. Statistical software, Minitab, is connected to the EFMS so as to assess the performance of the artificial advisor directly.

For the introduction of the EFMS a three-stage approach is followed. Why the EFMS is used is mentioned during the problem identification and selection stage.

On the second stage, EFMS, which is composed of knowledge base, inference engine mechanism, and user interface, is introduced. On the final stage, information concerning the operation of the EFMS is given. The knowledge-base consists of 22 rules and 17 conditions in terms of questions and facts. Inference engine mechanism interprets rules in the knowledge-base by means of forward chaining. Finally a case study is introduced to forecast the SFR of a firm producing household appliances. In this study, the most suitable method is selected by using the EFMS and the forecast results obtained with the selected method are compared to those of the firm according to MAD and MSE accuracy measures. By this way, the meaningful contribution of the EFMS is shown on the method selection process.

A forecast-error diagnostician module can be added to EFMS so managers may determine the error resources. In these systems, forecast results are continuously monitored and reported. Another possible enhancement for the system is to develop a knowledge acquisition module for self-learning by capturing expertise on new findings of forecasting methods through interfacing with users.

To reduce the problems which users are faced with, EFMS can be designed to give more detailed information about method's implementation so users will be ready for problems during forecasting process and will make more consistent decisions.

PROLOG was used to build EFMS. Visual programming languages such as Visual Prolog, Visual Basic or Delphi may be preferred to make the user interface more efficient and visual and easy integration with different programs.

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