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An Application of Mixed Method in Forecasting Global Fuel Injection System(FIS) Market

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Abstract:
Increased emphasis of customers on fuel economy and strigent emission norms enforced by countries all over the world has led to some drastic change in global automotive industry. The industry over the years has adopted various new technology in its pursuit to meet various challenges, with fuel injectuion system being one of them. Recent improvements in injection technology is changing the dynamics of automotive industry as a result providing accurate forecasting has become very essential to succeed in current business environment. This paper uses mixed method for forecasting future trends in fuel injection system market. This paper through its analysis offers enough confirmation on the suitability of mixed method model in forecasting applications.

Key words: *Fuel injection system (FIS), Holt-Winters, Autoregressive integrated moving average (ARIMA), Mixed method, Qualitative, Quantitative, and Triangulation*

1. Introduction

The global automotive industry in their ongoing quest to meet stringent emission regulations and fuel economy have adopted fuel injection system (FIS). Most of the cars produced have some sort of FIS fitted in them [18]. Competitiveness in the FIS market over the years has increased tremendously thus placing greater importance on accurate forcasting. For a business to be successful it needs accurate forecast, a survey reported that 93% of the companies have acknowledged that accurate forecasting was one of the important factor that contributed to their business success [19]. Depending upon user-friendliness and level of complexity involved forecasters across the world adopt various quantitative mathematical model to forecast [20]. This paper assesses the application of mixed method technique in analyzing patterns and forecasting global demand of FIS.

2. Research Methodlogy

In recent years mixed method research has gained lot of popularity, with researchers encouraging the use of qualitative and quantitative technique to solve intricate problems [2]. Mixed methods is defined as a technique of social research that combines both qualitative and quantitative tactics and concepts in a single research [3, 7]. While collecting, analyzing and interpreting data in its numerical forms represents quantitative methods, qualitative method consists of narrative forms of data [7]. This method helps researchers to build on strengths of qualitative and quanititative techniques and draw valuable inferences, thus helps researchers better understand the study under consideration [4].

There exists range of research design that are used to conduct mixed method study which vary according to the priority, implementation and integration of data being collected [7]. However, this study uses triangulation technique to collect, analyse, validate and interpret data as represented by figure 1.

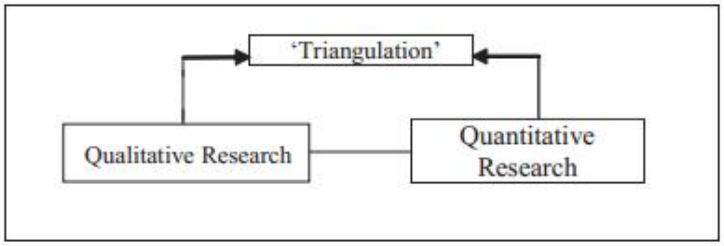

Figure 1: Basic Triangulation model (Sabina Yeasmin, 2012)

The triangulation technique helps to improve the accuracy of results by applying simultaneously and independently both qualitative and quantitative studies [5, 6]. This study makes use of triangulation for its benefit of validation of quantitative instruments with qualitative technique [8]. The main or key purpose is to assess the usage of mixed method in forecasting global FIS demand [1].

2.1. Quantitative Research

For the quantitative part of this study, historical sales data of global FIS were collected and analysed using two forecasting models i.e. Holt-Winters and Autoregressive integrated moving average(ARIMA) model in order to select the most accurate model for the forecasting future demand of global FIS. Holt-Winters and ARIMA are the most popular univariate model used by researchers. Data for the study was collated from various sources such as European Automobile Manufacturer's Association (EAMA), Korea Automobile Manufacturer's Association (KAMA), China Association of Automobile Manufacturers (CAAM), Society of Indian Automobile Manufacturers (SIAM), company annual reports, government publications etc. The Figure 2 plots the historic unit sales of global FIS from January 2009 to December 2013. The analysis was carried out with the help of R-3.0.2 software and user defined analysis using Microsoft excel 2010.

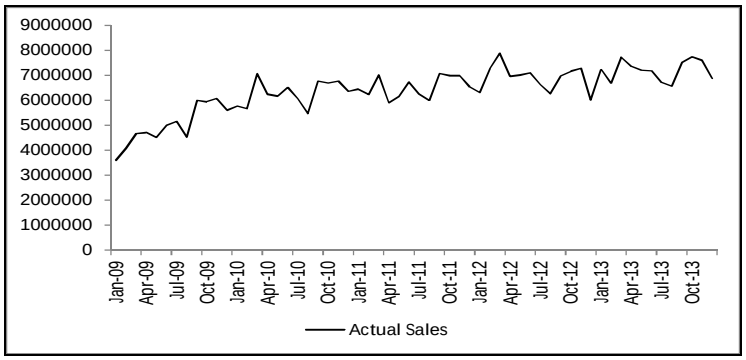

Figure 2: Global FIS historic sales

2.1.1. Holt-Winters Technique

A Holt-Winters forecasting technique has three components: trend (β), smoothing (α) and seasonality(γ). Equations related to Holt-Winters are given below where N is the number of observations, A, T & S are smoothed observation, trend factor and length of seasonal index respectively [9]. 'F' is the forecast for the 'm' periods ahead and 't' is the time period.

$A_t = \alpha (N_t/S_{t-L}) + (1-\alpha)(A_{t-1} + T_{t-1})$ (1)

$T_t = \beta (A_t - A_{t-1}) + (1-\beta)T_{t-1}$ (2)

$S_t = \gamma (N_t/S_t) + (1-\gamma)S_{t-L}$ (3)

$F_{t+m} = (A_t + mT_t)S_{t-L+m}$ (4)

Using R 3.0.2 software the best fit Holt-winters model was selected, table 1 gives the smoothing parameters for the best fit Holt-winters model selected.

Smoothing Factors			
Parameters	Alpha (α)	Beta (β)	Gamma (γ)
Values	0.5171	0.0591	0.4825

Table 1: Holt-Winters parameters

2.1.2. ARIMA Technique

In this section we discuss about the basic ARIMA model. ARIMA, being a univariate model portrays single variable as an autoregressive integrated moving average process [11]. An ARIMA(p,d,q) in its basic form has 3 factor: p an autoregressive factor, a moving average factor q and d, a differencing factor; which is represented as follows [10, 13].

$Z_t = \varepsilon + a_1 Z_{t-1} + a_2 Z_{t-2} + \ldots + a_p Z_{t-p} + \mu - \omega_1 k_{t-1} - \omega_2 k_{t-2} - \ldots - \omega_q k_{t-q}$ (5)

The ARIMA model also consists of a constant ε, an autoregressive operator a and ω is a moving average operator. In this study we use a variant of ARIMA model called Seasonal ARIMA(SARIMA) and are usually used when the series displays seasonal variations [10]. SARIMA model consists of a additional seasonal autoregressive component P, a seasonal differencing D, seasonal moving average component Q and length of time period s, which together form the multiplicative process SARIMA(p,d,q)(P,D,Q)s [10]. For an effective ARIMA model, McGough (1995) and Tse(1997) as a prerequisite had suggested a minimum of 50 observations [11].

The series under consideration for this study was first tested for the presence of unit root or stationarity by means of Augmented Dickey Fuller(ADF) which is represented as follows [14, 11]:

$\Delta Z_t = f_0 + pZ_{t-1} + \varepsilon_t$ (6)

The table 2 and 3 below provides a summary of ADF test. The null hypothesis for the test is that unit root exists whereas alternative hypothesis being that there exists no unit roots or in other words the series is stationary [12]. The unit root test for original series clearly shows it is insignificant at 1, 5 and 10 percent of significance level which led to the rejection of alternate hypothesis. The series was later differenced inorder make stationary. The unit root test conducted on first differencing led to the rejection of null hypothesis as series is significant at all levels of significance level. In other words we can say that data is stationary, thus determining the d in the ARIMA model.

Unit Root Test Values						
Unit Root test	**Test Statistics**	**Probability**	**Critical value for 1%**	**Critical value for 5%**	**Critical value for 10%**	**Results**
ADF	-3.1755	0.1	-4.15	-3.5	-3.18	Fail to reject null hypothesis

Table 2: Summary of unit root test for original series

Unit Root Test Values						
Unit Root test	**Test Statistics**	**Probability**	**Critical value for 1%**	**Critical value for 5%**	**Critical value for 10%**	**Results**
ADF	-5.8871	0.01	-4.15	-3.5	-3.18	Reject null hypothesis

Table 3: Summary of unit root test for first difference values

The best fit ARIMA model was selected based on least Akaike Information Criterion (AIC) and Schwartz Bayesian Information Criterion (BIC) value and are represented as follows:

$AIC = n \ln(R^2) + 2s$ (7)

$BIC = n \ln(R^2) + s \ln(n)$ (8)

In equations (7) & (8), n represents sample size, R^2 is the residual sum of squares and s represents the amount of regressors [7]. Based on the minimum AIC(1345.19) and BIC(1350.74) value the best fit ARIMA$(1,1,0)(0,0,1)_{[12]}$ was selected.

2.1.3. Error Analysis and Inference

As stated earlier, a minimum of 50 observations are needed for an efficient ARIMA model, therefore for consistency purpose, the forecasts from 51st sample onwards were used for error analysis. The error analysis was conducted based on three measurements: 1) Mean square error (MSE) 2) Mean average error (MAE) and 3) Mean average percent error (MAPE). The forecasting accuracy of both models were compared and analysed by means these error measurement.

Error measure			
	MSE	**MAE**	**MAPE (%)**
Holt-Winters	$6.1x(10)^{10}$	176,956	2.48
SARIMA	$8.1x(10)^{10}$	217,236	3.03

Table 4: Error Analysis

The table 4 gives the comparison of error analysis for both Holt-Winters model and SARIMA model. From the table we can see that Holt-Winters has the least MSE, MAE, and MAPE values thus leading to better accuracy than the ARIMA model, as a result Holt-Winters was chosen for forecasting the future demand for FIS. Figure 3 shows the forecast of global of FIS demand for the next 12 periods with 90% confidence limit.

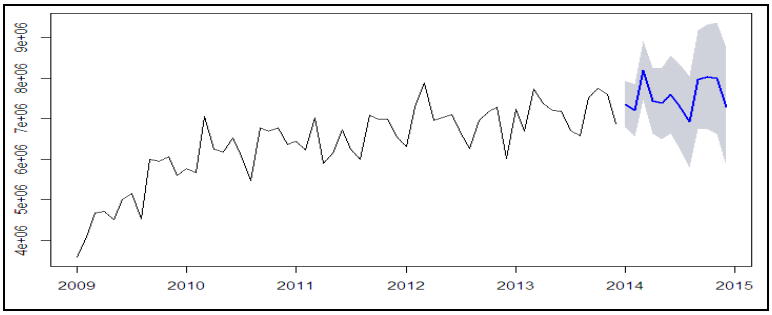

Figure 3: 12 period ahead forecast with 90% confidence interval

2.2. Qualitative Approach

While a quantitative techniques are associated with numerical data, questionnaire, and survey, the qualitative technique include focus group, depth or spot interviews and observational techniques. The qualitative approach is especially useful where there is limitation of knowledge [16]. The qualitative research is form of exploratory research which in mixed method research either precedes or follows the quantitative technique [17]. In this study the qualitative technique has been used as a tool to validate the inferences drawn from quantitative analysis. For the purpose this study, global industry leaders, automobile manufacturers, FIS manufacturers, parts suppliers and automotive consultants who are associated with FIS were interviewed with open-ended questions about the market orientation.

	Very Strong Decline	**Strong Decline**	**Moderate Decline**	**Slight Decline**	**Low Growth**	**Moderate Growth**	**Strong Growth**	**Very High Growth**
Range	< -10%	-10% > -7%	-6% > 3%	-2% < 0%	0% > 2%	3% > 7%	7% > 10%	10%>
No of Participants	0	13	29	26	43	93	8	3

Table 5: Summary of participants response

A total of 215 industry participated in the study and provided insights about FIS market orientation, the table 5 provides summary of the responses provided by the study participants. The table 5 validates and strengthens the quantitative part of the study, with more than 95% of participants saying that future demand for global FIS will vary within the ±10% confidence limit as specified by quantitative section of this study.

3. Conclusion

The paper assessed the use of mixed method in application to forecasting global FIS market. Quantitative analysis was conducted using Holt-Winters and ARIMA model, out of which Holt-winters was selected for forecasting based on the error analysis. The qualitative part of the study was used as a validating tool for the quantitative measurement. This paper through its analysis offers enough confirmation on the suitability of mixed method model in forecasting applications. The use of time series models to provide improved and accurate forecast is a widely accepted phenomenon, however these models are not always accurate. Most times forecasts based sound judgement have provided better results than complex and sophisticated methods thus highlighting the inadequacy of both the models when used independently [21, 22]. There is no harm in using alternative methods which combine both complex models and some basic qualitative technique to get better forecast as the main purpose of any forecast is to facilitate better planning. FIS parts manufacturers and investors can use these forecasting technique to develop more effective strategy to gain comepetitive edge as well as to increase operational efficiency.

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