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Forecasting Global Turbocharger Market: A Mixed Method Approach

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Abstract:
Change in consumer preference had led automotive manufacturers across the globe to adopt turbocharger technology in their pursuit to provide improved fuel economy and engine performance. Turbocharger helps automakers provide better performance in smaller engine, thus making this technology accessible for larger section of the automotive market and increasing the competition in this market. Recent developments in turbocharger technology are fluctuating automotive industry dynamics, so precise forecasting of turbocharger technology acts as a very important factor to sustain in the existing business environment. This paper evaluates the application of mixed methodology which is a combination of qualitative and quantitative research to forecast global turbocharger demand.

***Key words**: Turbocharger, Mixed Method, Triangulation, Autoregressive Integrated Moving Average (ARIMA), Forecast, Holt-Winters, Seasonal Autoregressive Integrated Moving Average (SARIMA)*

1. Introduction

Automotive turbochargers are categorized under forced induction, a system which utilizes the heat energy available from the exhaust gas and compresses the air entering into the engine. This in-turn helps in introducing a greater volume of air-fuel mixture in each cylinder during power stroke; thus boosts the vehicle performance. The emphasis on providing greener vehicles has led manufactures to adopt various turbocharger technologies, thus making it a popular entity in vehicle applications [15]. It is because of these benefits that the competitiveness in the global turbocharger market has increased, thus placing greater importance on accurate forecast. In a survey, 93% companies had acknowledged forecasting as one of the important factor for their success [2]. This paper gauges the usage of mixed method research application in forecasting global turbocharger demand.

2. Research Methodology and Data Collection

Currently there exist several quantitative forecasting methods which fluctuate in their complexity, data required and ease of use [5]. When compared to these quantitative techniques, judgmental method was found to be preferable [6, 7]. But, there exists various studies which say that the judgmental method is less precise, more biased, and lead to poor forecasts [8, 9]. Each forecasting method has its own drawbacks and fits into only limited set of situations, thus considering the situation and the accuracy level, the forecaster have to select the appropriate technique required for the study. In order to generate reliable and accurate forecasts, selecting an appropriate forecasting technique plays a major role [10, 11]. In this paper it has been evaluate the use of mixed method technique to provide accurate forecasting for global turbocharger demand.

In a view of solve intricate problems researchers around the world are encouraging the use of mixed method [12]. Johnson, Onwuegbuzie, and Turner (2005) defined mixed method as a research where quantitative and qualitative research techniques are applied to single study in order gain better understanding. There exists numerous designs in mixed method; however for the purpose of this study triangulation has been used, as shown in figure 1.

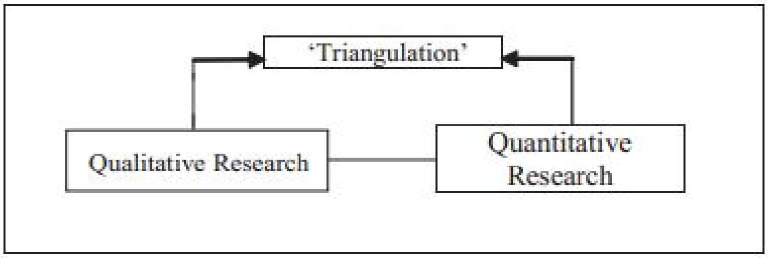

Figure 1: Triangulation model (Sabina Yeasmin, 2012)

Triangulation, in this study is used as a tool to collect, and analyze data. In addition to collecting and analyzing, triangulation is also used to validate the quantitative results with qualitative approach. Triangulation helps provide improved forecasting by applying both techniques simultaneously and independently [3, 4].

2.1. Quantitative Research

Quantitative study is nothing but collecting and analyzing data in its numerical form. The data for the quantitative part of the study was collected from various secondary sources like Society of Indian Automobile Manufacturers (SIAM), European Council for Automotive R&D (EUCAR), European Automobile Manufacturers Association (ACEA), Japan Automotive Manufacturers Association (JAMA), ASEAN Automotive Federation, Society of Motor Manufacturers and Traders (SMMT), company annual reports, government publications and various other sources. This data was analyzed using R 3.0.2 software and Microsoft Excel 2010. The figure 2 provides past sales trend of the global turbocharger market from 2009 (Jan) to 2013 (Dec).

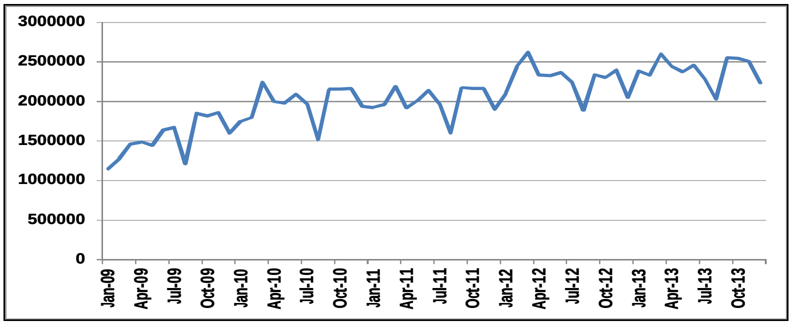

Figure 2: Historical Trend of Global Turbocharger

The quantitative part of study compares two models (Autoregressive integrated moving average (ARIMA), Holt-Winters) and proposes a model for forecasting the turbocharger demand based on the error analysis.

2.1.1. Autoregressive Integrated Moving Average (ARIMA)

Autoregressive Integrated Moving Average process is also known as ARIMA model. It is a univariate (Single Random Variable) model with three parameters (p, d, q) where p is the order of the AR component, q is the order of the MA component and d is the order of differencing. If F_t the series for ARIMA model then it will be represented as following:

- $F_t = r_1F_{t-1} + r_2F_{t-2} + \ldots + r_pF_{t-p} + C_0 + C_1e_{t-1} + C_2e_{t-2} + \ldots + C_qe_{t-q}$ (1)

Where e is the error component, C_0 is a constant, q is the number of lagged terms of e and p is the number of lagged terms of F_t. Since there is seasonality in the series considered, a variant of ARIMA model called Seasonal ARIMA or SARIMA has been considered in the study. The Seasonal ARIMA model contains an seasonal autoregressive component (P) and a seasonal moving average component (Q) which is nothing but a multiplicative process of SARIMA and is represented as (p,d,q)(P,D,Q)[s]. The term "s" in Seasonal ARIMA signifies the length of the seasonal period. The stationarity of the series was verified by conductingthe Augmented Dickey-Fuller unit root test and then differenced accordingly. This test is represented in form of an equation given below:

- $\Delta y_t = \theta_0 + pX_{t-1} + \mu_t$ (2)

The table1 and table 2 given below provides the summary of Augmented Dickey-Fuller unit root test. The hypothesis for the test is given below:

Null Hypothesis: Unit root is present in the series.

Alternative Hypothesis: Unit root does not exist in the series i.e. the series is stationary.

Test Outcomes						
Unit Root test	**Test Statistics**	**Probability**	**Test critical value (1%)**	**Test critical value (5%)**	**Test critical value (10%)**	**Results**
Augmented Dickey-Fuller	-3.1397	0.1141	-4.15	-3.5	-3.18	Fail to reject null hypothesis

Table 1: Original Series- Unit Root Test

Test Outcomes						
Unit Root test	**Test Statistics**	**Probability**	**Test critical value (1%)**	**Test critical value (5%)**	**Test critical value (10%)**	**Results**
Augmented Dickey-Fuller	-5.4128	0.01	-4.15	-3.5	-3.18	Reject alternate hypothesis

Table 2: First Difference Values- Unit Root Test

From table 1 it can be concluded that Augmented Dickey-Fuller unit root test for the original series of turbocharger market is insignificant at 1, 5 and 10 percentage of significance level, thus resulting in alternate hypothesis rejection. In order to make the series stationary the data was differenced. The Augmented Dickey-Fuller unit root test for first differencing values illustrations that the data used for the study is significant at all significance level. Hence based on the findings null hypothesis is rejected.

The next step that needs to be carried out in ARIMA model is to determine p and q component. The best model for the study was selected based on the least value of Schwartz Bayesian Information Criterion (BIC) or Akaike Information Criterion (AIC), using R 3.0.2 software. The equation used to calculate BIC and AIC is mentioned below:

- Akaike Information Criterion = $S \ln(R^2) + 2N$ (3)
- Bayesian Information Criterion = $S \ln(R^2) + N \ln(S)$ (4)

Where S is the sample size, R^2 is the residual sum of squares and N is the number of regressors. Based on the least value of Akaike Information Criterion (1228.61) and Bayesian Information Criterion (1234.16), the best fit ARIMA $(0,1,1)(0,1,1)_{[12]}$ model was selected for the study.

2.1.2. Holt-Winters technique

This technique includes seasonal smoothing (S_t), overall smoothing (Q_t) and trend Smoothing (K_t) parameters. And they can be represented in the form of an equation given below:

- $Q_t = \alpha\ (N_t/S_{t-L}) + (1-\alpha)\ (Q_{t-1} + X_{t-1})$ (5)
- $K_t = \gamma(Q_t - Q_{t-1}) + (1-\gamma)S_{t-1}$ (6)
- $S_t = \beta\ (N_t/S_t) + (1-\beta)S_{t-L}$ (7)
- $F_{t+z} = (Q_t + mX_t)_{Lt-L+z}$ (8)

Where N is the number of samples, Q is the smoothed observation, K is the trend component, S is the seasonal index, F is the forecast for the z periods ahead and t is the index representing a time period. Based on the least accuracy measure like mean absolute error, mean absolute percentage error, mean square error the smoothing parameters ($0 \le \alpha \le 1$, $0 \le \beta \le 1$ and $0 \le \gamma \le 1$) was selected. The seasonality in the data is represented by the gamma value.

Smoothing Parameter Values			
Smoothing parameter	alpha	beta	gamma
Value	0.723232	0.028885	0.95

Table 3: Holt-Winters Parameters

2.1.3. Error Analysis

There has been lot of argument on the minimum number of samples need for efficient ARIMA model with lot of researcher suggesting a minimum of 50 observations [13, 14]. Hence to maintain uniformity in the comparative error analysis, forecast from 51st observation (March 2013) was considered as shown in figure 2.

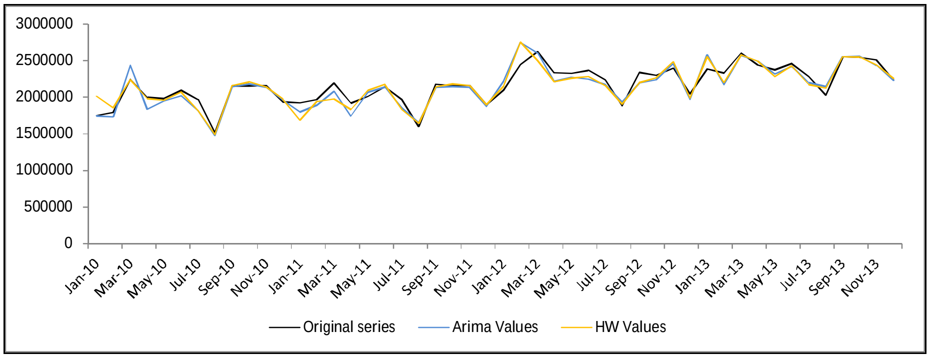

Figure 2: Comparison of Arima and Holt Winters Model vs Original Series

By using various accuracy measures like mean absolute error, mean absolute percentage error and mean square error, accuracy of both the model was measured.

Error Measurement			
	MSE	MAE	MAPE (%)
Holt-Winters	0.42 $\times 10^{10}$	49075	10.8
SARIMA	0.388 $\times 10^{10}$	47659	2.07

Table 4: Forecast Accuracy Measure

From table 4 it can be observed that when compared to Holt Winters model, ARIMA model has the least mean absolute error, mean absolute percentage error and mean square error values. Hence ARIMA model was preferred to forecast global turbocharger market. Figure 3 shows the next 12 months forecast projection of global turbocharger market with 95% confidence limit.

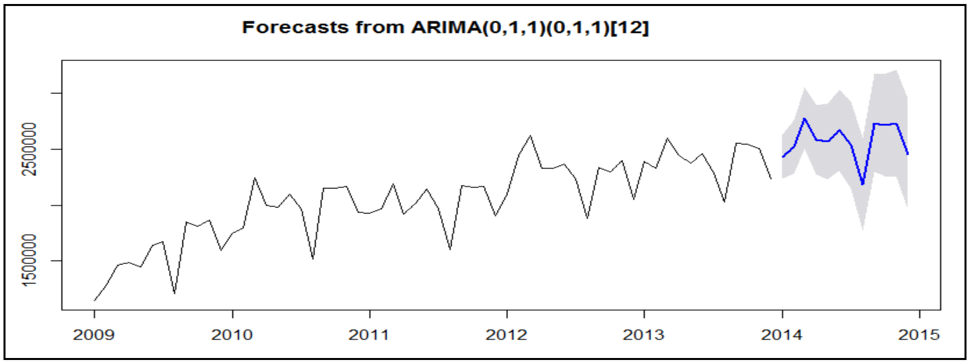

Figure 3: Global Turbocharger Historic Sales Figures

2.2. Qualitative Research

Qualitative Research is a tentative research used to validate the quantitative part of the study. It is preferred when understanding of underlying reasons, opinions, and motivations play a major role in the study. It helps to gain knowledge of the environment or helps to build concepts or hypotheses. In Qualitative Research, there is wide range of data collection methods. Some common technique includes focus groups (group discussions), interviews, and participation/observations. In these study global leaders, automakers, FIS manufacturers, parts suppliers and automotive consultants were intensively interviewed with open-ended questions to understand the market insights and orientation.

	Very Strong Decline	Strong Decline	Moderate Decline	Slight Decline	Low Growth	Moderate Growth	Strong Growth	Very High Growth
Range	-13% < -11%	-10% < -7%	-6% < -4%	-3% < 0%	0% > 3%	4% > 6%	7% >10%	11%>13%
No of Participants	0	0	0	0	3	74	132	28

Table 5: Forecast Accuracy Measure

A total of 237 industry personals have been a part of this study. The insights provided by the industry personals on turbocharger market have been represented in table 5. From Table 5 it can be inferred that more than 95% of participants say that the future demand for turbocharger has a strong growth with a confidence limit of ±5%.

3. Conclusion

In this study Mixed Method has been used as a tool to forecast global turbocharger market. The Quantitative analysis of the study was conducted using ARIMA Model and the outcome was validated by conducting in-depth interviews of global leaders, automakers, FIS manufacturers, parts suppliers and automotive consultants. The suitability of mixed method in forecasting application is further strengthened from this study.

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