Journal of Aeronautical and Automotive Engineering (JAAE)
Print ISSN: 2393-8579; Online ISSN: 2393-8587; Volume 2, Number 1; January-March, 2015 pp. 27-32

http://www.krishisanskriti.org/jaae.html

An Initial Exercise for Obtaining the Effect of Fuel Consumption Reduction on the Growth of Civil Aviation Industry

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Abstract—*Civil Aviation industry contributes towards increasing commutation, trade, tourism and improving standard of living. But, there are many challenges which hinder the growth of aviation industry. One of main challenge is fuel availability, consumption and its prices. In present scenario, fuel consumption reduction has gain importance. This study has provided the empirical justification for the proposed research framework which describes the relationship between Fuel Consumption Reduction (FCR) governing variables and Civil Aviation Growth (CAG). The paper tailors the information for the FCR governing variables and CAG in terms of information development, information evaluation and information refinement. The information is evaluated and refined using exploratory and confirmatory factor analysis. Structural Equation Modeling is used to test the relationship empirically.*

1. INTRODUCTION

Aviation is a critical socio-economic pillar for nations. The aviation industry has in fact gone through a sustained development phase since the first commercial aircraft in service. Airbus [2] reported that since 1960s, aircrafts have become 75% quieter and have reduced fuel consumption by 70%. In 1950, there were just 30 million passenger trips made by air; this grew to over 1,100 million by 1990 [1]. According to the aviation industry, air transport provides 28 million direct, indirect and induced jobs worldwide and carries over 40% of the world trade of goods. But, there are many challenges faced by aviation industry. The foremost challenges in aviation explored by literature are regional connectivity, high fuel consumption, aircraft noise emission, shortage of airport facilities, etc. Among these, fuel availability and fuel consumption originate as high impacting challenges in the present scenario [33]. Limited fuel availability and increasing fuel prices have emphasized the need for fuel consumption reduction (FCR). The Federal Aviation Administration (FAA) and aviation community are striving to provide more fuel efficient operations in the system. The global aviation industry aims to minimize fuel consumption so that the depleting fuel reserves may be utilized in a more efficient and optimum manner. According to Daggett et al.[8], jet fuel originates from crude oil and crude oil is itself a limited natural resource subject to depletion in the near future. A constant increase in demand means that either the present fuel resources have to be increased or fuel consumption itself needs to be arrested as far as possible. The prior case has several constraints upon it, primary of which is the fact that these fuel resources are limited and extinguishing rapidly. Thus the latter emerges as the more prudent course of immediate action; i.e., a reduction in fuel consumption. To achieve these goals, J. Green[10], Daggett et al.[8], Kennedy, Combes, and Bellamy[19] propose five potential areas for FCR, which are aircraft operations, aircraft technology and design, socio economic and political factors, aviation infrastructure, alternate fuels and fuel properties. Singh and Sharma [34] established the relationship between fuel consumption optimization and their five potential areas. In this study, the effect of FCR on the growth of civil aviation industry is explored. This study will identify, evaluate and suggest the relationships among the decision variables of FCR, and their impact on the growth of civil aviation industry.

2. CONCEPTUAL BACKGROUND AND HYPOTHESES

The conceptual domain of FCR includes five factors that affects civil aviation growth (CAG) emerged from various schools of thought. Aircraft technology and design includes engine features and airframe design features. Technology development can be effectively utilized for FCR. Blanco, Hall, and Crichton[4] emphasized that fuel consumption and mechanical reliability are key considerations for innovative aircraft design. D. Green [9] examined the technological potential to improve commercial aircraft energy efficiency and suggested that the fuel consumption reduction is possible by reducing the drag and weight of aircraft. Stenzel, Wilke, and Hage [36] clearly indicated the potential of the riblet technology used to reduce lift or drag for fuel-saving in the aviation sector. Aircraft operations include on ground features, en route features, arrival features etc. Good flight planning, correct aircraft loading, proper maintenance, flight procedures, and fuel tankering etc. have significant impact on aircraft fuel management during its operations. Nikoleris, Gupta and kistler [27] stated that the majority of the fuel consumption and subsequent emissions are from taxiing at constant speed or braking. However, arrival aircraft's fuel consumption and emissions during stops are distinctly lower than departure aircrafts, indicating more uninterrupted surface trajectories for arrivals. Ground delay programmes lead to extra fuel consumption, since the aircraft will typically depart after having absorbed on ground their assigned delay and, therefore, they will need to cruise at more fuel consuming speeds. Alternate fuel properties include physical, chemical and distillation properties of fuels. Khandelwal at al. [20] investigated properties and traits of hydrogen with regard to environmental concerns and viability in near future applications. Since the energy crises of 1970s, all the aircraft companies, aviation sectors, engine companies, and other government organizations have been working towards practicality issues of using alternative fuel in aircraft. An alternative fuel has the potential to reduce fuel consumption as well as to stabilize the fluctuating fuel prices. Verstraete et al.[37] evaluated the potential of hydrogen as a fuel for long range transport aircraft at current and future technology levels. Various socio-economic and political factors of aviation industry such as government regulations, charges and taxes, aircraft scheduling affect the fuel consumption. Itani, Connell, and Mason [14] highlighted the significant impact of the national macro environment factors on a country's air transport sector and suggested including these elements within the context of civil aviation strategic planning. Ryerson and Hansen [31] examined the impact of fuel price on aircraft costs and airline operational strategies by developing two classes of operating cost models for jet aircraft and comparing the results. Aviation infrastructure includes air traffic management features, airport design and geographical conditions of airport. Kazda and Caves [18] suggested that optimum design of taxiways reduces the fuel consumption of aircrafts. Senzig, Fleming, and Iovinelli [32] modeled terminal area fuel consumption and it resulted in fuel consumption reduction. Aviation is one of the fastest growing industries of the global economy. Over the past 20 years, the industry grew by an average annual rate of around 5%. Along with the growth of aviation industry, there are many factors for which its dependence has not been explored yet. One of the factors among them is FCR. The increasing passenger and freight traffic entail a proportional increase in fuel consumption. At the same time, constrained supply due to limited availability and environmental consideration calls for reduction in fuel consumption also. Kumar, A. Sharma, and S. Sharma [23] have developed a model for fuel consumption optimization in aviation industry and obtained the optimized values using neural networking. Now the effect of fuel Consumption reduction on growth of civil aviation industry is studied in this article. Our proposed model (Fig. 1) is based on the assumption that the five governing variables of FCR are all positively correlated with CAG. Briefly there are five path hypotheses(H1,H2,H3,H4,H5) among the five influencing factors and CAG and each path represents a causal relationship with the direction of effect identified as either positive (+) or negative(-).

H_1: FCR governing technology and design based parameters contributes positively towards the growth of civil aviation industry.

H_2: FCR governing operational parameters of aircraft contributes positively towards the growth of civil aviation industry.

H_3: FCR governing alternate fuel properties contributes positively towards the growth of civil aviation industry.

H_4: FCR governing socio economic and political factors of aircraft contributes positively towards the growth of civil aviation industry.

H_5: FCR governing aviation infrastructure oriented parameters contributes positively towards the growth of civil aviation industry.

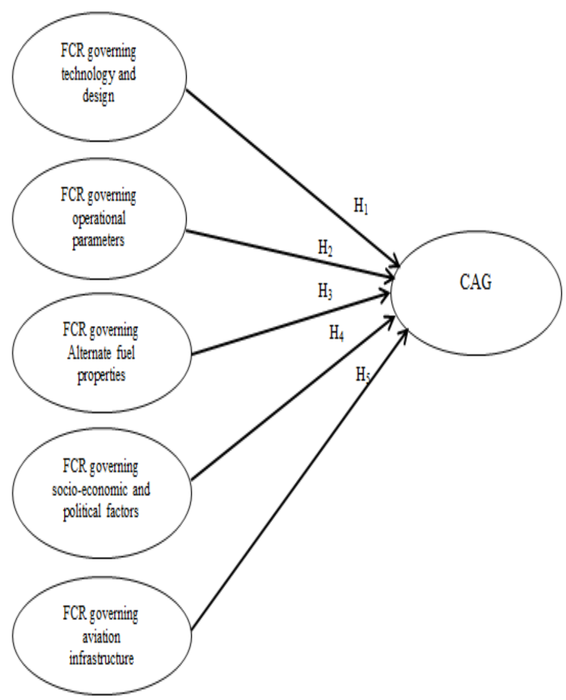

Fig. 1: The conceptual model of the study

3. METHODOLOGY

3.1 Questionnaire design and sampling

A questionnaire was prepared from the explored variables to collect the empirical data. Although, the items and questions in the proposed questionnaire were based upon existing studies, the questionnaire was pre tested by several aviation experts. The questionnaire was developed on a 5 Point Likert Scale, in order to eliminate the unimportant variables. The format of a typical five-level Likert item is 1= strongly disagree, 2= Disagree, 3= neither agree nor disagree, 4= Agree, 5= strongly agree.

3.2 Data analysis

Based on the studies of Lu, Lai, and Cheng[24], Koufteros [21], Koufteros, Vonderembase, and Doll [22], our research steps included exploratory factor analysis, confirmatory factor analysis, and testing of structural model. In the first stage exploratory factor analysis (EFA) using principal component analysis (PCA) with varimax rotation was used to provide the grouping of variables underlying the complete set of items based upon strong correlation. EFA is used to reduce the number of variables, examine the structure or relationship between the variables and evaluate the interpretation. In the next stage, a confirmatory factor analysis (CFA) was used to test the proposed model. CFA is a method to specify and estimate one or more hypothetical models of factor structure each of which propose a set of latent variables to account for covariance within a set of observed variables. In the last stage SEM (Structural equation modeling) technique is used that empirically tests the relationships between CAG and FCR governing technology and design based parameters, FCR governing operational parameters of aircraft, FCR governing alternate fuel properties, FCR governing socio- economic and political factors, FCR governing aviation infrastructure oriented parameters. SEM is a multivariate statistical modeling technique that can allow the simultaneous estimation of multiple equations and can handle large number of variables (endogenous and exogenous) and explain the relationships [12].

4. EMPIRICAL RESULTS

4.1 Exploratory factor analysis

We analyze the civil aviation growth and FCR governing technology and design based parameters, FCR governing operational parameters of aircrafts, FCR governing Alternate fuel properties, FCR governing socio- economic and political factors, FCR governing aviation infrastructure oriented parameters. Principal Component factor analysis shows that two factors with Eigen value greater than one explained 41.370% variance of civil aviation growth. The item whose factor loading is less than 0.5 is removed from the scale. Cronbach's α [7] is a coefficient of internal consistency which is used to estimate the reliability of each factor. Factors whose value of α is greater than 0.7 satisfies Nunnally [28] recommendations. The varimax-rotated factor pattern implies that the first factor concerned 'Contribution of aviation industry' (2 items, α= 0.85) and the second concerned 'Service of aviation industry' (2items, α= 0.81) of civil aviation growth. Similarly, in exploratory factor analysis of FCR governing technology and design parameters, Principal Component Factor Analysis shows two factors, 'factors related to engine features' (6 items, α=0.87) and 'factors related to design features' (7 items, α= 0.82), with Eigen value greater than one explained 48.16% variance parameters. Similarly, in exploratory factor analysis of FCR governing operational parameters of aircrafts, Principal Component Factor Analysis shows three factors, 'factors related to on ground features' (6 items, α=0.85), 'factors related to En- route features' (6 items, α= 0.89) and 'factors related to arrival features' (2 items, α= 0.81) with Eigen value greater than one explained 57.15% variance. Similarly, in exploratory factor analysis of FCR governing Alternate fuel properties, Principal Component Factor Analysis shows three factors, 'factors related to physical properties' (4 items, α=0.85), 'factors related to chemical properties' (2 items, α= 0.81) and 'factors related to distillation properties' (1 items, α= 0.82) with Eigen value greater than one explained 68.29% of variance. Similarly, in exploratory factor analysis of FCR governing socio- economic political factors, Principal Component Factor Analysis shows three factors, 'factors related to social features' (2 items, α=0.81), 'factors related to economic features' (2 items, α= 0.87) and 'factors related to political features' (2 items, α= 0.82) with Eigen value greater than one explained 71.42% variance. Similarly, in exploratory factor analysis of FCR governing aviation infrastructure oriented parameters, Principal Component Factor Analysis shows three factors, 'factors related to air traffic management features' (2 items, α=0.82), 'factors related to airport design' (3items, α= 0.84) and 'factors related to geographical conditions of airport' (1 item, α= 0.87) with Eigen value greater than one explained 70.85% variance. Here, the value of Cronbach coefficient, α, lies in the range of 0.89 to 0.81. The value of α for each factor is greater than the cut off value i.e. 0.7 [28]. Hence, each factor is reliable.

4.2 Confirmatory factor analysis

Confirmatory factor analysis (CFA) is used to test the hypotheses. In CFA it is possible to place substantively meaningful constraints on the factor model such as setting the effect of one latent variable equal to zero on a subset of the observed variables (Albright and Park 2009). CFA requires special purpose software packages such as Mplus, LISREL, Amos, EQS, and SAS/STAT CALIS [3]. Confirmatory factor analysis is used to test the validity. The fit indices calculated in confirmatory factor analysis are used to assess the model [16,12]. In confirmatory factor analysis the convergent validity is given by standardized factor loading, t-value, construct reliability, average variance extracted [12]. The construct reliability lies between 0.72 to 0.89 and the average variance extracted lies between 0.52 to 0.72, the values of construct validity and average variance extracted are greater than the critical values i.e. 0.7 and 0.5 respectively [12]. CFA reduces the 46 variables of FCR into 34 based on their impact on FCR.

4.3 Structural Equation Modelling

SEM is a comprehensive statistical approach for testing hypotheses about relations among observed and latent variables [13]. It is a methodology for representing, estimating, and testing a theoretical network of linear relations between variables [29]. It is used to test hypothesized patterns of directional and non-directional relationships among a set of observed (measured) and unobserved (latent) variables [25]. Confirmatory factor analysis of the proposed model was completed and covariance matrix had 38 measurement items as input. The SEM technique was applied to examine the relation between the hypotheses. The results of hypotheses testing indicate a good fit between model and the observed values. The overall fit indices of the measurement model (x^2= 128 with 40 degree of freedom, p= 0.00001), Goodness of Fit Index (GFI) =0.92, Adjusted Goodness of Fit Index (AGFI) = 0.90, Comparative Fit Index (CFI) = 0.93, Normed Fit Index (NFI) = 0.94, Non Normed Fit Index (NNFI) =0.91, and Root Mean Square Error of Approximation (RMSEA) = 0.061 and the ratio of our model was 2.15. The values of GFI, AGFI, CFI, NFI and NNFI are greater than the recommended threshold value i.e. 0.9. [35, 5]. Hair et. al.[12] stated that if RMSEA < 0.05 then it is considered as good fit whereas an RMSEA > 0.05 and <0.08 is considered as fair fit [17,38,26]. H1, H2, H3, H4, H5 were supported at the p <0.01 and our analysis shows that the FCR governing technology and design based parameters (γ=0.55,t-value=5.68), FCR governing operational parameters of aircraft (γ=0.45,t-value=4.31), FCR governing Alternate Fuel Properties (γ= 0.38,t- value= 3.10),FCR governing socio- economic and political factors (γ=0.42,t-value=3.78) and FCR governing Aviation Infrastructure oriented parameters (γ= 0.29,t- value= 2.78) has positive effect on civil aviation growth. Hence, our conceptual model is totally supported.

5. DISCUSSIONS

Based on the results of structural model, our findings show that the essential factors contributing to civil aviation growth in terms of its measurement are 'factors related to contribution of aviation industry' and 'factors related to service of aviation industry'. Itani, Connell, and Mason [14] suggested that during the process of aviation systems planning governments should perceive the generic conditions which exist in the economy as a whole as equally important to air transport exclusive conditions. The study shows that five governing factors of FCR affect the CAG. Development of new generations of larger and faster aircraft has resulted in an increase in air transport productivity, and a decrease in the average level of noise and fuel consumption [15]. Thus, effective technology and customized design contributes not only to the minimization of fuel consumption but also helps the civil aviation industry to improve their service and contributes towards generating employment and boosting the GDP of a country. The construct effectiveness of FCR governing technology and design based parameters consists of two factors, 'factors related to engine features' and 'factors related to design features' which also contributes towards the growth of civil aviation industry. The next evolved construct is that of FCR governing operational parameters of aircraft that consists of three factors 'Factors related to on ground features', 'Factors related to En route features' and 'Factors related to arrival features'. Airline efficiency can be increased by managing the aircraft operations properly. Effective management of these operations also contributes towards growth of civil aviation industry. The third evolved construct in this study is FCR governing alternate fuel properties. A viable alternative aviation fuel can stabilize fuel price fluctuation and reduce the reliance from the crude oil. Thus, Customized utilization of these alternative fuels affects the growth of civil aviation industry. The fourth construct is that of FCR governing socio economic and political factors. Social, political and economic factors of a country affect FCR. Strategic planning of these factors contributes toward growth of civil aviation industry. Last construct of FCR governing aviation infrastructure oriented parameters consists of 'Factors related to air traffic management features', 'Factors related to airport design' and 'Factors related to geographical conditions of airport'. Aviation infrastructure improvements present a major opportunity for fuel consumption reduction in aviation. Effective management of aviation infrastructure contributes towards the growth of civil aviation industry. Our results support hypotheses because they indicate that FCR governing technology and design based parameters, operational parameters of aircraft, alternate fuel properties, socio-economic and political factors, aviation infrastructure oriented parameters affect positively towards the growth of civil aviation industry. Therefore, this study has provided an empirical justification for the proposed research framework which describes the relationship between FCR and CAG. The findings also revealed the ranking priority of FCR governing parameters that affect the civil aviation growth which are supported with statistical justification and previous findings from literature. Moreover, these factors cannot be ignored as there p- value is less than 0.01 in the research model. The validation of findings indicates that hypotheses related to FCR governing technology and design based parameters are ranked first on priority scale. It may be because many researchers have been investing efforts focusing on aircraft technology and design. Hypotheses H2 emerged ranked second on priority scale which shows that FCR governing operational parameters of aircraft are second most affecting parameters of civil aviation growth. Hypotheses H4 related with FCR governing socio economic and political factors emerged as third most affecting issue on civil aviation growth. FCR governing alternate fuel properties is the fourth most affecting factor to civil aviation growth evolved in findings. Cecere et al. [6] illustrated the various applications of hydrogen fuelled engines that can be successfully used for civilian transport. Finally, FCR governing aviation infrastructure emerged as the last factor affecting civil aviation growth.

6. CONCLUSION

The research work presented in this paper makes contribution in a variety of ways. It uses empirical methods to evaluate the relationship between FCR and CAG. The findings of this study emphasize the importance of FCR for the sustainability and growth of the aviation industry. The knowledge of relationship among variables can lead to the framing of an objective function, constraints, and set of equations pertaining to situations with regard to aviation industry of a country. To constitute the equations, data of identified critical factors with regard to aviation industry of a country can be utilized, which will help develop an optimization based model for fuel consumption. This encapsulates the scope for further study. This study produces the results which represent the base for optimum solution of fuel consumption on which future researchers can build upon.

7. LIMITATIONS AND FURTHER STUDIES

There are several limitations to this study. First, for the growth of civil aviation industry output, we restricted the analysis to only four indicators due to the unavailability of reliable data on other outputs. Only positive impacts of civil aviation growth are considered in this study. A future study is suggested to include other variables for civil aviation growth. Secondly, cross- sectional data was used for association of variables. In future, longitudinal research can be designed to present the evidence of causation which cannot be achieved through cross sectional design. The model developed in this study is restricted to civil aviation industry. Future study could use it to test for military aviation industry as well. Finally, further studies can also include even more variables.

8. ACKNOWLEDGEMENTS

This work was supported fully by a grant from the TEQIP-II.

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