Identification of Dimensions of the Optimization of Fuel Consumption in Air Transport Industry: A Literature Review

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Abstract
The objective of this paper is to identify the parameters regarding the fuel consumption optimization in air transport industry. Today due to high oil prices, energy crises, boomed competition, and traffic growth, fuel consumption is becoming a critical aspect in aviation industry. Therefore in such a highly competitive environment optimization of fuel consumption is essential in the airline industry for the survival of an airline. This literature reviews the various journals, articles, conference papers, and thesis work etc. related to fuel consumption in aviation industry after the Arab oil embargo in 1973 to 2010. Literature review identifies the several parameters which effect the fuel consumption in airline. This paper also suggests the importance of research gaps and bridging of research gaps for the optimization of fuel consumption. Current research effort for the optimization of fuel consumption needs a holistic model for customized optimization of fuel consumption. For developing the holistic model the study identifies parameters which effect the fuel consumption in aviation industry. This work develops informational framework of optimization of fuel consumption. The evaluation of informational framework will be done in term of reliability and validity checking. The extracted information will further be subjected to factor analysis. This study would form an input for aviation sector to achieve optimal fuel consumption.
Keywords: Aviation industry, Fuel consumption, Optimization

1. Introduction

Aviation industry is one of the fastest growing industries in the world. Aviation industry has contributed more than anything else to the increased commerce, communications, trade, and tourism among the industries of the world. Beside this growth today's airline industry are facing challenges like, fuel consumption , oil prices , air-traffic, high competition, economy crisis , aviation emission , safety , design and operational challenges. In this study among all these challenges fuel consumption was taken as one of the major challenge facing aviation industry. Due to high oil prices and boomed competition fuel consumption is becoming a critical aspects in aviation industry. Widespread improvements in the global economy during the past year have also been fueling demand and inflating the price of oil. High oil prices led to increases in ticket prices. In 2011, Southwest Airline, Delta Airline, JetBlue, American, and United Airlines have increased their airfares and this was due to higher costs of fuel. JetBlue and Southwest Airlines said that they earned a penny per share in the first quarter of 2011 as higher demand and airfares helped them to offset the rising cost of fuel. United Continental and American Airlines reported loss per share in first quarter of 2011, as it dealt with rising price of fuel, winter storm, and weakened demand in Asia (ATA Smart Brief, 21 April, 2011). According to A. Majka, (2007) at one time fuel extraction cost and availability had little impact on the evolution of aviation industry but today fuel conservation is one of most critical concern to aviation industry and according to International Petroleum Finance News, (2008) jet fuel currently accounts for 36% of airline operating expenses, up from historical average of 12%. Mohammad Mazraati, (2010) pointed out toward the continuously increased fuel consumption. Fuel is one of major direct operating cost parameter in the aviation industry. Economy of a country largely depends on fuel prices. Increases in fuel consumption affect the airlines in two ways; direct impact on the cost of operation, and decline in demand for air travel and air cargo. Today most of the airlines are struggling to keep their financial viability and facing operational difficulties. Therefore in such a highly competitive environment in order to reduce the direct operating cost of an aircraft, the optimization of fuel consumption is essential. Optimization of fuel consumption in aviation industry will further help in economic and social development, reduce the fuel consumption, conserve the aviation fuel, enhance the efficiency of aviation operations, and reduce the cost of air travel. Many research studies are going on for the optimization of fuel consumption in aviation industry but these study deals with separate aspects like optimized design, optimized operations, alternative fuels, and aviation infrastructure etc. several model have been proposed and some study suggests the fuel saving & conservation measures. While the researchers have made the significant effort on new technology & product design, optimized operations, and alternate fuels etc. for the optimization of fuel consumption in aviation industry, certain important issues remain unexplored. But a collectively effort is still needed to blend all these aspects in a customized manner.

This paper is organized as follows. Section 2 of this paper present methodology of the study. Section 3 reviews the literature of potential areas of fuel consumption optimization. Section 4 discusses the research gaps of the studied literature. Section 5 shows the importance and bridging of research gaps. Section 6 identifies dimensions of optimization of fuel consumption from the literature. Section 7 presents limitation of the study. Section 8 concludes the study and suggests the future work.

2. Methodlogy

The literature review was begun by searching several databases such as Science direct, Jstor, Emerald, MITRE, RAND, AIAA, ICAO, IATA, CAAFI , Thesis work on aviation, several and other articles written in the past years. The attempt was made to review more recent articles due to rapid pace of the growth of the aviation industry. The identification of parameters was done on the basis that the parameters which effect fuel consumption in direct and indirect way in the literature were taken. Logical reasoning and mathematical relationships were taken into the account while identifying the parameters from literature. The parameter which was appeared in two or more two areas was only explored once, on the basis of by seeing their relevance to potential areas of fuel consumption optimization. Identified parameters were divided into primary dimension, secondary dimension, and decision variables

3. Reviewing the Potential Areas of Fuel Consumption Optimization in Aviation Industry

To date, studies that focus on the aviation fuel consumption, fuel conservation, fuel burn reduction, list the factors one must consider fuel consumption optimization. Most of the studies on the aviation fuel, fuel optimization, fuel conservation, fuel efficiency improvement, fuel burn reduction, and alternate fuel were begun after Arab oil embargo in 1973. After the oil crises people had known that the fuel is a limited natural resource and will subject to depletion sooner or later. Here the five potential areas of aviation industry; technology & product design, operational area, alternate fuels & fuel properties, socio-economic & political, and infrastructural are reviewed for the identification of parameters of optimization fuel consumption. These areas have the significant effect on the fuel consumption in aviation. This section reviews the literature regarding the study since from 1973 to 2010 and their key findings.

3.1 Technology & Product Design

The rise in fuel prices has led to the increase in ticket prices of the air travel. So saving fuel is the most efficient way of saving money and to reduce the tariffs. Today technology development is going on at a rapid rate and we can effectively make use of this technological revolution to reduce the fuel consumption of a commercial aircraft. Improvement in aircraft fuel efficiency depends upon the design of the engine and airframe products. Evolutionary developments of engine and airframe technology have resulted in a positive trend of fuel efficiency improvements. Design features are generally related to the products and aircraft configuration. The merging technology and design feature finally leads to the fuel consumption optimization. New material technology has also high impact on fuel consumption. The reduction of aircraft weight can be achieved by the introduction of new material technology and advance structural design. There are various conventional methods of saving fuel mostly used in commercial airline industry, and some of them are, towing the aircraft rather than taxiing, reducing the quantity of potable water and reserve fuel to reduce the weight. But nowadays new methods and technical expertise is there to develop more efficient designs of the aircraft. For an aircraft a lot of energy is wasted in overcoming the resistance offered by the ambient air during the flight. This resistance is termed as drag. An efficient design can reduce the amount of drag and thus reduce the fuel consumption of the aircraft. To deal with the improvement of external design of the aircraft to reduce the drag, a field of science called aerodynamics comes in picture. Aerodynamics is extensively used in the design of an aircraft. An aircraft can be designed for high speed or low speed. A high speed aircraft comes with a high fuel usage and a low speed aircraft with low fuel usage. For slow speed aircrafts larger wing area is required to produce the necessary lift which in turn increases the frontal cross sectional area leading to an increase in drag. Therefore an optimum balance is required in such situation to increase the fuel efficiency. To achieve this optimum balance, design of the aircraft should have good aerodynamics. Aerodynamics deals with the drag of an aircraft at a given velocity and weight. There are two types of drag which act on an aircraft: induced drag and parasite drag. Induced drag is the drag force occurs in airplanes due to wings or a lifting body redirecting air to cause lift. Lower is the speed of the aircraft, larger is the angle of attack needed to produce the necessary lift, thus larger the induced drag. A reduction in weight of the aircraft reduces the angle of attack required for a given velocity and thus reduces the induced drag. A finite element analysis of the aircraft structure can result in a lighter structure of the aircraft capable to carry the given amount of payload and fuel, thus reducing the gross weight of the aircraft. High strength light composite materials are available in the market (for example carbon fiber) which can be used to manufacture the structural components of the aircraft, to reduce the weight of the aircraft. Parasite drag (also called skin friction drag) is drag caused by moving a solid object through a fluid medium. For a given air density and velocity parasite drag is a function of how aerodynamically clean the aircraft is and of the wing area. A better aerodynamic profile and smooth surface of the aircraft can reduce the parasite drag on the aircraft. Propulsion technology used in the aircraft is also one of the major factors deciding the efficiency of the aircraft. More efficient turbofan engines can reduce the fuel usage. A lot of research is going on to improve the design of the turbofan engines used in aircrafts for the efficient utilization of the fuel. An aircraft designer faces many tradeoffs for example, there is tradeoff between fuel and time, tradeoff between cruise performance and takeoff and landing performance. This study explores the parameters which effect the aviation fuel consumption. Explored parameters would form an input for aviation sector to achieve optimal fuel consumption.

Aircraft design has long been recognized as one of the most difficult and challenging problems in aviation industry. This study tries to review the aircraft design & technology parameters which effect the fuel consumption. David L. Greene, (1990) examined the technological potential to improve commercial aircraft energy efficiency. He suggested that the fuel consumption reduction is possible by reducing the drag and weight of aircraft. He also suggested some major improvement in the fields of engine efficiencies, aerodynamic, and structural changes of aircraft. Engines, airframe, bypass ratio, light weight material, weight, and drag were the major parameters explored in this study. Joosung Lee, (2000) and Raffi Babikian, (2002) studied the aircraft technological performance. Specific fuel consumption, lift/drag, operating empty, and maximum takeoff weight were the major technological variables which effect the fuel consumption of aircraft. ICAO environmental report, (2007) and IATA technology road map, (2009) points towards technological improvements. Parameters explored in these studies were; Propulsions systems, engines and nacelle weight, materials, structures, and aircraft systems etc.

Rajkumar Pant and J. P. Fielding, (1999) studied the aircraft configuration and flight profile optimization using simulated annealing. Wing aspect ratio, wing area, wing taper ratio, wing thickness ratio, real fuselage length factor, takeoff flap deflection, takeoff mass, mission fuel mass, maximum takeoff power, climb throttle, climb speed , cruise mach number, descent speed, cruising altitude, cruise stage fraction, and balance field length were the main design variables explores in this study. Nicolas E. Antoine and Ilan M. Kroo, (2002) and (2005) studied the aircraft optimization for minimal environmental impact. Explored parameters were ; maximum takeoff weight , wing reference area, wing thickness over chord, wing location along fuselage, wing aspect ratio, wing taper ratio, wing sweep, horizontal tail area, turbine inlet temperature, bypass ratio, engine pressure ratio, initial cruise altitude , final cruise altitude, and cruise mach number. Surya N. Patnaik, (2004) studied the subsonic aircraft design optimization with neural network and regression approximators. Aircraft weight, wing aspect ratio , engine thrust, wing area, sweep angle, thickness to chord ratio, turbine inlet temperature, overall pressure ratio, bypass ratio, and fan pressure ratio were parameters explored.

Ryan P. Henderson, (2009), J.J. Alonso, P. LeGresley, (2009) and J. Vankan , (2009) studied the aircraft design optimization. Explored design parameters in these study were; Maximum takeoff weight, wing reference area, wing aspect ratio, wing sweep angle, wing longitudinal position, initial cruise altitude ,final cruise altitude, range, payload weight, cruise mach number, number of engines, thrust specific fuel consumption. studied the multiobjective optimization of aircraft range and fuel consumption engine , airframe, span, chord, sweep, takeoff weight, and cruise altitude were the major parameters discussed in this study. Daniel Neufeld, Joon Chung, and Kamaran Behdinan, (2008) developed a flexible multi-disciplinary optimization framework for aircraft conceptual design. This study allows a high degree of freedom in the implementation of different objectives, constraints, and disciplinary analysis. Explored design variables were; Wing span, wing area, wing taper ratio, wing diehedral, wing sweep, horizontal tail span, horizontal tail area, horizontal tail taper, horizontal tail diehedral, horizontal tail sweep, vertical tail span, vertical tail area, vertical tail taper, vertical tail sweep, fuel mass, cruise altitude, fuselage configuration. Geoffrey C. Bower, and Ilan M.Kroo, (2008) studied the multi objective aircraft optimization for minimum cost and emissions over specific route networks. The explored design parameters were; maximum takeoff weight, maximum zero fuel weight, wing loading, wing aspect ratio, wing taper ratio, wing quarter chord sweep angle, wing average thickness to chord ratio, horizontal tail area, wing location on fuselage, thrust to weight ratio , overall pressure ratio, fan pressure ratio ,and turbine entry temperature.

3.2 Operational Area

Aircraft consumes large amount of fuel during its takeoff, climb, cruise, descent, and landing phases of flights. The amount of fuel consumed by an aircraft during its operation from one airport to another depends upon several factors and parameters. Most of the factors are directly controlled by airlines with proper operations planning and strategies. Good flight planning, correct aircraft loading, proper maintenance, flight procedures, and fuel tankring etc. have significant impact on aircraft fuel consumption during its operations. Operational improvements increase the performance of any of the aircraft. Airline efficiency can be increased by managing the aircraft operations properly. Through proper flight planning aircraft fuel consumption can be reduced. Weight, speed, and wind resistance are the major parameters which effect the fuel consumption to a greater extent during the operations of aircraft. Reducing the weight will reduce the fuel consumption because for lighter the engine will work less. There are several methods which reduces the weight of the aircraft. This includes the using one engine while taxing, using ground tugs for aircraft movement on ground, using ground electric power instead of onboard power, removing non essential items, and proper fuel tankering etc.

David A. Pilati, (1974) explained the energy use and conservation alternative for airplanes. He evaluated the fuel saving for various energy conservation strategies and he discussed how to implement these fuel saving strategies. John W. Drake, (1974) suggested the slower cruise speed, flight profile optimization, and reduced fuel tanking for fuel consumption reduction. D.N. Dewees and L. Waverman, (1977) highlighted the energy conservation policies for the transport sector and they evaluated the conservation policies for railroads, trucking, bus, and including airlines. D. Wayne Darnell and Carolyn Loflin, (1977); Barry Nash, (1981); John S. Stroup,and Richard D. Wollmer, (1992); Zouein, Abillama and Tohme,(2002); Khaled Abdelghany,(2005) developed the fuel management models and all these models resulted in fuel saving. R. R. Covey, (1979) explained the operational energy conservation strategies in commercial aviation, he explained the twelve fuel conservation strategies and these strategies were resulted in fuel saving. David J. Goldsmith, (1981) and Rob Root, (2002) suggested the airliner and airframe maintenance for the fuel saving. Henry S.L. Fan, (1990) discussed the fuel conservation during the ground operations. He discussed the fuel saving during single engine taxiing, and towing the aircraft between terminal area and runways. Burno Miller, (2001); Florentina Viscotchi, (2006); Airbus report getting to grips with fuel economy, (2004); ICAO, (2005) APIRG/15-WP/41; Thomos Andrew Box, (2006) suggested the operational measures for fuel conservation and fuel burn reduction. Pedro Miguel Faria, (2009) studied the regional airline's operational performance and appropriate enhancement techniques. Sherry Lance, (2009) explained the approach for reducing the airline fuel consumption through ground delay program. Raffi Babikian, (2002), and Joosung Lee, (2010) explored the operational parameters which effect the aircraft fuel consumption.

3.3 Alternate Fuels and Fuel Properties

Aviation alternative fuels can also play an important for the optimization of aviation fuel consumption. Since the energy crises of 1970s, all the aircraft companies, aviation sectors, engine companies, and other government organization are working for practicality of using alternative fuel in aircraft. A viable alternative aviation fuel can stabilize fuel price fluctuation and reduce the reliance from the crude oil. Due to the high growth rate of aviation sector, supply security of fuel, and environmental impact of fuel has caused the aviation industry to investigate the potential use of alternative fuels. But now due to increase of oil prices and fuel consumption the research in this field has been became important. Jet fuel is going to deplete sooner or later, therefore we are looking for alternative fuels. Today numbers of flying aircrafts and fuel consumption have been doubled and it is difficult to maintain the future crude oil demand. Therefore it is essential that alternatives to crude oil be developed to reduce the fuel consumption and fuel prices. There are numbers of alternative fuel options for aviation such as synthetic liquid fuels, bio-jet fuel, ethanol, fuel and hydrogen. The most likely alternatives for aviations are those which are having similar properties like conventional fuel. Jet fuel should be very energy dense because the aircraft has limited volume and weight capacities. The fuel having less energy content reduces the aircraft range. High volumetric energy content maximizes the energy that can be stored in a fixed volume and thus increase the flight range. Aviation fuel also needs to be thermally stable, to avoid freezing at low temperature and to satisfy other requirement in term of ignition properties, surface tension, and compatibility with the aviation material. Best alternative fuel amongst the alternative fuels can be compared on the basis of compatibility with current systems, fuel production technology, chemical, physical, and thermal properties of fuel. This study tries to identify the various aviation alternative fuels of present term, midterm, future fuels, and their properties which effect the fuel consumption in aviation industry.

N. Veziroglu and F. Barbir, (1992) compared the hydrogen with conventional and unconventional fuels, and concluded that hydrogen has the best characteristic and Robert O. Price ,(1991) explained the potential of liquid hydrogen relative to conventional jet fuel. Tim Edwards, (2002) described the composition and selected properties of kerosene fuel for use in aerospace application. Military jet fuels JP-5, 7, 8 and T-6, commercial jet fuels jet A, jet A-1 and TS-1, and kerosene rocket- propellants RP-1 and RG-1 were discussed. The properties which were studied include the approximate formula H/C ratio, boiling range, freeze point, flash point, and specific gravity. He also calculated the heat of formation of these fuels. Appearance, composition, volatility, fluidity, combustion, corrosion, stability, contaminants, conductivity, lubricity, and additives were suggested by the Aviation Fuel Quality Requirements for Jointly Operated Systems, (2005). Chevron, (2006); kazuhiro Tsuchida (2007); David L. Dagget, (2007); James Hileman, (2008) studied the alternatives fuels and their properties. Simon Blakey, Lucas Rye, and Christopher Willam Wilson, studied the aviation gas turbine alternative fuels and their properties.

3.4 Socio-Economic, & Political

Aviation is the fastest growing sector of economy. It provides the number of social and economic benefits. There are many social, political, and economic factors which effect the airline fuel consumption optimization. If these factors are carefully managed then significant amount of fuel can be saved. These factors includes the ways of airline operations, training , maintenance , reservation, fuel prices, ticket prices, taxes, aircraft scheduling, planning , routes, labour, airways , and social awareness etc. The work is going on; scheduling, collusion among the competitor, route swapping, labor flexibility etc. but most of these factors remains largely unexplored. These factors sometimes may be individual and sometime blend of one another. These factors affect the fuel consumption to greater extent e.g. schedule smaller, older aircraft which may burn less fuel, probabilistic tanning planning also saves the fuel. Also the rise in fuel prices and taxes reduces the fuel consumption. The social, political, and economic factors needs to be expressed convincingly which will provide the input for optimal fuel consumption in airline industry.

John W. Drake, (1974) studied the fuel saving measures and constraints in airline fuel optimization of airline operation, training, maintenance and reservation policies, scheduling, planning and routes, airways and labour. He also explained, how the Government approved collusion among the competitor for route swapping and labour flexibility. All these measure were for the reduction of fuel consumption. All these measure were for reducing fuel consumption. Mazraati, (2009) explained the effect of jet fuel prices, airline ticket prices on the fuel consumption and travel demand. Joosung J. Lee, (2010) suggested the social pressure and public awareness for fuel burn and emission reduction. Larry M. Austin, (1976) optimized the procurement of aviation fuel for defense industry. D. N. Dewees and L. Waverman, (1977) studied the recent government policies and fuel taxes for the fuel conservation of airline and transport sector.

3.5 Infrastructural Area

Aviation infrastructure also plays an important role in fuel consumption optimization. Infrastructure improvements present a major opportunity for fuel consumption reduction in aviation. Airport congestion and improper air traffic management increases the fuel consumption. Airport congestion occurs whenever the actual traffic demand is greater than what the system can handle without the delay. Better airport design and route redesign can also reduce the fuel consumption. A new form of Air Traffic Management is being introduced, with the aim of redesigning routes around the performance of the flight, managing the optimized use of airspace. Scientists and aviation experts worldwide are investigating improved air traffic management, route redesign, better airport design, and fuel acquisition to reduce the fuel consumption.

Larry M. Austin and William W. Hogan, (1976) developed POLKA model for optimizing the procurement of aviation fuel. David A. Van Cleave, (2009) suggested the reduction in the level-offs of terminal airspace and using cross runways in the airports for reducing the fuel burn. Anderson R. Correia, (2005) suggested that the airport's design, influences the aircraft fuel consumption in maneuvering on the airport between the runways and terminals.

Antonin Kazda and Robert Caves suggested that the optimum design of taxiways reduces the fuel consumption of aircrafts. Anthony Andrews, (2009) department of defense studied the fuel spending, supply, and acquisition. Rapoza, Amanda, (2010) studied the factors affecting fuel burn and fuel flow rate in aircraft departure and arrival. All these studies explore the several parameters effecting the aviation fuel consumption.

4. Research Gaps of the Studied Literature

From the literature survey several research gaps were indentified in the previous studies in the field of optimization of fuel consumption in aviation. Technology and product design plays an important role in the fuel consumption optimization. Propulsion systems, airframe & structure design, materials, and aircraft systems effects the aircraft fuel consumption to a greater extent. In this field most of the studies are concerned with a particular element of fuel consumption instead of looking at the holistic fuel consumption optimization architecture. This study identifies the several gaps; some of the studies deal separately with turbofan, turboprop, and rotor engines, structure and airframe design, aircraft size, and material etc for the optimization of fuel consumption. In the most of studies the integration of fuel consumption modeling in the product design for fuel consumption optimization is not solved satisfactorily. Most of the fuel consumption models are used for estimating the fuel consumption rather than reducing the fuel consumption.

A large amount of fuel is consumed during the aircraft operations takeoff, climb, cruise, descent, and landing phases of flight. Several studies have been conducted for the operational performance of the aircraft during the different phases of flight. Researchers suggested several, optimized operations, fuel conservation strategies, models for the fuel ferrying & tankering and aircraft maintenance for the fuel consumption optimization. But study still lacks a comprehensive and parametric analysis which can conserve the maximum energy on minimum input.

Alternative fuels can also optimize the aviation fuel consumption. Research work is going on the several alternative fuels and fuel properties. But the comprehensive comparison by utilizing Analytic Hierarchy Process to select the most feasible alternative fuel, supported by questionnaires survey to aeronautical engineering and aviation fuel experts is identified as major research gap in this field for the fuel consumption optimization.

Social, political, & economic aspects related to airline fuel consumption can also optimize the aviation fuel. These aspects include the training, maintenance, reservations policies, taxes, fuel prices, aircraft scheduling, planning and routes, airways, social awareness and labor etc. The major research gap in this field was that unexplored mathematical relationships, and decision variables were absent from study regarding the fuel consumption optimization in aviation industry.

Aviation infrastructure effect the fuel consumption to a larger extent. Several research works is going on air traffic management, airport design and use, fuel storage, and transportation etc. But certain parameter in these areas remains largely unexplored of the optimization of fuel consumption

5. Importance and Bridging of Research Gaps

Identified research gaps are very important for the fuel consumption optimization in aviation industry. Most of the fuel consumption optimization studies are concerned with a particular field of aviation industry i.e. product design, operational, alternate fuels & properties, social, political, & economic, and infrastructural. This leads to highly specific model to particular area rather than generic model. Most of the studies are not easily auditable and transparent. The fuel consumption optimization study should show the variables and parameters which have the most impact on the fuel consumption process. In some studies some of the important decision variables which effect the fuel consumption were not considered but this study tries to consider all the decision variable from different fields i.e. product design, operational, alternate fuels & properties, social, political, & economic , and infrastructural fields of aviation industry. While researchers have made significant efforts on new techniques and approaches for the optimization of fuel consumption, certain important issues remain largely unexplored. First, it is not challenging to find methodologies and approaches for the technology & product design area, operational area, alternate fuels & fuel properties area, social, political, & economic area, and infrastructural area, but in understanding how to blend them together for tailoring of fuel consumption optimization. There is a need for developing holistic model for customized optimization of fuel consumption that aims on translating optimization process into global competitive advantage. Another observable omission in the past literature is the missing link among five technology & product design, operational, alternate fuels & fuel properties, social, political, & economic, and infrastructural areas of aviation industry. To address this neglect, the present study attempts to develop a model for optimization of fuel consumption, which uses multi criteria decision making phases. Development of a significant bond among five potential areas of fuel consumption, not only creates harmony among them, but makes optimization of fuel consumption more effective.

For the bridging the research gaps the study needs conceptualization of a multi variable construct by selecting the decision variables from the technology & product design , operational area , alternate fuel and fuel properties, social , political , & economic, and infrastructural areas of aviation industry for fuel consumption optimization. After that an informational framework is needed. This informational framework should be checked for reliability and validity. This leads to development of a model of fuel consumption optimization in aviation. After that it needs a comprehensive set of conclusions of fuel consumption optimization.

6. Identifications of Dimensions

Table 1. Shows the identified dimensions from literature for the optimization of fuel consumption in airline industry.

7. Limitation of the Study

The literature review has some limitations. First limitation is that limited number of articles, journals, reports that were used. Second limitation is that a very few articles were reviewed from socio-economic & political area, and infrastructural area of aviation industry effecting the fuel consumption in aviation. Finally, we acknowledge that this review cannot be claimed to be exhaustive, but it does provide reasonable insight into the sate-of-the-art on optimization of fuel consumption research in aviation industry.

8. Conclusions, and Future work

The result shows that, there were total 5 primary dimensions, 16 secondary dimensions, and 119 decision variables which effect the fuel consumption in aviation industry. This paper is based on the literature review on the fuel consumption optimization, fuel conservation measures and strategies, fuel burn reduction, fuel efficiency improvement etc. in aviation industry, and its application from 1973 to 2010. Literature review identifies the five potential areas for fuel consumption optimization such as: (1) Technology & product design, (2) Operations, (3) Alternate fuels and fuel properties, (4) Socio-economic & political, and (5) Infrastructure. Technology and product design plays an important role in the fuel consumption optimization. Most of the aircraft were designed in an environment in which fuel was relatively inexpensive. In this field most of the studies are concerned with a particular element of fuel consumption instead of looking at the holistic fuel consumption optimization architecture. A large amount of fuel is consumed during the aircraft operations. This area still lacks a comprehensive and parametric analysis which can conserve the maximum energy on minimum input. Alternative fuels can also optimize the aviation fuel consumption and in this area to select the most feasible fuel still need attention. Socio- economic & political and infrastructure aspects also effect the fuel consumption to a greater extent. In these areas the study still needs mathematical relationships and parameters. This paper also identifies importance of research in the study, bridging of gaps, and dimensions effecting the fuel consumption in aviation industry from these areas. To the best of our knowledge no attempt has been made to develop the informational framework and analyze the literature dealing with fuel consumption optimization in aviation industry. Thus, in this paper we have attempted to review and identify the parameters of the fuel consumption optimization. Current research effort of the optimization of fuel consumption attempt to develop a holistic model for customized optimization of fuel consumption. For developing the holistic model the study needs the set of parameters which effect the fuel consumption in aviation industry. This paper identifies the different parameters from literature. This work develops informational framework of optimization of fuel consumption. The evaluation of informational framework will be done in term of reliability and validity checking. The extracted information will further be subjected to factor analysis. This study would form an input for aviation sector to achieve optimal fuel consumption. Thus, it is hoped that this review will provide a source of reference for other researchers/readers interested toward optimization of fuel consumption research and help stimulate further interest.

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Table 1. Shows the Identified Dimensions from Literature for the Optimization of Fuel Consumption in Airline Industry.

Primary Dimensions	Secondary Dimensions	Decision Variables
Technology and Product Design	1.Engine Design	1. Engine Weight 2. By Pass Ratio 3. Temperature Ratio 4. Pressure Ratio 5. Nozzle Area 6. Air Fuel Ratio 7. Engine Thrust 8. Engine type
	2.Airframe Design	9. Structural Weight 10. Lift/Drag 11. Wing Reference Area 12. Wing Thickness Over Chord 13. Wing Aspect Ratio 14. Aircraft Centre Of Gravity 15. Wing Taper Ratio 16. Horizontal Tail Area 17. Vertical Tail Area 18. Aircraft Size 19.Wing Location Over Fuselage 20. Lift co-efficient 21. Drag Co-efficient 22. Angle of Incidence 23. Induced Drag 24. Seating Capacity 25. Aircraft Design Range 26. Aircraft polishing 27. Mach No.
	3.Material Composition	28. Weight 29. Strength 30. Corrosion Resistance 31. Fatigue Resistance
	4. Auxiliaries	32. Air cooling 33. Electrical Systems in aircraft
Operations & Performance	1.Ground operations	34. Taxiing 35. Fuel Tankering 36. Maintenance 37. Aircraft takeoff weight 38. Aircraft landing 39. Fuel availability 40. Idle Time 41. Use of Ground Power Instead Of APU 42. No. of Engines Operating on Ground 43. Airplane Towing 44. Aircraft replacement 45. Refueling Segment 46. Cabin Dead Weight 47. Payload Weight 48. Aircraft Extra Weight 49. Roll speed 50. Roll distance 49. Phone coach ovens weight 50. Catering supply weight 51. Primer and paint weight 52. Baggage weight
	2.Airborne operations	53. Climb Rate 54. Flap Setting 53. Flap Retraction Schedule 56. Flight profile 57. Altitude 58. Cruise Speed 59. Fuel ferrying 60. Air-To-Air Refueling 61. Crew Wight 62. Airborne Hour 63. Block Hour 64. Flight Hour 65. Aircraft Balance 66. Contingency Fuel 67. Cost of Index for Flight Path 68. Pilot Techniques
	3. Arrivals	69. Descent Approach 70. Descent Speed 71. Angle Of Descent
Alternate Fuels And Fuel Properties	1. Composition	72. Aromatics 73. Sulphur Total Mass 74. Sulphur Mercaptan Mass 75. Contaminants 76. Existent Gums 77. Additives 78. Water vapour
	2.Physical Properties	79. Boiling Point 80. Flash Point 81. Density 82. Fluidity (Viscosity) 83. Lubricity 84. Electrical Conductivity 85. Freezing Point 86. Smoke Point
	3.Chemical Properties	87. Acidity 88. Energy Per Unit Volume 89. Energy Per Unit Mass 90. Corrosivity
Socio-Econom ic & Political	1. Social	91. Scheduling 92. Labour & Work Rule 93. Voluntary Measures 94. Community Awareness 95. Social and political pressure
	2. Economic	96. Training 97. Fuel Prices 98. Ticket Prices 99. Economic Incentives 100. Operating Cost 101. R & D Funding For Technology 102. Reservation Policies
	3. Political	103. Government Regulations 104. Charges and Taxes 105. Emission Trading 106. Political Obstacles 107. Leadership Role 108. Tax Credits And Subsidies To Promote The Technologies
Infrastructure	1.Airport Design	109. Runway 110. Taxiway 111. Apron 112. Terminal Area
	2.Fuel Management	113. Fuel Procurement 114. Fuel Transportation 115. Fuel Acquisition 116. Fuel Handling
	3.Air Space Management	117. Air Routes 118. Weather condition 119. Flexible Usage Of Military Airspace