# THE USE OF TRM AS A GUIDING TOOL FOR THE PLANNING INNOVATION IN THE DEVELOPMENT OF ECO-EFFICIENT FUELS FOR AIR TRANSPORT

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## ABSTRACT

It is anticipated that in the next twenty years, air transport will have a growth of almost twice the rate of global GDP growth. This accelerated industry expansion has caused some negative consequences. The aviation industry has committed to change this scenario and the goal is to halve the emissions of carbon dioxide by 2050. To achieve this goal, it is necessary to develop eco-efficient aviation fuels that minimize the negative impacts as in the case of replacing fossil fuels derived from renewable resources fuel, which allows the reduction by 80% of the CO2 emission. In this sense, this study seeks to contribute to this issue by proposing a management tool to guide innovation in this sector, the technology roadmap - TRM. From the desk research and content analysis, studies of reports and database were made in order to identify future and present needs to the planning process of innovation in the development of eco-efficient fuel used for air transport in Brazil needs. The framework is presented as a result contributes to planning innovation in this sector to this sector and identified products, technologies, resources and partnerships necessary for the development of eco-efficient fuel for the sector in Brazil.

**Key Words:** Eco-efficient fuel; air transport; technology roadmap; management of innovation

## INTRODUCTION

Considering the growing $CO^2$ emissions (carbon dioxide) caused by air transport, equivalent to 2% of total emissions caused by human action as a way to reduce their impact on climate encourages the need of development of eco-efficient solutions for the sector .

In support of this reduction in negative environmental impacts caused by air transport, the aviation industry has determined targets for the reduction of global emissions of greenhouse gases (GHG), among which we highlight the improvement of 1.5% per year in fuel efficiency by 2020, carbon neutral growth, which implies that the total $CO^2$ emissions from international air transport in 2020 will continue to be equal to the emissions in 2005 and halving carbon dioxide emissions by 2050, considering 2005 levels alternative fuels produced from renewable sources or waste appear as a promising solution for achieving these goals (IATA, 2013b).

In modern jet engines, fuels derived from renewable sources can replace those non-renewable sources, such as oil products (NAIR; PAULOSE, 2014). Efforts to identify alternatives to fossil fuels has been identified in different research groups, as shown in Chiramonti et al. (2014). However, despite the various proposals and numerous test flights, such eco-efficient alternatives have not yet become widely marketed (GEGG, BUDD and ISON, 2014).

To reverse this situation, initiatives such as the "Flight Path to Aviation Biofuels in Brazil: Action Plan", a result of a partnership between Boeing, Embraer, Support Foundation of São Paulo (FAPESP) and the State University of Campinas (Unicamp), and the training organizations for sustainability sustainable aviation Fuel as the Users Group (SAFUG) by airlines aim to accelerate the development and commercialization of biofuels for aviation. The study consists of a national assessment of the challenges and technological opportunities, economic and sustainability associated with the development and marketing of sustainable biofuels for aviation in Brazil. The potential of Brazil as eco-efficient fuel supplier for the domestic and international markets was confirmed by the study. The big Brazilian territory and its subtropical and tropical area allows the cultivation of different crops suitable for eco-efficient fuel.

According to Scott (2005), most of the problems of companies related to the innovation process focuses on planning. Even considering how important this step is, it is necessary to make good plans and use tools to support the planning, such as the Technology Roadmap (TRM) (GEUM et al, 2013). Practical and geared for action, the TRM is a tool that aims to guide the efforts of the innovation process from a map (roadmap) with technological routes of organization (PHAAL, FARRUKH and PROBERT, 2004).

The wide range of strategic contexts, to which the TRM tool can be applied, characterizes it as an inherently flexible tool. Thus, different types of roadmaps have been developed (PHAAL, FARRUKH and PROBERT, 2004). The application of TRM to air transport is exemplified by Neto and Oliveira's work (2010), that provide the sort of organizational processes for the generation of technological roadmaps geared to the needs of the Department of Aerospace Science and Technology (DCTA). Rinne (2003) proposes a roadmap for the development of future wing design for civil aircraft designed by Boeing, while Bueno et al. (2006) uses the roadmap as a tool in planning the relationship´s network of the Brazilian Space Agency (AEB). In the work of Clendenin and Reaser (2003) the roadmap is used for technology integration in a wide variety of legacy automatic test equipment from the United States Air Force (USAF). None of  these proposals appear to contribute to the development of new eco-efficient fuel.

The use of alternative energy in transport is one of the most representative groups on logistics innovation management (14% of the studies analysed by Caetano (2014)). Another aspect highlighted by the author is that most of the articles identified in his study were developed in the last three years, showing the contemporary concern for clean energy in transport. The study shows that the proposals do not systematize the process of innovation in logistics. Although Tuominen and Ahlqvist (2010) propose an technology roadmap to increase logistics systems in Finland, they don't approach the activities to be performed or the conditions which will make the integration of new technologies in processes along the chain supply, as the authors present only necessary technologies, actors that are according to user needs markets.

In the approaches to the process of innovation, recent studies have emphasized the growing importance of external sources of ideas in an approach of open innovation (DEWES et al., 2010), which can be defined as the various forms of relationship between innovative companies and external agents (DAHLANDER and GUNN, 2010; DEWES et al., 2010). This form of relationship can be seen in countries like France, the United States and Canada that demonstrate positive results, such as technology and production expertise, and economies of scale, identified in the aeronautical segment due to the development of regional productive innovation systems or parks technological specialized in R & D (ABDI, 2009). Producers, users and government agencies, when working in networks, share skills and allow for more successful innovations (FRENKEN, 2000).

Caetano and Amaral (2011) highlight the growth of the inclusion of elements of open innovation in the design of new technologies, products, services or processes, according to market opportunities and propose a road map which includes the market to be exploited, the product be developed, main and complementary technologies, resources and partners. The proposed model serves as a guide in planning the technology and relationship management between partners. - The model proposed by the authors, is used as a reference for identifying the player in the development of eco-efficient fuels for aviation and simulation scenarios favourable for this context.

To identify theoretical and empirical contributions prior dealing with eco-efficient fuel in air transport was used the literature review. The conceptual basis proposed by Caetano and Amaral (2011) provides for the presence of employees and co-workers in a roadmap that considers the market to be exploited, the products to be developed, main and complementary technologies to be developed, necessary resources and partners to be triggered in the innovation process. Cooper (2008) suggests that the identification of the market to be explored are necessary data regarding the size of this market, exemplified by the volume of business generated in recent years, as well as the expected future growth.

**PROPOSAL OF A TECHNOLOGY ROADMAP FOR ECO-EFFICIENT FUELS IN AIR TRANSPORT**

For the development of the technology roadmap becomes necessary first to identify potential markets to be explored by new solutions. With this information, identifies the possible product, possible technologies and resources, as well as partners for each resource. Finally, the map is drawn up.

This study assesses the possibilities of mapping technologies, products, services or processes and their resources and partners for the commercial airline industry, which is 56.6 million jobs and 2.2 trillion of global GDP, demonstrating the recent decades an average growth of 5% per year (IATA, 2013b).

For the product to be identified, this study focuses on the development of eco-efficient fuels, which may be conventional biofuels produced from vegetable oils and fats, or biofuels that can be blended with fossil fuels currently used, resulting in performance characteristics equivalent and not thus requiring significant changes in aircraft and engines.

The next step is to identify the technologies needed for the product reaches the market. According to the study "Flight Path to Aviation Biofuels in Brazil: Action Plan", all of the following conversion and refining technologies has the potential to be considered in biofuel production for aviation: gasification, fast pyrolysis, liquefaction solvent, enzymatic hydrolysis cellulosic and lignocellulosic biomass, alcohol oligomerization to jet fuel (TKA), hydroprocessing esters and fatty acids (HEFA) and fermentation of sugars and waste (aka, municipal solid waste, combustion gases, industrial waste) in alcohols, hydrocarbons (DSHC), and lipids. The knowledge of these refining methods is the technological resources necessary for the development of eco-efficient fuel.

Potential partners can be market partners, representing the major players in the market, sources of information and future suppliers of the technology being developed. There are also technology partners, characterized as organizations or individuals with expertise and complementarity of useful technical resources for the development or delivery of solutions for each technology required. Besides these, there are also financial partners who can act in the financing of projects technologies or products, services and processes, as in the case of the Financier of Studies and Projects (FINEP), active in Brazil from resources of the Sectorial Funds of Science and Technology, which are financing instruments of research, development and national innovation.

The level of involvement with the technology being developed classifies partners in employees or co-workers in a relationship a win-win (Thompson and Sanders, 1998). While the first group has a co-development relationship, the second is characterized by lesser involvement and commitment to results.

The co-financing partners may be those that provide secondary resources to maintain essential facilities or activities for the development of technologies, such as the Research Support Foundations, which are agencies that support scientific research active in each Brazilian state. For example, the State of São Paulo is FAPESP, in Goiás the responsible agency is the FAPEG and Rio de Janeiro, the FAPERJ.

With knowledge about the needs of the market and the characteristics of the aircraft, the three most expressive aircraft manufacturers in Brazil both represent the market collaborating partners, as technology. According to data published by the ANAC (2014), the Airbus leads the ranking of number of aircraft operating in the Brazilian commercial aviation, accounting for 37% of the national fleet, corresponding to about 210 aircraft in operation in Brazilian companies. The second position is occupied by Boeing, with 33% stake, or 183 aircraft, followed by the domestic manufacturer Embraer, which has a 15% stake - 82 aircraft of the Brazilian commercial aviation.

Already airlines are characterized as market co-partners, they can cooperate by providing information and testing fuel for commercial flights. Of 946 684 domestic flights carried out in Brazil in 2013, GOL company held 300,323, representing 32% of the total. Then TAM company with 27%, 253 207 flights, and AZUL with 18%, equivalent 174,552 flights. Together the three companies accounted for 77% of the domestic market in Brazil Aviation (ANAC, 2014).

Azul and Gol made demonstration flights using eco-efficient fuel for the Rio + 20. Using renewable fuel "drop-in" produced in Brazil by Amyris, Azul Airlines flew with an Embraer E-195, while Gol, using fossil fuel with biofuel derived from inedible corn oil and used cooking oil, flown a Boeing 737-800. TAM in 2010, had already tested an aviation fuel containing 50% fuel made from jatropha seeds produced in Brazil (UNICAMP, 2013). This experiment companies flight tests are useful for access to market information, for example, responses demonstrated by the market. Another partner cooperative market is the National Civil Aviation Agency (ANAC) to be a regulator source of information about the national civil aviation market.

The complementarity of technical resources can come from companies such as the Brazilian Agricultural Research Corporation (EMBRAPA) - public research institution linked to the MAPA (Ministry of Agriculture, Livestock and Supply) of Brazil - through extension mechanisms to transfer knowledge of best production practices between agricultural institutes and research institutions.

The regulation of commercial aircraft design and operation is done by national air safety agencies. In Brazil, this responsibility is the ANAC. In addition, the fuel used in aircraft must also be regulated and, in Brazil, the regulatory agency with legal authority to establish fuel specifications is the ANP (Brazilian Agency of Petroleum, Natural Gas and Biofuels). In addition to the fuel meet the requirements and properties defined by engine manufacturers and aircraft, it must also be approved by the security organ. To develop a process of qualification and certification of alternative fuels, ASTM (International Aviation Fuel Subcommittee) has been used to coordinate the review of data and the establishment of specification criteria (IATA, 2013).

These regulatory agencies (ANP, ASTM) and EMBRAPA and Higher Education Institutions (HEIs), can act as technological co-partners as they allow access to technical information.

Energy companies such as Petrobras, Total and industrial biotechnology company, as Amyris, can act as technological cooperation partners, have know-how and strategic objectives aligned to the development of eco-efficient fuel.

Figure 1 presents a sketch rodmap technology for the development of eco-efficient fuels in Brazil.

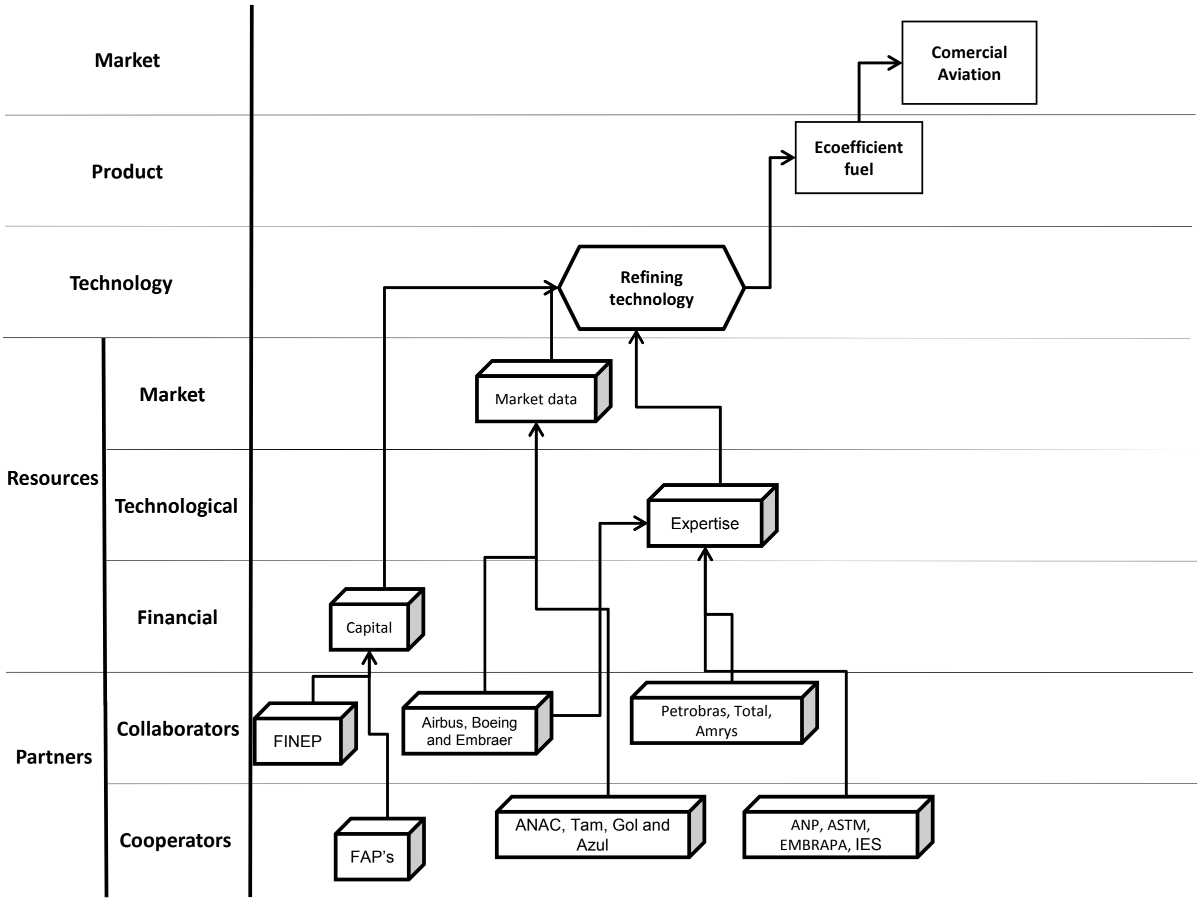


*Figure 1: Survey data based on the model of Caetano and Amaral (2011)*

According to Figure 1, are identified the market to be explored, in the case of commercial aviation go, the possible product, eco-efficient fuel, possible refinement of technologies and resources, as well as partners for each different type of resource. This proposal has to be relevant both to the state of the art in innovation management on the state of the practice in the air transport management, as there is the proposal of a tool to guide the following efforts to be developed customized solutions for the sector from the involvement of different partners.

## CONCLUSION

Brazil may become one of the leading global players in the oil use replacement process in aviation. This study presented a partnership suggestion map as a contribution to the development of eco-efficient aviation fuel. The identification of partners is presented as one of the main advantages of the proposed technology roadmap, because as has been shown by studies on open innovation, application of partnerships is a strong tendency in the innovation process.

Future research suggestions are made in order to increase and validate the model in real cases of development of eco-efficient fuel.

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