ProQR

COMBUSTÍVEIS ALTERNATIVOS
SEM IMPACTOS CLIMÁTICOS

Costs Analysis of Aviation Fuels in Brazil

Por ordem do
Ministério Federal do Meio Ambiente, Proteção da Natureza, Construção e Segurança Nuclear
da República Federal da Alemanha

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

DLR

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES

BRASIL GOVERNO FEDERAL

COSTS ANALYSIS OF AVIATION FUELS IN BRAZIL

Elaborado por: TH Köln - Institute for Technology and Resources Management in the Tropics and Subtropics (ITT)

Autor: Florian Roth

Executado por: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Por ordem de: BMUB, GIZ Brazil

Coordenação: Professor Dr. Ingo Stadler,
Dipl. Ing. Msc Torsten Schwab

Maio de 2018

Informações Legais

1. INTRODUCTION

Brazil has immense potential regarding renewable energies. The country comprises best prerequisites for photovoltaics, wind and other decentralized renewable energy generation options with very low production costs compared nationally as well as internationally. At the same time, national fuel demand for the aviation sector is rising. In particular, aviation fuels are traded in US dollars, which means that jet fuel accounts for highest portion on operating costs for a Brazilian airline at the current exchange rate. The expansion of Brazil´s already broad flight network into remote regions is therefore a loss-making business for the airlines and implies a political challenge for the government. As a logical consequence, synthetic fuels produced from wind, hydro and solar energy are being discussed to serve as a drop-in fuel solution as a viable alternative to conventional kerosene in the aviation sector. Proving that the production and use of synthetic fuels from renewable energy sources under real conditions is economically feasible in Brazil, opens up a new climate-neutral fuel option for aviation and other transport segments without electromobility potential.

Taking into consideration that Germany consists of know-how concerning the production of climate-neutral synthetic fuels, the project PRO QR (Querosene Renovável) - Climate-Neutral Alternative Fuels for Aviation launched by the Gesellschaft für Internationale Zusammenarbeit – GIZ in context of the overarching International Climate Initiative – IKI aims to create an international reference model for the production and application of climate-neutral alternative fuels for aviation and other transport segments without electric mobility potential. Proof of economic viability concerning the production line of climate-neutral alternative fuels is still internationally pending. Consequently, the core element of the project defines a pilot plant in which smaller amounts of jet fuel are produced and then applied in air traffic to prove on the one hand feasibility and on the other economic viability of the technology. If the project outcomes deliver valuable arguments, the basis for climate-neutral mobility can been laid and subsequently the international fuel market will be revolutionized in the long term. The present paper pretends to carve out specific market niches where the technology, which is still expensive today, can be applied cost-efficiently tomorrow and therefore set the basis for positive scale effects and thus an economic viability of the new technology in the future.

2. PROBLEM ANALYSIS

In particular, the research elaborated and discussed in the present paper was realized in cooperation with the Empresa de Pesquisa Energética – EPE, based in Rio de Janeiro and tries to deliver results considering the following objectives. The main purpose of the present paper can be defined as a market and cost analysis to study the existing value chain for conventional aviation fuels in Brazil. Basically, main goals to examine are firstly the status quo of the jet fuel value chain in Brazil and secondly the real market cost of one-liter aviation fuel sold by distributors taking into account all cost factors that occur along the life cycle of the jet fuel value chain. The study also comprises description of the aviation market organization and participants, volumes, fuel costs for airlines, aviation infrastructure, particularities and challenges. More precise, flight operations of the Brazilian air fleet, airport infrastructure and dimensions of the aviation market are going to be highlighted. Furthermore, regulatory bodies, institutes and companies involved in the market are described. The term aviation kerosene is applied as Querosene de Aviação, short just defined as QAV, named accordingly and congruently throughout this paper. Moreover, the fluxes between points of production, distribution and consumption along the value chain of QAV will be emphasized. In more detail, there will be illustrated maps of demand and supply fluxes of QAV among Brazils regions from both, the consumer and producer perspective. In addition to that, figures and maps of the aviation infrastructure, capacities of airport and jet fuel volume data will be elaborated.

Further are analyzed corresponding transport costs for jet fuel. At this, market effects and influences that trigger the purchase price of aviation fuels are examined by means of a comprehensive life-cycle-cost-analysis. Hence, the objective is to find out where can be detected most appropriate niches that suite a viable production and distribution of synthetic renewable aviation fuels in Brazil. Furthermore, dimensions of jet fuel infrastructure regarding figures about demand and supply as well as transport costs among most costly routes for supply of aviation combustibles are explained. Also, the paper tries to reflect the most inefficient cost drivers that point out opportunities for improvement of production, transport and distribution efficiency for a future alternative fuel value chain. In particular, special attention is paid to the Amazonas region and its remote aviation infrastructure that are connected by challenging transport routes. Hence, the present paper tries to outline several cost components and parameters that can be defined throughout the value chain and detect influences on the purchase price for the distributor of jet fuel to subsequently be able to obtain baseline reference prices that can be compared to the price of one-liter synthetic aviation fuel in further research. A final long-term objective of further research is to determine the break-even point when commercial viability of a plant producing 500 liters alternative jet fuel per day is to be expected.

Overall, the following hypothesis and research questions are tried to be answered throughout the present paper:

Hypothesis: The production and transport of synthetic jet fuel from renewable energy sources is economically feasible considering real market conditions in Brazil.

Research Question 1: What is the actual cost of one-liter conventional jet fuel throughout its downstream value chain life-cycle?

Research Question 2: Where is the production and transportation of synthetic jet fuel economically feasible across Brazil?

Figure 1: Brazil´s Regions & States
Source: Eliachar 2015

Figure 2: Natural Vegetation of Brazil
Source: Berglee 2016

3. FUNDAMENTALS

3.1. STATE OF THE ART – POWER TO LIQUIDS

Generally speaking, aviation fuel or kerosene consists of a combination of numerous hydrocarbon chains, namely C10 to C16 and is composed of approximately 75 percent paraffins, characterized by a high heat removal per mass as well as their combustion features, and of 25 percent aromatics, that influence swelling behaviors of polymers and prevent possible leakages within the fuel components assuring its stability, hence the security of an airplane fueled with kerosene. Moreover, aviation fuels are bound to international standards approved by the International Association for Testing Materials - ASTM. Due to the fact that the previous directive ASTM D1655-18 only approved jet fuel made out of the feedstock crude oil, the new directive ASTM D7566 accredits synthetic fuels produced by methods such as Hydro Processed Ethers, Alcohol to Jet and Fischer Tropsch Synthesized Paraffinic Kerosene. However, the pathway applied within the project PRO QR is defined as Fischer Tropsch respectively Power to Liquids which rely on the feedstock water and carbon dioxide as well as on electricity from renewable energy sources.

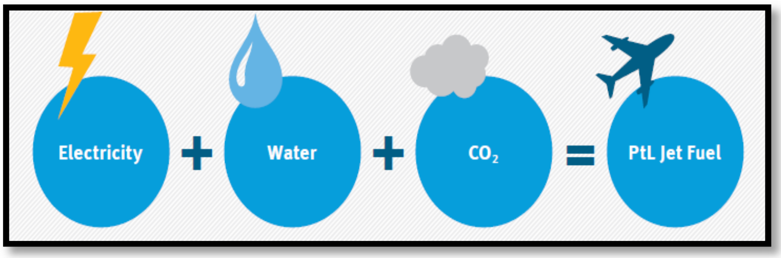

Figure 3: Feedstock for Power to Liquid Jet Fuel
Source**:** German Environment Agency (2016)

In further detail, the Fischer Tropsch Synthesis is comprised of a polymerization process including a syngas made of hydrogen and carbon monoxide with a ratio of 2:1 per liter jet fuel. Hence, hydrogen is obtained by electrolysis in mostly gaseous form but attaining liquid and solid hydrocarbons of different chain lengths. According to Ahola et al. (2017), the Fischer Tropsch Synthesis pathway derives outputs of approximately 15 percent gas (C1 - C4), 42 percent gasoline (C5 - C12), 21 percent diesel (C13 - C18), 22 percent wax (C18 and above). Also, hydrogen as one of the principal process compound is gained by the electrolysis of water and can be realized by the application of Alkaline Electrolysis - AEL, Electrolysis in Acid Environment - PEM electrolysis and by Solid Oxide Cells Electrolysis - SOC. Simultaneously, oxygen is released as a byproduct.

$$2H_2O \rightarrow 2H_2 + O_2$$

The second main compound carbon monoxide is obtained by the Reverse Water Gas Shift Reaction -WGS. Thus, inside reactors carbon dioxide and hydrogen is converted to water and carbon monoxide.

$$CO_2 + H_2 \rightarrow H_2O + CO$$

Furthermore, there exist a few sources of CO2 to feed the reverse WGS reaction. Important for the water gas shift reaction is the aspect of a high CO2 purity since impurities like sulfur, nitrates and others could harm the vessel. In fact, carbon dioxide can be obtained applying the following methods. Since it is customary practice that in most biogas upgrading plants carbon dioxide is simply released into the atmosphere, the Water Gas Shift Reaction to make use of the available CO2 efficiently. In particular, the biogas can be treated by an amine wash where an amine solution reacts in a reversible chemical reaction with the carbon dioxide and subsequently releases the carbonate at a regeneration stage under moderate temperatures around 130°C. In comparison, applying the pressure swing adsorption of biogas results in a separation of carbon dioxide from the biogas methane through activated carbons or molecular sieves. Hence, the absorbent carbon dioxide binds easier than methane and is evacuated with a vacuum pump at 100 mbar. Furthermore, the technique of air capturing allows a cyclic adsorption and desorption of the air from the atmosphere to a sorbent filter material. So, the carbon dioxide is sucked in from the air by a device and chemically bounds on a sorbents layer. When the saturation point of the filter material is reached, the CO2 is released at around 90°C heat. In addition. the flue gas scrubber method captures carbon dioxide out of flue gases released by several industry processes and conventional power plants while burning natural gas, coal or waste among others. Subsequently, the actual CO2 capture is ensured by an amine wash of the gases.

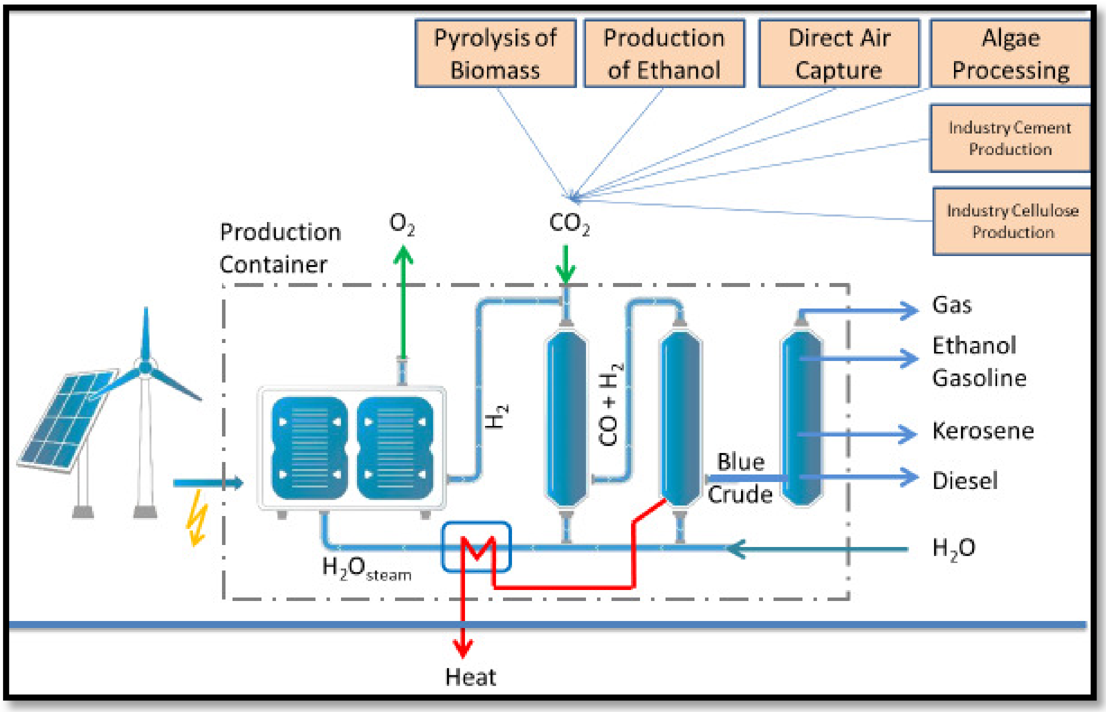

Figure 4: Principle of Power to Liquid Technology and CO_2 Sources
Source: Sunfire GmbH, Climeworks AG, Deutsche Gesellschaft für Internationale Zusammenarbeit mbH

Within the system it is crucial to determine a fitting configuration specifically designed for a particular location. At this, a significant information for the Fischer Tropsch production unit is the required feedstock amount of carbon dioxide, hydrogen and the electricity demand considering a jet fuel production of 500 liters kerosene per day.

Required Energy	15.1908	kWh/L
Required Volume CO_2	5.0810	Nm3/L
Required Volume H2	14.9344	Nm3/l

Figure 5: Feedstock Requirement for the FT technology to procures 500 liters Kerosene/Day
Source: Cubillos, Ebner, Loechle (2018)

3.2. BRAZILIAN AVIATION MARKET

During the initial phase of any project it is crucial to first get a comprehensive overview about the actual market one intends to enter when introducing a new technology or product. In order to obtain an understanding about the socio-economic environment of

Brazil´s aviation industry, a synopsis of the domestic aviation industry, its main players and dynamics is outlined. In addition, the jet fuel value chain infrastructure is analyzed and specific features of it are highlighted. First, an overview about some key data of Brazil´s aviation industry:

Figure 6: Executive Summary of the Brazilian Aviation Industry
Source: IBA - Instituto Brasileiro de Aviação Brasil 2017

Figure 7: Distances between mayor Brazilian Airports
Source: Crafted by the author

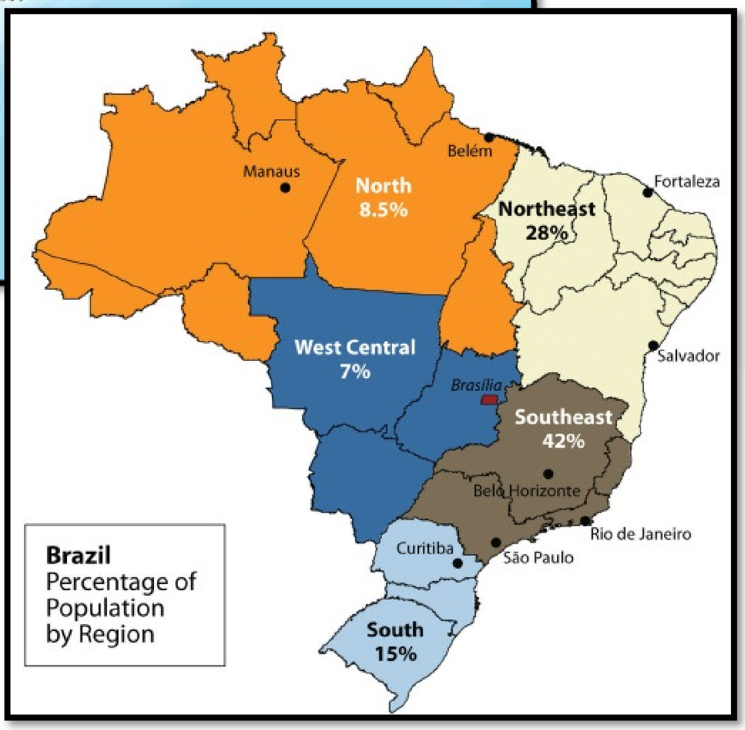

Figure 8: Distribution of Population
Source: Berglee 2017

In order to contextualize the reader about the dimensions of Brazil´s aviation industry, first are shown the aspects of Brazilian aviation by different types.

Figure 9: Brazilian Civil Aviation Context
Source: IBA - Instituto Brasileiro de Aviação Brasil 2017

The total number of civil Brazilian aircrafts in 2016 was defined to 21.895. Whereas 15.342 airplanes are categorized as general aviation, 5.867 as experimental use and 686 as commercial aviation which are produced from 117 manufacturers and distributed among 14.998 owners including individuals as well as companies (ANAC 2017). There are currently 13 Brazilian and 92 international airline operators certified in the Brazilian market. Within the domestic market 2, 3 million aviation operations have been realized in the year of 2016. Hence, 93 percent originated from domestic airports and 7 percent originated from foreign airports (IBA 2017). As figure 9 shows, there are many auxiliary services, types and purposes for the civil aviation including a wide range of business applications beneficial to the commercialization of synthetic aviation kerosene.

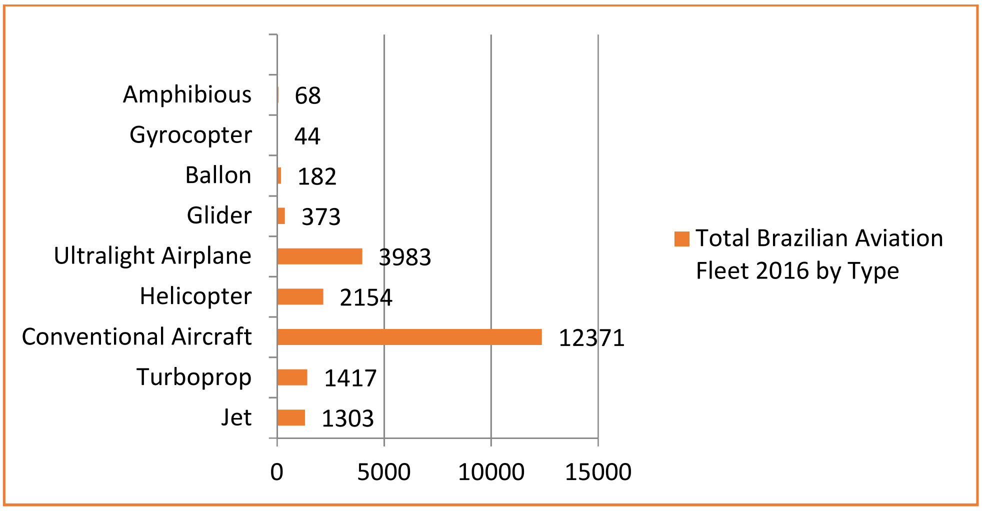

Figure 10: Number of Brazilian Aviation Fleet 2016 by type
Source: IBA - Instituto Brasileiro de Aviação Brasil 2017

However, considering a forecast of the growth potential of commercial aviation, the development of total passenger in commercial flights realized in the domestic aviation market between 2012 and 2020 is expected to increase substantially as illustrated in figure 11. Indeed, the passenger transport is forecasted to grow by 109 percent and the cargo transportation by 58 percent respectively. During the same time, the value of exports and imports by airway is calculated to grow by 31 Billion US Dollar between the year of 2012 and 2020. Accordingly, in the year of 2016, 828.935 domestic flights have been operated; 96.191.412 domestic passengers and 357.129.447-kilogram domestic cargo were transported. All over the country there exist 126 major airports that are designed for commercial flights (ABEAR 2016).

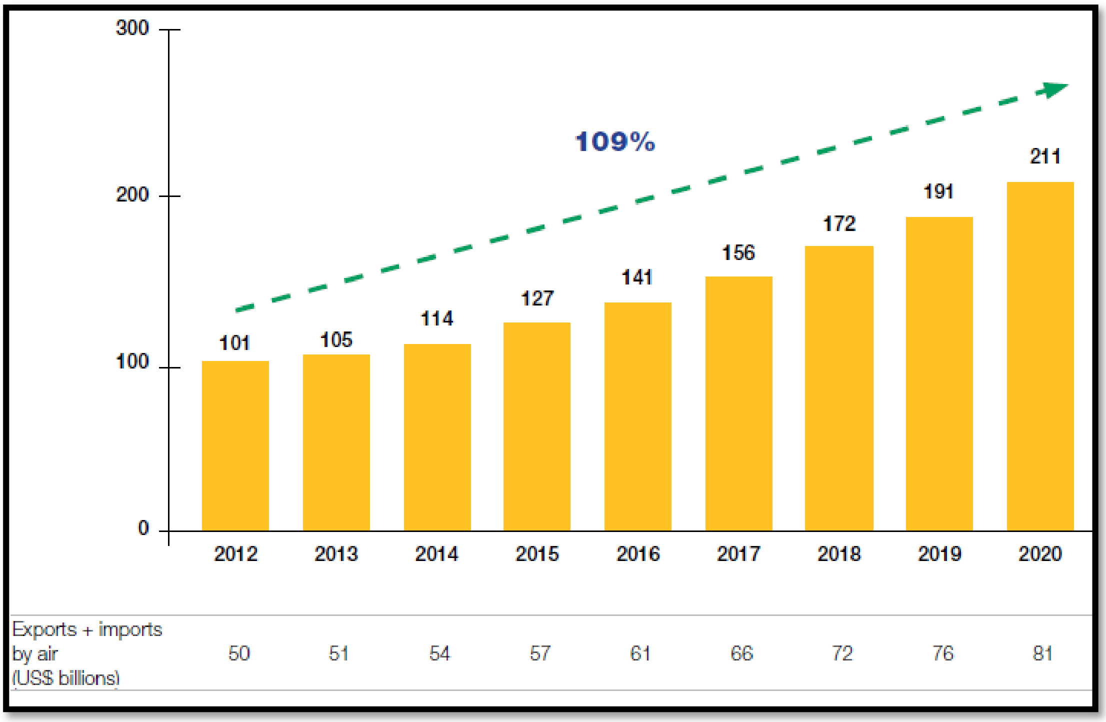

Figure 11: Potential Number of Passengers Carried in Brazil - Domestic and International in Millions
Source: Brazilian Aviation Agenda 2020 - ABEAR (2017)

Principally, the market is distributed among four major commercial airlines considering domestic flights. In 2016, there have been realized 828.935 domestic flights in total. However, this number is expected to rise accordingly to the forecast until 2020 illustrated above.

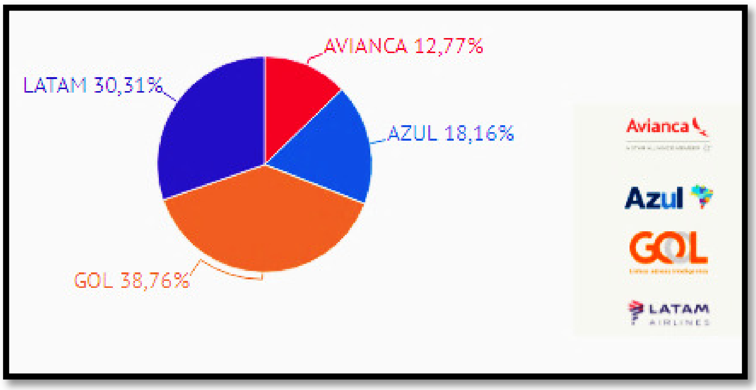

Figure 12: Market share in number of flights of four major Brazilian airlines: Domestic aviation market 2016
Source: ANAC (2015)

The value chain among the aviation industry involves airport infrastructure, aeronautical infrastructure, operators, manufacturers, aircraft vendors, parts distributors, service providers and agencies that regulate all aspects of the aviation industry. In the following, the main commercial flight operations of airplane types among the major Brazilian airlines considering passenger transport is emphasized for the year of 2014.

Main Operations (commercial flights) in Brazilian domestic aviation market by type of Aircraft: 2014			
Aircraft Type	***Flights p.a.***	***Aircraft Type***	***Flights p.a.***
B738	***336.152***	*AT72*	***59.239***
A320	***297.094***	*E50P*	***25.351***
E190	***181.739***	*A318*	***25.130***
A319	***127.988***	*AT43*	***21.980***
B737	***120.278***	*B320*	***19.080***
		A321	***18.547***

Figure 13: Main domestic flight operations by type of aircraft 2014

Source: ABESATA - Associação Brasileira das Empresas de Serviços Auxiliares de Transporte Aéreo 2016

Here, clearly stand out the Aircrafts AIRBUS 320, BOEING 737-800 and EMBRAER E190/195 which are mostly operated by LATAM, GOL, AVIANCA and AZUL. Those execute most flights per year as to compare in figure 13. Therefore, calculations on the fuel capacity, volume and capable dimensions of blue crude synthetic jet fuel should be taken into consideration to estimate the demand of jet fuel among the commercial aviation sector. In continuation, the data of these three aircraft models are briefly carved out as a standard value.

Airbus - A320NEO

Fuel efficiency (l/pass*100km)	**2.61**
Fuel flow rate (kg/h)	**2600**
Standard Fuel Capacity (L QAV):	**24210 – 27200**
Range (KM):	**6 850**

Sources: Airlines Inform (2017) Airbus (2017) Aircraft Commerce (2005)

BOEING – 737MAX8

Fuel efficiency (l/pass*100km)	**2.68**
Fuel flow rate (kg/h)	**2530**
Standard Fuel Capacity (L QAV):	**26020**
Range (KM):	**6 510**

Sources: Aircraft Commerce (2005) and Boeing (2017)

EMBRAER – E190

Fuel efficiency (l/pass*100km)	**3.32**
Fuel flow rate (kg/h)	*No Data*
Standard Fuel Capacity (L QAV):	**16153**
Range (KM):	**4 448**

Sources: Embraer (2017) and Leeham News and Comment (2017)

For a better understanding the following tables show codes and abbreviations of Brazil´s states and airports as they are going to be mentioned throughout this paper.

State	Code	State	Code
Acre	AC		
Alagoas	AL		
Amapá	AP		
Amazonas	AM	Distrito Federal	DF
Roraima	RR	Tocantins	TO
Rondônia	RO	Goiás	GO
Pará	PA	Mato Grosso do Sul	MS
Paraíba	PB	Mato Grosso	MT
Maranhão	MA	Rio de Janeiro	RJ
Piauí	PI	São Paulo	SP
Pernambuco	PE	Minas Gerais	MG
Rio Grande do Norte	RN	Espírito Santo	ES
Ceará	CE	Rio Grande do Sul	RS
Sergipe	SE	Santa Catarina	SC
Bahia	BA	Paraná	PR

ID	ICAO	MUNICÍPIO	UF	ID	ICAO	MUNICÍPIO	UF	ID	ICAO	MUNICÍPIO	UF
1	SBAR	Aracajú	SE	21	SBIL	Ilhéus	BA	41	SBPL	Petrolina	PE
2	SBBE	Belém	PA	22	SBIZ	Imperatriz	MA	42	SBPP	Ponta Porã	MS
3	SBBG	Bagé	RS	23	SBJC	Belém	PA	43	SBPR	Belo Horizonte	MG
4	SBBH	Belo Horizonte	MG	24	SBJP	João Pessoa	PB	44	SBPV	Porto Velho	RO
5	SBBI	Curitiba	PR	25	SBJR	Jacarepaguá	RJ	45	SBRB	Rio Branco	AC
6	SBBV	Boa Vista	RR	26	SBJU	Juazeiro do Norte	CE	46	SBRF	Recife	PE
7	SBCG	Campo Grande	MS	27	SBJV	Joinville	SC	47	SBRJ	Rio de Janeiro	RJ
8	SBCJ	Carajás	PA	28	SBKG	Campina Grande	PB	48	SBSJ	São José dos Campos	SP
9	SBCM	Criciúma	SC	29	SBLO	Londrina	PR	49	SBSL	São Luís	MA
10	SBCP	Campos dos Goitacazes	RJ	30	SBMA	Marabá	PA	50	SBSN	Santarém	PA
11	SBCR	Corumbá	MS	31	SBME	Macaé	RJ	51	SBSP	São Paulo	SP
12	SBCT	Curitiba	PR	32	SBMK	Montes Claros	MG	52	SBSV	Salvador	BA
13	SBCY	Cuiabá	MT	33	SBMO	Maceió	AL	53	SBTE	Teresina	PI
14	SBCZ	Cruzeiro do Sul	AC	34	SBMQ	Macapá	AP	54	SBTF	Tefé	AM
15	SBEG	Manaus	AM	35	SBMT	São Paulo	SP	55	SBTT	Tabatinga	AM
16	SBFI	Foz do Iguaçu	PR	36	SBNF	Navegantes	SC	56	SBUF	Paulo Afonso	BA
17	SBFL	Florianópolis	SC	37	SBPA	Porto Alegre	RS	57	SBUG	Uruguaiana	RS
18	SBFZ	Fortaleza	CE	38	SBPB	Parnaíba	PI	58	SBUL	Uberlândia	MG
19	SBGO	Goiânia	GO	39	SBPJ	Palmas	TO	59	SBUR	Uberaba	MG
20	SBHT	Altamira	PA	40	SBPK	Pelotas	RS	60	SBVT	Vitória	ES

Figure 14: Codes of Domestic Airports Operating Commercial Aircrafts In Brazil 2017
Source: Infraero 2017

Nowadays there are 651 public aerodromes and 3,136 private airfields for all sorts of aviation purposes recognized by ANAC (2017). The main public airports used for most passenger transportation are distributed among the federal states and shown in the figure 15. There is a clear concentration of airplane fleet and airports used for domestic flight operations along two regions in Brazil.

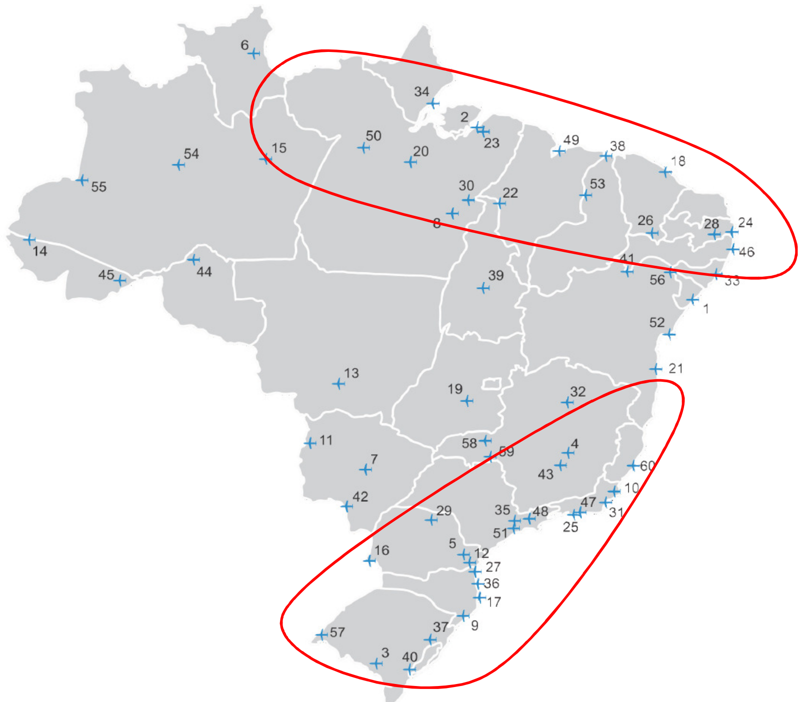

Figure 15: Spatial Distribution of Domestic Airports Operating Commercial Aircrafts Brazil 2017
Source: Infraero 2017

There is to distinguish a clear concentration, notably of private airfields (Aeródromos Privados) at the central land of the country among the states of Mato Grosso and further a hub of private airfields at the north of the Amazonia at the border to Venezuela. Interestingly, at these minor airfields do operate small piston - engines airplanes that use solely aviation gasoline (Gasolina de Aviação - GAV) as a fuel source. The rest of the airport infrastructure is supplied with Aviation Kerosene – QAV and is distributed mostly along a north-south axis among the states of Bahia, Minas Gerais, Rio de Janeiro and São Paulo. Herewith, the map reflects the greatest accumulation of major public airfields (Aeródromos Publicos) within the states of São Paulo and Minas Gerais. In addition, a third hub of airports is to detect in the most southern region between the states of Paraná, Santa Catarina and Rio Grande do Sul and there is to notice the military air bases (Aeródromos Militares) at the remote central land and the Brazilian borders.

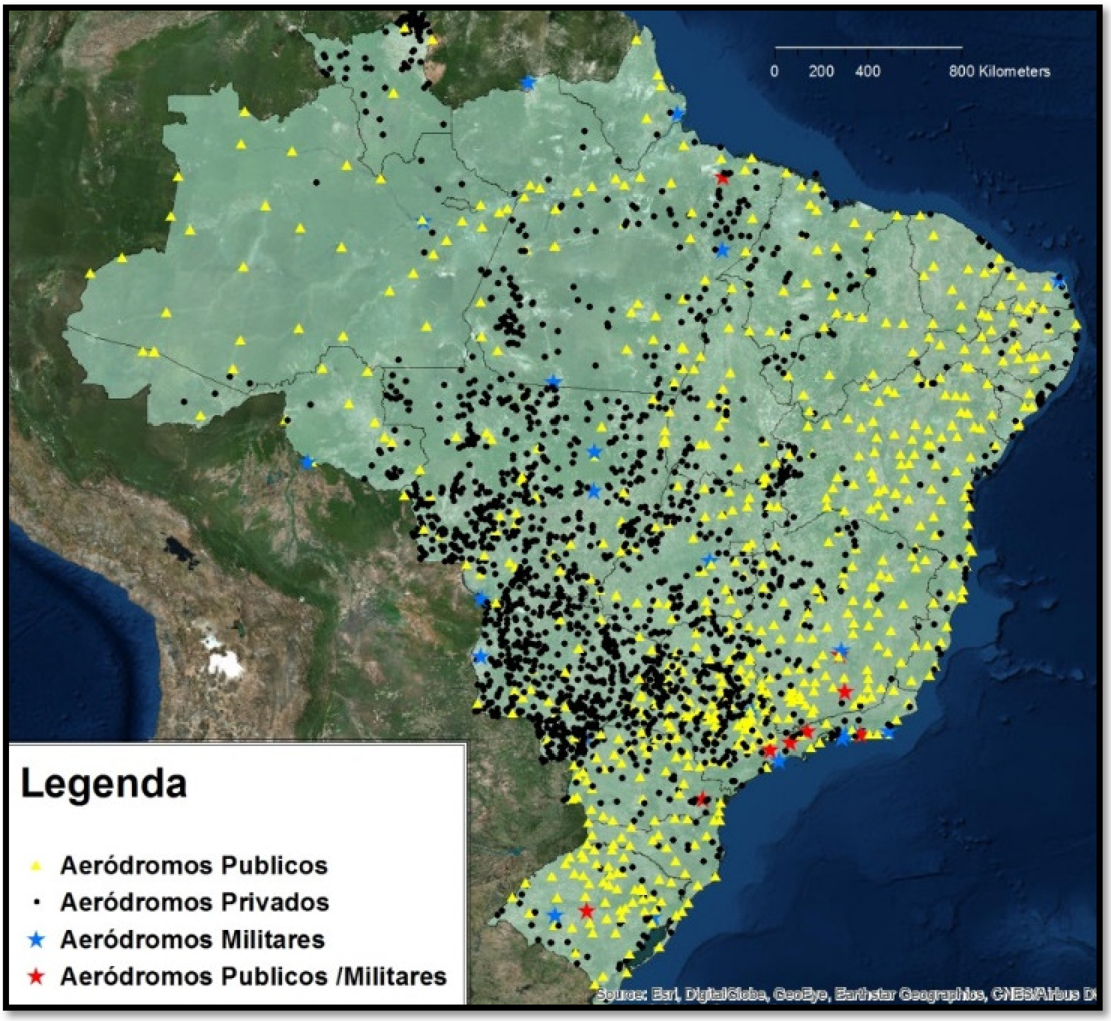

Figure 16: Distribution of Airfields by purpose of utilization
Source: ANAC - Agência Nacional de Aviação Civil (2017)

To zoom into detail considering the distribution of the aircraft fleet each by type of airplane among the 20th mayor airports among Brazilian states, the following table show the cargo transported in tons per year and the jet fuel demand in liters per year of each airport as well as how many flights per year have been realized of each type of airplane.

Brasilia International Airport - Jucelino Kubitscheck		*Belo Horizonte International Airport – Tancredo Neves*		*Belo Horizonte Airport– Carlos Drummond de Andrade*		*Goiânia Airport – Santa Genoveva*	
*Cargo: **39.468 t** Jet Fuel demand p. year: **569.743.485 liters***		***Cargo:** 28.085 t **Jet Fuel demand p. year:** 281.816.277 liters*		***Cargo**: 95.000 t **Jet Fuel demand p. year**: 10.599.572 liters*		***Cargo**: 9.228 t **Jet Fuel demand p. year:** 78.926.175 liters*	
Aircraft Type	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***
A320	42.006	E190	34.980	E50P	18.778	E190	8.084
B738	39.213	B738	23.737	AT43	14.970	B138	6.728
A319	17.631	B737	12.513	AS50	3.977	A320	6.424
B737	13.348	A320	10.436	BE9L	3.118	AT72	4.047
A318	9.189	A319	8.089	C208	2.397	B737	2.648
R44	2.844	AS50	205	R44	2.335	BE9L	3.019
C208	2.291	R44	145	45	1.012	BE20	1,086
BE9L	1.650	BE9L	80	AT72	15	MU2	855
As50	1.474	R66	58			C525	779
E50P	946	B06	44			AS50	154

Porto Alegre International Airport – Salgado Filho		*Salvador International Airport - Luís Eduardo Magalhães*		*Curitiba International Airport – Afonso Pena*		*Recife/Guararapes International Airport – Gilberto Freyre*	
*Cargo: **20.885 t** Jet Fuel demand p. year: **192.598.253 liters***		***Cargo:** 23.136 t **Jet Fuel demand p. year:** 291.563.643 liters*		***Cargo:** 29.278 t **Jet Fuel demand p. year :** 149.486.539 liters*		***Cargo:** 32.912 t **Jet Fuel demand p. year:** 227.635.901 liters*	
Aircraft Type	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***
B738	20.077	A320	24.191	B738	22.571	B320	19.080
E190	14.247	B738	18.441	E190	16.974	E190	11.202
A320	16.102	AT72	10.544	A320	12.659	B738	10.048
B737	4.714	E190	9.860	E319	8.589	B737	9.874
AT72	3.819	B737	8.863	AT72	4.365	AT72	5.354
R22	1.580	AS50	1.577	SK76	2.232	R44	2.364
C208	1.427	S76	1.207	C208	679	E50P	692
R44	1.055	BE9L	941	E110	348	R66	675
BE9L	938	EC35	863	AS65	342	AS50	663
AS50	918	R44	819	E50P	312	BE9L	662

Fortaleza International Airport – Pinto Martins		*Manaus International Airport – Eduardo Gomes*		*Cuiabá International Airport – Marechal Rondon*		*Belém / Val-de-Cans International Airport – Júlio Cezar Ribeiro*	
*Cargo: **47.087 t** Jet Fuel demand p. year : **230.907.530 liters***		***Cargo:** 121.295 t **Jet Fuel demand p. year:** 158.011.842 liters*		***Cargo**: 6.493 t **Jet Fuel demand p. year:** 74.362.665 liters*		***Cargo:** 24.459 t **Jet Fuel demand p. year:** 152.074.533 liters*	
Aircraft Type	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***
A320	15.004	A320	8.588	E195	11.907	A320	11.809
B738	13.923	E190	4.421	A320	5.158	B737	7.347

E190	6.287	B738	4.354	AT72	4.951	AT72	5.412
A321	4.374	AT72	4.281	B738	3.497	B738	5.318
A318	3.936	B737	3.068	B734	734	E190	4.392
F100	124	A321	728	C152	2.943	C208	4.453
BE9L	955	AT43	2.417	BE58	1.340	AT43	2.417
AS65	528	B763	2.399	PA34	2.123	B763	2.399
B737	3.623	A330	1.327	C208	1.448	B06	582
A319	1.338	E170	1.327	AS50	1.034	R44	513
A332	701	B733	1.024	PAY1	1.407	AS50	499
AT72	642			A318	667	E110	400
B763	142						
AS50	1.062						
C208	699						

Florianópolis International Airport – Hercílio Luz	*Ribeirão Preto Airport – Leite Lopes*	*Maceió International Airport – Zumbi dos Palmares*	*Campo Grande International Airport – Antônio João*
*Cargo: **5.910 t** Jet Fuel demand p. year: **88.061.036 liters***	***Cargo:** 1.076 t **Jet Fuel demand p. year:** 276.394 liters*	***Cargo:** 3.039 t **Jet Fuel demand p. year :** 51.536.888 liters*	***Cargo:** 4.361 t **Jet Fuel demand p. year:** 39.963.075 liters*

Aircraft Type	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***
A320	8.984	AT72	11.609	B738	4.429	B738	3.353
B737	5.296	A319	2.406	A320	3.602	A320	3.072
B738	9365	A320	2.052	AT72	2.328	E190	3.006

A318	4.661	E145	1.109	E190	2.301	F100	2.851
E190	3.506	E190	609	A321	1.465	AT72	1.872
AS50	2.002	R22	5.042	BH06	1.500	C150	530
A119	1.154	R44	1.625	AS50	925	BE9L	525
R44	447	R66	1.084	R44	298	A29	492
E50P	432	BE9L	1.006	AS55	289		
BE9L	401	AS50	1.257	E50P	261		

Rio de Janeiro International Airport – Antônio Carlos Jobim		***Guarulhos International Airport – André Franco Montoro***		***Rio de Janeiro Airport – Santos Dumont***		***São Paulo Airport – Congonhas***	
*Cargo: **119.753t** Jet Fuel demand p. year: **709.401.578 liters***		***Cargo:** 479.247 t **Jet Fuel demand p. year:** 2.368.994.616 liters*		***Cargo:** 8.139 t **Jet Fuel demand p. year**: 472.934.386*		***Cargo:** 50.921 t **Jet Fuel demand p. year:** 244.485.036 liters*	
Aircraft Type	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***	**Aircraft Type**	***Flights***
B738	38.977	B738	36.649	A319	35.019	B738	52.000
A320	38.075	A320	58.046	B738	30.200	A320	30.886
A319	11.693	B737	21.005	E190	23.043	A319	51.812
E190	7.953	E190	18.964	B737	8.264	B737	22.363
A318	6.427	PAT4	489	AT43	2.176	A318	917
C208	665	A321	11.980	RH44	774	A109	5.303
E50P	282	A109	2.834	C56X	777	E50P	2.536
GLF5	282	AS50	1.339	E50P	830	C56X	2.832
GLEX	229	C208	581	A109	896	BE20	2.012

AS50	289	BE9L	469	AS50	1.525	BE9L	2.393

Figure 17: Distribution of Airplanes and Jet Fuel Demand at 20 Major Brazilian Airports
Sources: EPE - Empresa de Pesquisa Energética (2017); IBA - Instituto Brasileiro de Aviação Brasil (2017)
ABESATA - Associação Brasileira das Empresas de Serviços Auxiliares de Transporte Aéreo (2016)
ABESATA - Associação Brasileira das Empresas de Serviços Auxiliares de Transporte Aéreo (2014)
Infraero (2017)

Furthermore, the frequency of flight operations between those major airports is drafted. Interconnections between airfields among the Brazilian airport network will indicate where exists most demand for QAV. At this, figure 18 shows the proportional degree of interconnection frequency between two airports, also labeled as betweeness centrality (Couto et al. 2015). Red color and greater size of the nodes means high frequency of connection flights between airports, the quantity of domestic passengers transported however is indicated by the color of the line between departure and arrival airport. To conclude, major airports, like the ones located at Sao Paulo, Rio de Janeiro, Brasilia and Belo Horizonte are not well spread over the country. This is of course due the concentration of industry and commerce centers in the south-east area and its population epicenters. Hence, the most connected airports are concentrated in this region. According to Couto et al. (2015), passengers living in the north and northeast regions need to fly to some hub in the southeast region in order to fly back to cities located next by to a northern departure airport. Actually, the only airport of major importance in terms of connectivity in Brazil’s north is the Manaus Airport. In comparison, the majority of airports are not well interconnected because the flight connections do not always display the shortest route of an airline domestic flight network.

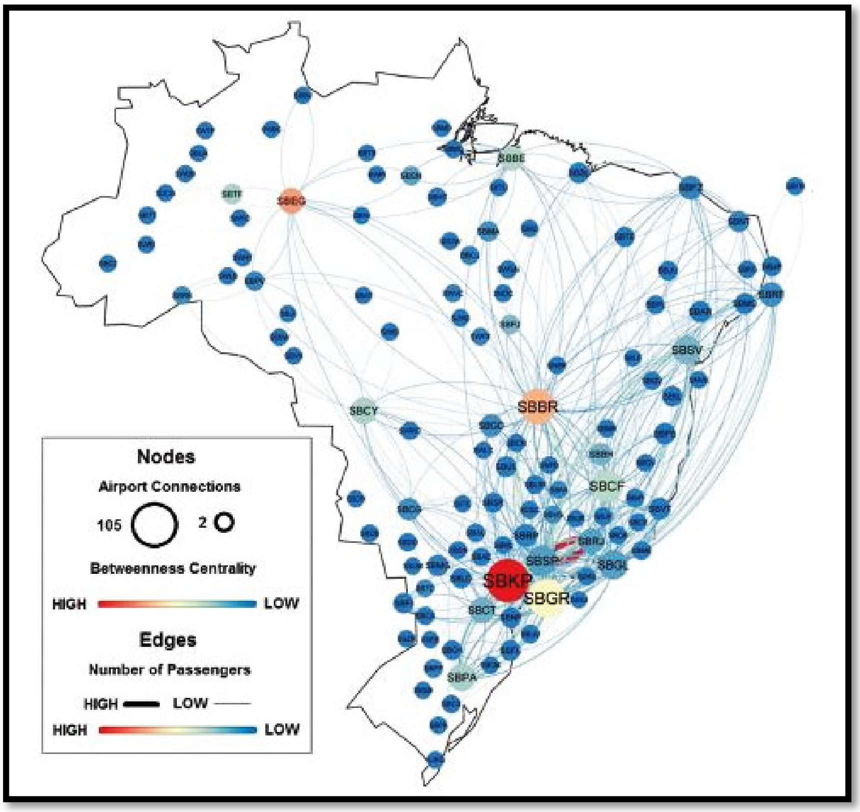

Figure 18: National Flights Between Brazilian Airports 2015
Source: Couto et al. (2015)

According to ABAER (2016), the airport of Brasilia is an important domestic hub for passenger transport, mostly of business nature, but due to a less regional industrial production capacity, air cargo between this airport is relatively low. In comparison, the Sao Paulo Guarulhos – Manaus Airport Axis in both directions is responsible for about 20 percent of all domestic air cargo. In Brazil there exists a high regional concentration of industrial production spread unequally among the country. Thus, massive air cargo is just executed at few airports (figure 17) because air cargo service in Brazil is realized more for high end products consisting of high economic value rather than for heavy primary resources.

3.3. FUEL PRICES FOR AIRLINES

Aviation kerosene is a derivative of petroleum used specifically as a fuel in aircrafts. In Brazil, two types of aviation kerosene are produced. QAV-1 for general use, aligned with the AFQRJOS Jet A-1 specifications and kerosene of aviation specially produced for the Brazilian navy, also known as JP5 or naval fuel (Petrobras 2017). When domestic aviation was still under development a few decades ago, the number of passengers and freight carried was still considerably low and the reality for the energy sector was also different. At this time, fuel consumed by domestic aviation industry was primary imported. Thus, the formula for fuel price calculation considered the fluctuations of the crude oil price at the international market and the Brazilian Reais was linked directly to currency fluctuations in US Dollars. Nowadays, Brazil is close to self-sufficiency regarding oil production and refines almost all the kerosene consumed by the airline industry within Brazil (ABEAR 2017). Considering the financial performance of the aviation industry one might expect that businesses operate cost-effective, financially robust and competitive. Notwithstanding, as figure 19 states, regardless of the industry growth and actions on cost savings taken, the financial performance of the two major Brazilian airlines TAM and GOL is modest and very volatile.

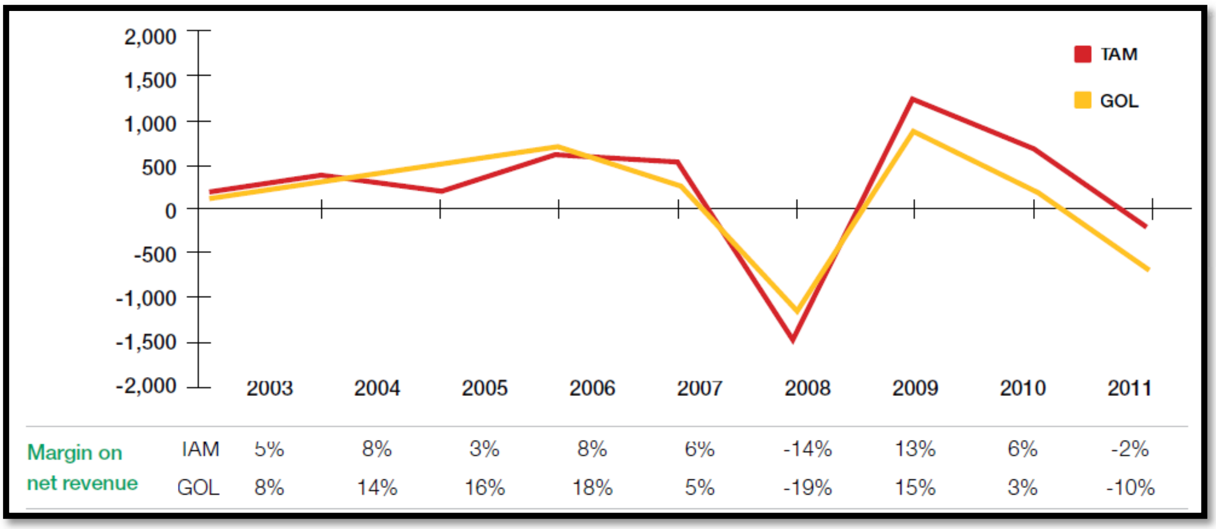

Figure 19: TAM And GOL Historical Income in Brazil R$ Thousands
Source: ABEAR (2016)

The logistical and financial planning of aviation fuel supply is becoming a crucial condition for the survival of Brazilian airlines due to the increase of total operational costs and in particular to the cost portion of aviation fuel. Therefore, the decrease of expenditures for the cost component jet fuel must be a top priority to airlines. The so-called tanking, a practice where airlines refuel their tanks in low tax burden states in order to save on total fuel costs, tends to be a common reality nowadays in Brazil. Paradoxically, this is performed despite longer distances and inefficient routes between airports. In fact, aviation fuel in Brazil is up to 40 percent more expensive than the international average price on QAV and makes up of approximately 30 percent of an airlines total cost, as figure 20 stresses. In the United States, another strong aviation world market, the cost for aviation fuel makes up just 14 percent of total expenditures (ABEAR 2016).

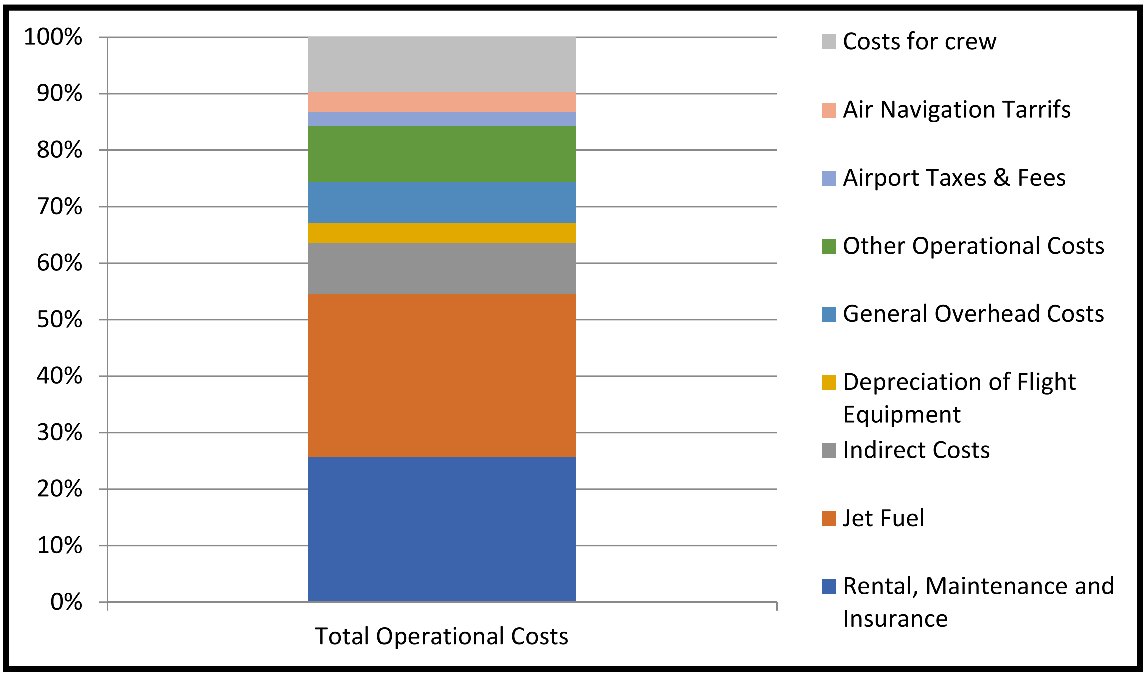

Figure 20: Cost Composition for Brazilian Airlines year of 2015
Source: ABEAR (2016)

In that respect, it is to consider that the price for jet fuel in Brazil rose by a value of 74 percent between the years of 2002 and 2015. The portion of 30 percent decreased relatively in comparison to the period between 2011 and 2014 when the cost for jet fuel experienced its peak around 39 percent of all operational costs (ABEAR 2017). One major reason for this phenomenon might be the jet fuel supply dependency of an airline on the major aviation fuel distributor Petrobras. In effect, airlines become inflexible considering margins for alternative financial planning in case Petrobras decides to interrupt or suspend the jet fuel supply. A second reason might be the exchange rate variation from the Brazilian Reais to the US Dollar, since Petrobras charges the price quoted in dollars even though the QAV is produced in large parts within Brazil. Especially, the sharp devaluation of the national currency between 2011 and 2015, did diminish the prosperous additional revenues of the aviation industry linked to the depreciation of the international oil price. The costs of aviation kerosene on international average is 19 percent.

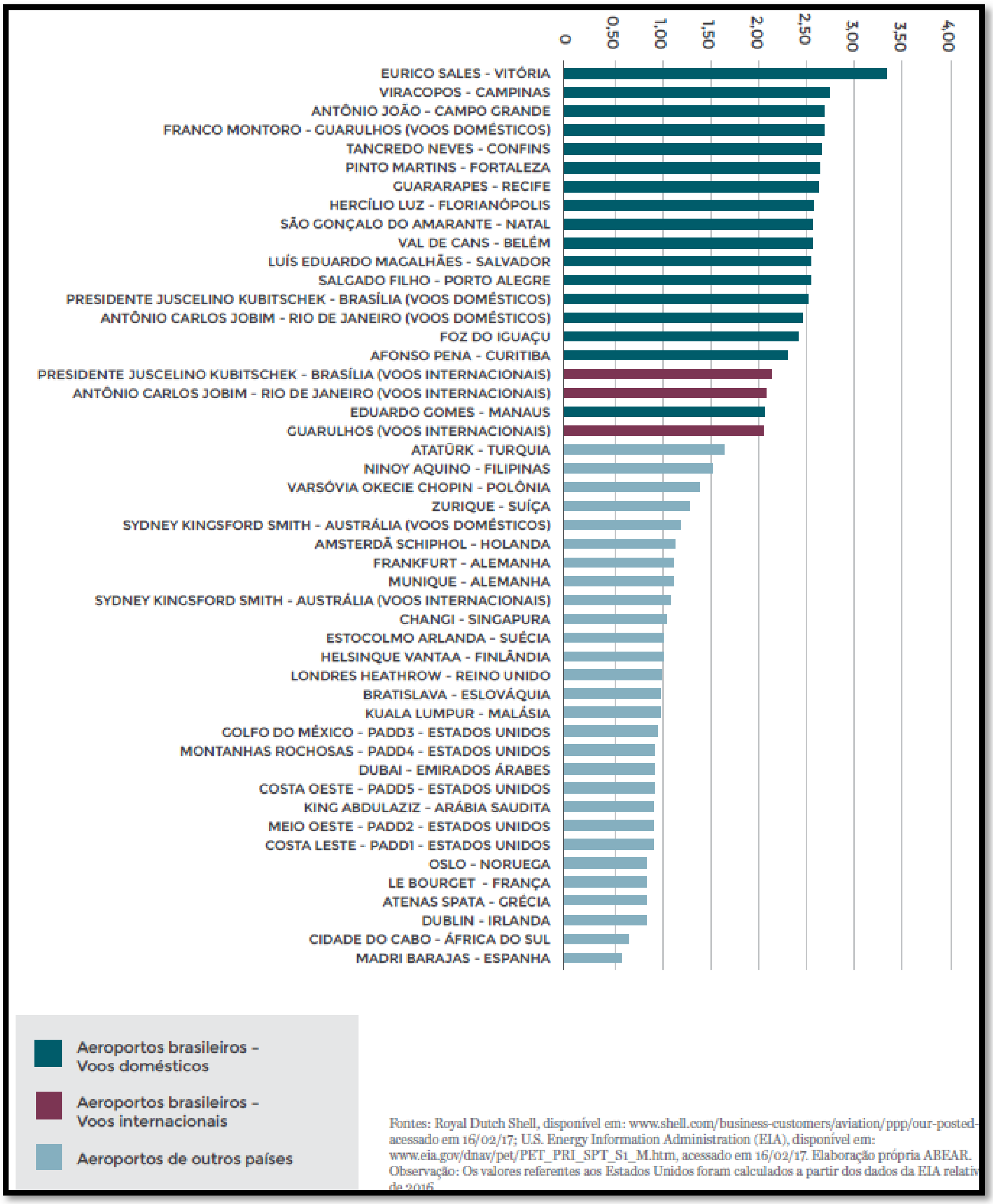

Figure 21: Comparison of Aviation Fuel Prices in US Dollar per Liter at Several Airports in 2017
Source: ABEAR (2016)

A Brazilian singularity and reason for those unreasonable prices is the ICMS tax rate on aviation kerosene used in domestic flights, which varies between states the jet fuel is supplied. ICMS refers to a value added tax form. The result is a joint effect that increases fuel prices on domestic flights by 22 percent depending further on the federal state at which the fuel supply occurs. This high tax margins along the value chain make the purchase of aviation fuel between 35 and 50% more expensive than in the developed markets. At the same time uncertain costs drivers linked to frequent fluctuations of the US Dollar as others like maintenance, leasing, depreciation of aeronautical items led to a substantial increase in operating expenses and significant difficulties for cost planning and management of airlines. This led to a substantial change in the operation cost composition of an airline (ABEAR 2017). To conclude, it might be necessary to establish and new pricing formula of fuel costs and consider tax exemptions to increase competitiveness of national airlines and secure a sustainable growth of the domestic industry. (Boeing/Embraer/ FAPESP and UNICAMP 2013)

3.4. THE JET FUEL VALUE CHAIN

To examine which cost drivers have what kind of effect on the total cost of aviation kerosene production throughout its whole life-cycle (figure 22), the fluxes of QAV, from cradle to grave and between points of production, distribution and consumption, will be emphasized. In relation to that, figures about QAV quantities, importation point as well as redistribution is relevant to understand how the whole QAV value chain in Brazil works.

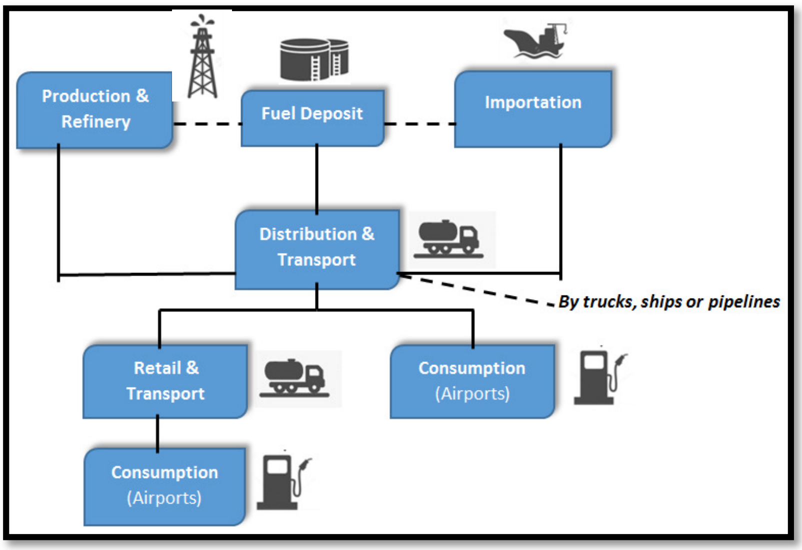

Figure 22: Fluxes of QAV Value Chain
Source: Petrobras (2017)

The domestic jet fuel production and supply infrastructure is relatively straight forward. The market for aviation fuel supply and distribution is held to about 55 percent by the national petroleum company Petrobras, which operates along the whole value chain and delivers jet fuel to more than 100 Airports across the country. The QAV supply to airports and final consumers is handled by 3 distributors namely, Petrobras, Raízen and Airbp. The fuel supplier Raízen, a subsidiary of Shell, accounts for 32 percent and Airbp with 13 percent market share on QAV distribution. Moreover, the QAV supply to airports and final consumers is handled by three distributors namely, Petrobras, Raízen and Airbp whose evolution of market share and volumes of supply are indicated in the following graphics (ANP 2016).

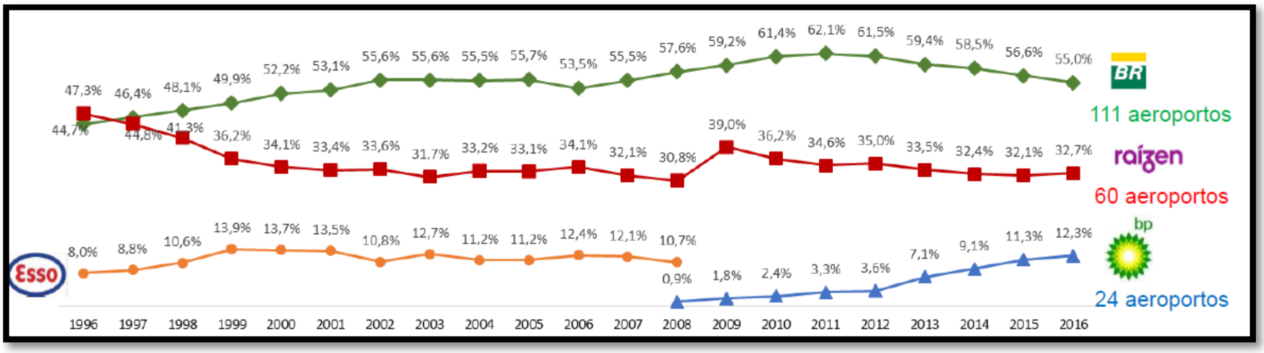

Figure 23: Evolution of Jet Fuel Market Share of Distributors in Brazil 2016
Source: Petrobras (2015) and Sindicom (2017)

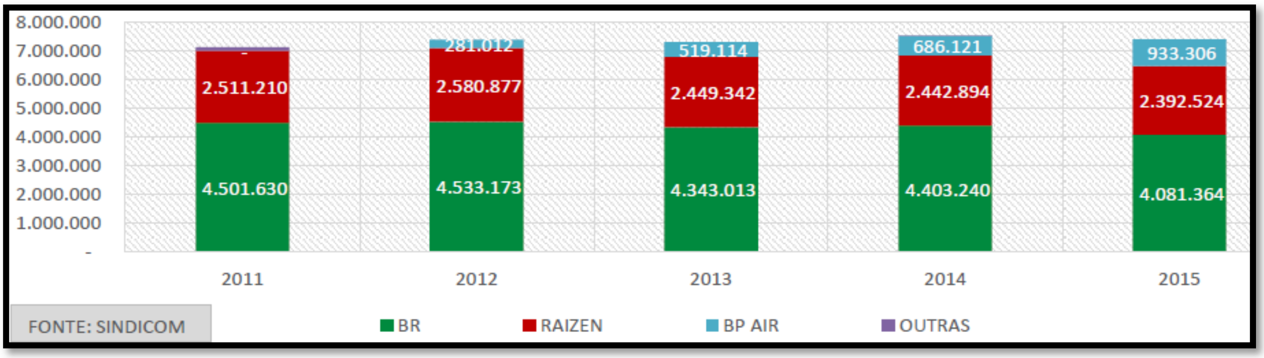

Figure 24: Total Volume of QAV Supply of Distributors per Year in m^3
Source: Petrobras (2015) and Sindicom (2017)

Along the value chain, 271 retail agents are operative. There exist 9 refineries which all Petrobras operates. Hence the company holds a monopoly on the QAV production and importation in Brazil as 100 percent of QAV production is controlled. Distribution is realized via 191 fuel depots and 6 greater fuel stock terminals, which are owned by Petrobras the company Transpetro and other private firms. In the year of 2016, Petrobras produced 5.8 million m^3 QAV domestically. Per day 2.330.000 barrels of QAV were produced by all national refineries. In comparison, aviation gasoline in 2016 was produced to a maximum number of 53.902 m^3, all by the refinery RPBC near the city of

São Paulo. In fact, the south-east region with the states of São Paulo, Rio de Janeiro and Minas Gerais accounts alone for 82 percent of all QAV production. This is due to the high demand of aviation kerosene of the most frequented airports located between these cities. Most QAV is produced in the refineries of REDUC and REVAP based in Duque de Caixas and São José dos Campos situated nearby major airports (EPE - Empresa de Pesquisa Energética 2017).

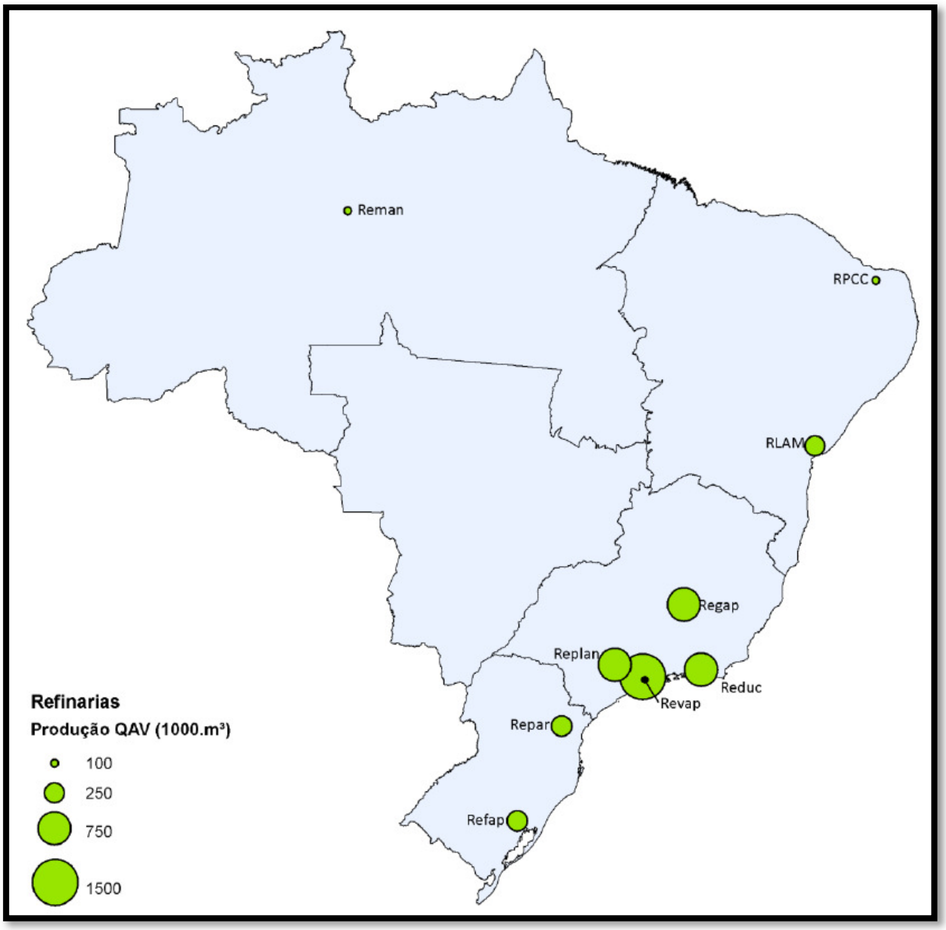

Figure 25: Refineries and Production Capacity of QAV in Brazil
Source: Ferreira Gonçalves (2015)

REDUC	1.402
REFAP	**189**
REGAP	**575**
REMAN	**118**
REPAR	**265**
REPLAN	**992**
REVAP	**1.829**
RLAM	**281**
RPCC	**138**
TOTAL	**5.789**

Figure 26: Production of QAV in 2016 by Brazilian Refineries (Millions of m^3 / year)
Source: Empresa de Pesquisa Energética (2017)

Consequently, the distribution of airfields in figure 15 can be compared with the demand of QAV among the Brazilian states. Thus, figure 27 emphasizes that most demand occurs in the south – east region, especially in the states of São Paulo and Rio de Janeiro. This makes sense as the most demand for QAV occurs at the locations with the strongest concentration of airport infrastructure as shown before in figure 16. The total demand of QAV in Brasil was recorded to 6.764.745.525 liters in the year 2016

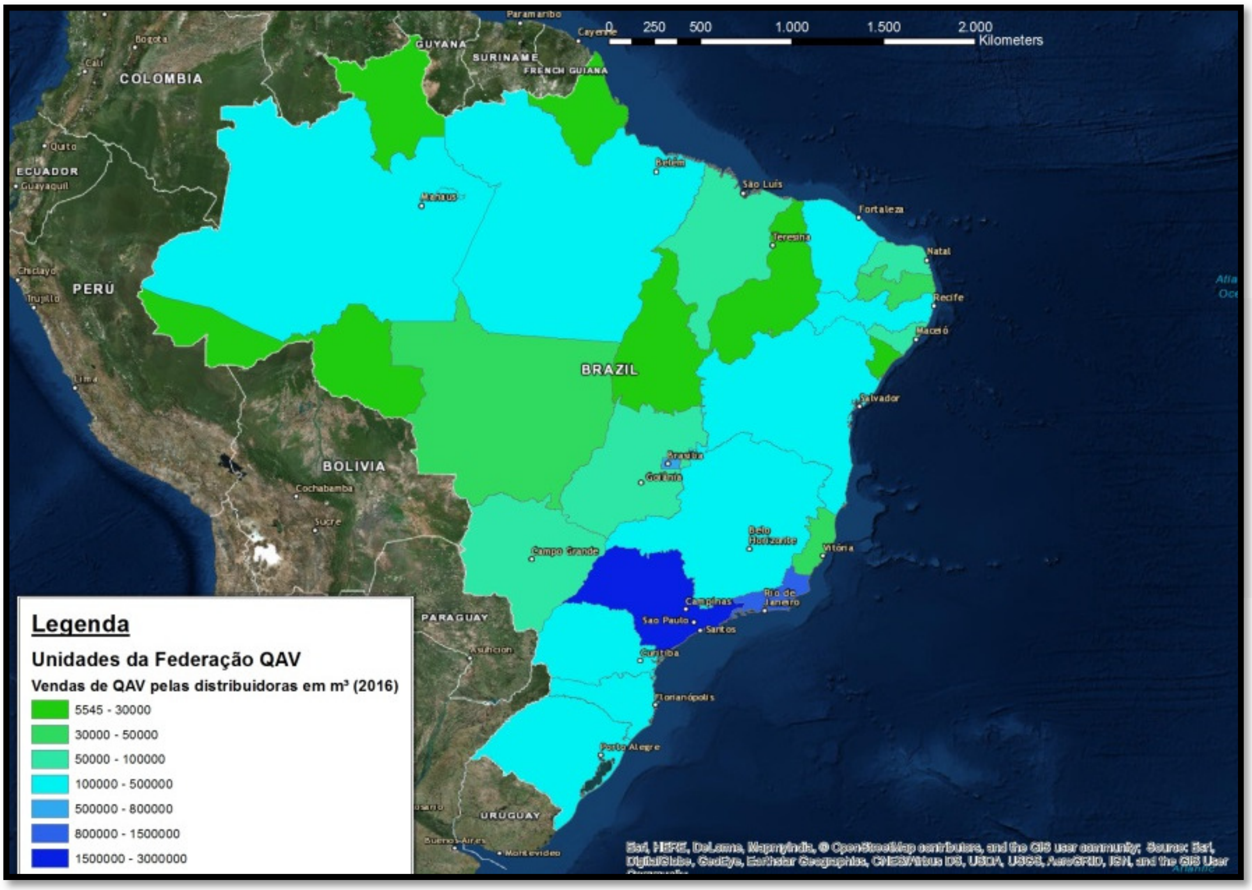

Figure 27: QAV Sold by Distributors in m^3 by Federal States in 2016
Source: ANP (2017)

In order to compare these outcomes to the distribution of aviation gasoline – GAV or AVGAS, the following figure 28 illustrates the respective volume sold by jet fuel distributors. Notably, the demand is much more equally spread then it is in the case of QAV as the network of small airports operating GAV fueled airplanes is distributed among more states, especially among the ones in the central land. However, the most demand occurs within the state of São Paulo and is also distributed strongly among the states Minas Gerais, Mato Grosso and Pará. Though the maximum amount of GAV sold (11.000m^3), does not reach the quantities of QAV distributed (2.800.000 m^3). To summarize, at the coastal area there is a vast demand for QAV where a strong airport infrastructure is located but smaller amounts of GAV are demanded in more remote areas and are overall more equally distributed among federal states.

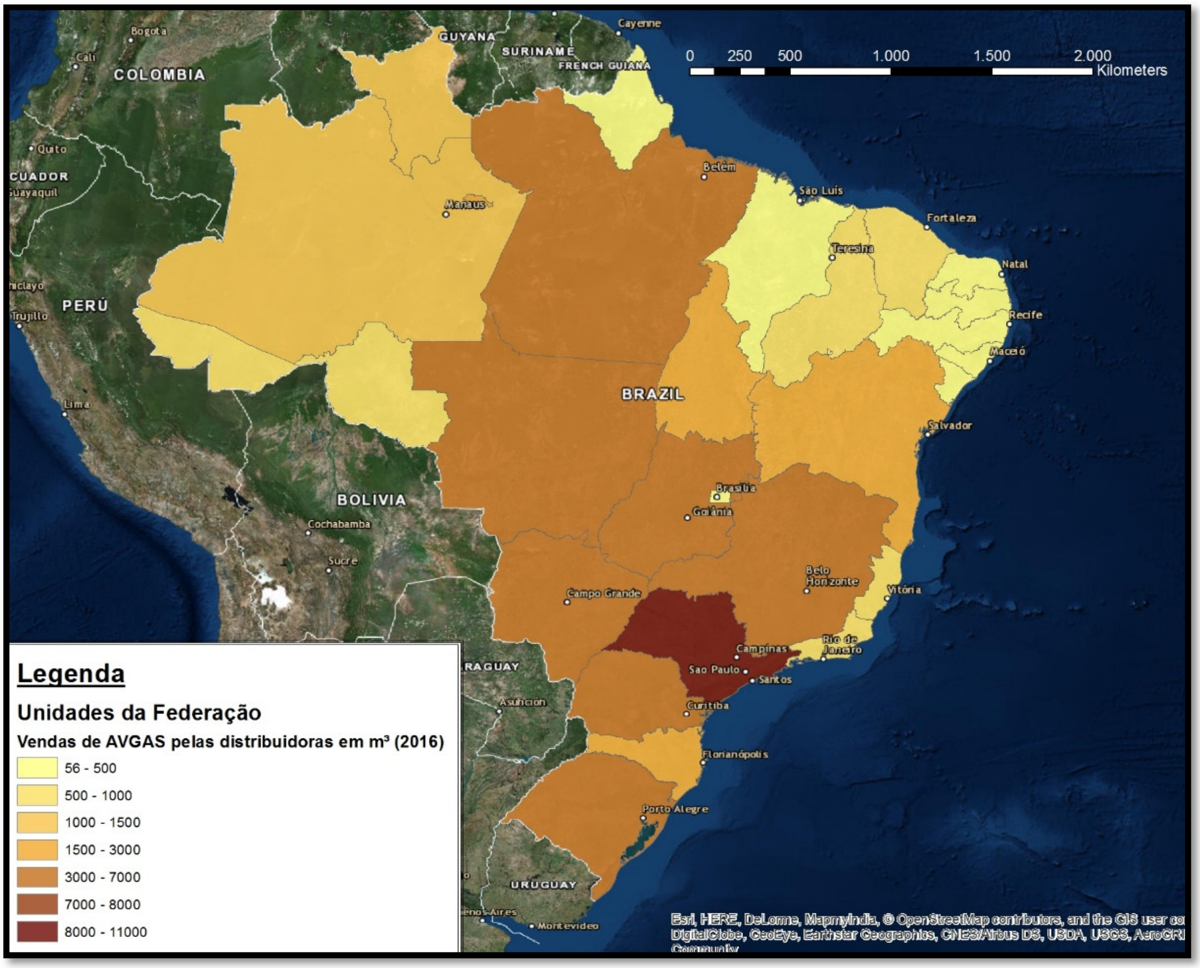

Figure 28: Aviation Gasoline (GAV) Sold by Distributors in m^3 By Federal States in 2016
Source: ANP (2017)

However, it is of major interest to obtain specific data about the demand of QAV in m^3 or litres at each point among the value chain. Therefore, the total demand indicated by states will be interpreted in terms of detailled figures, specifying how much jet fuel is transported between and within each state as well as between points of production, distribution and consumption. Therefore, the flux diagramms in the following represent the QAV infrastructure corresponding to each region in

Brazil. Herewith, the supply of aviation fuel does vary between a proximate pipeline to major airports in Rio de Janeiro and São Paulo and terrestial as well as jet fuel distribution by waterways. The abreviations in the flux diagramm refer to the codes for refineries, terminals and major or minor airports. The amount of QAV by liters refers to the demand per year in 2016.

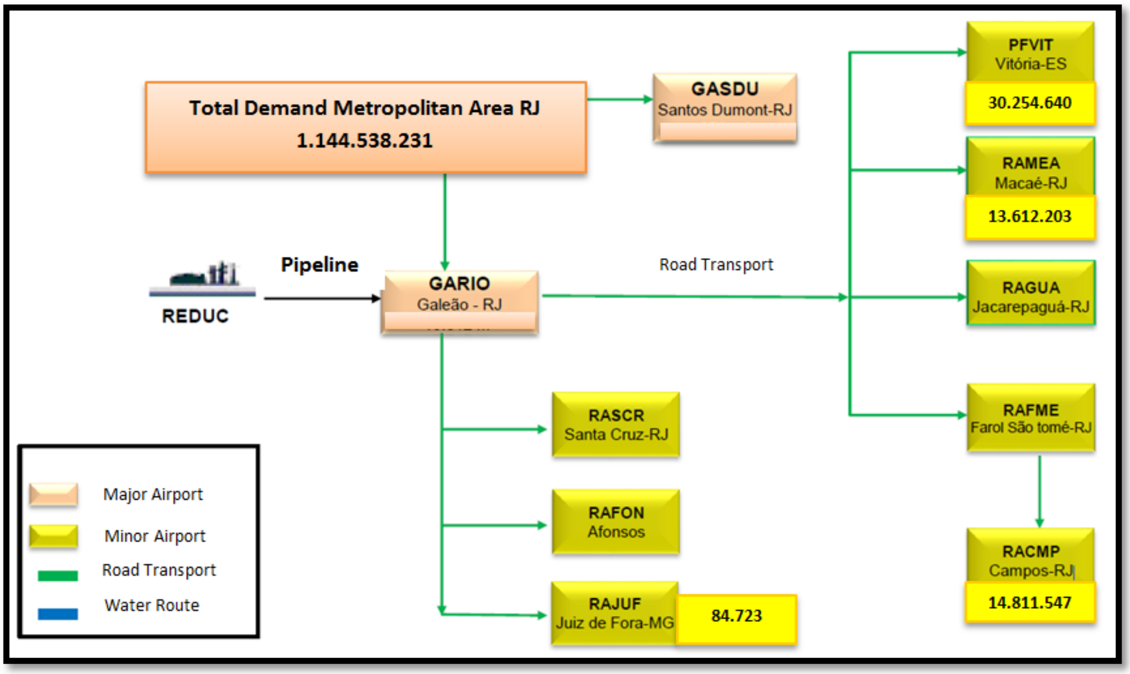

Figure 29: Distribution Fluxes: QAV Demand Region Rio de Janeiro in liters per year 2016
Source: ANP (2017) and (Petrobras 2015)

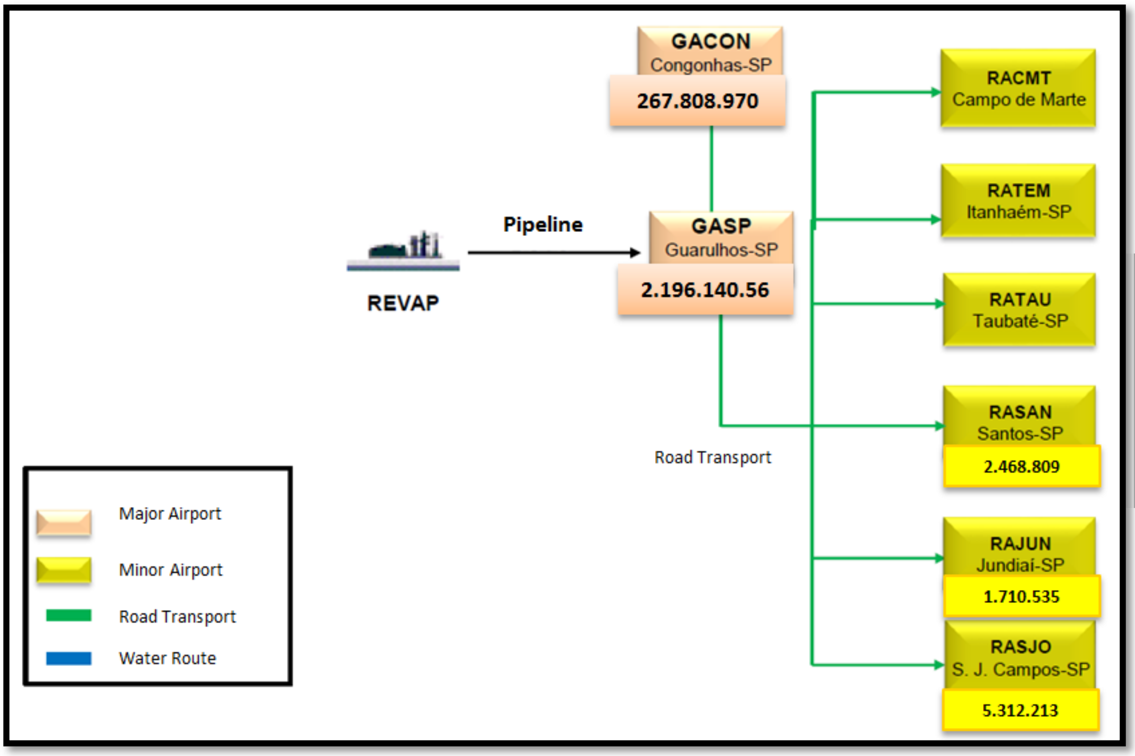

Figure 30: Distribution Fluxes: QAV Demand Region São Paulo in liters per year 2016
Source: ANP (2017) and (Petrobras 2015)

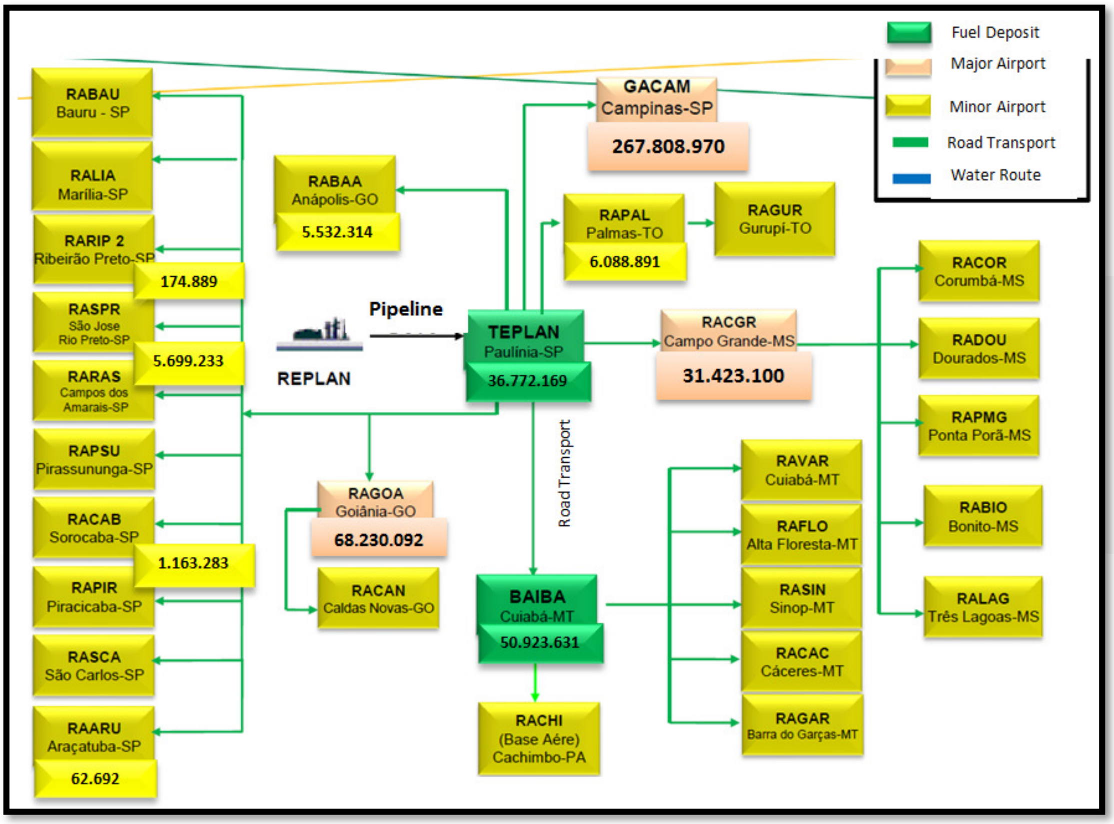

Figure 31: Distribution Fluxes QAV Demand Inland Region São Paulo and East-Central in liters per year 2016
Source: ANP (2017) and (Petrobras 2015)

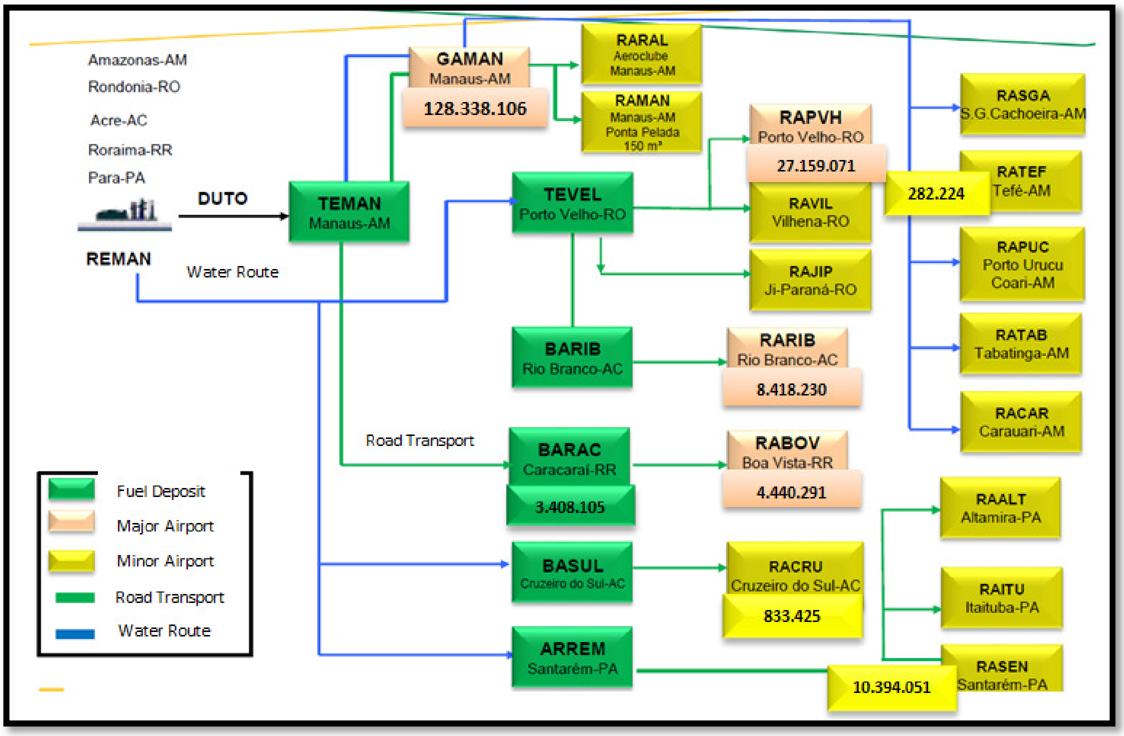

Figure 32: Distribution Fluxes: QAV Demand Inland Region São Paulo and East-Central in liters per year 2016
Source: ANP (2017) and (Petrobras 2015)

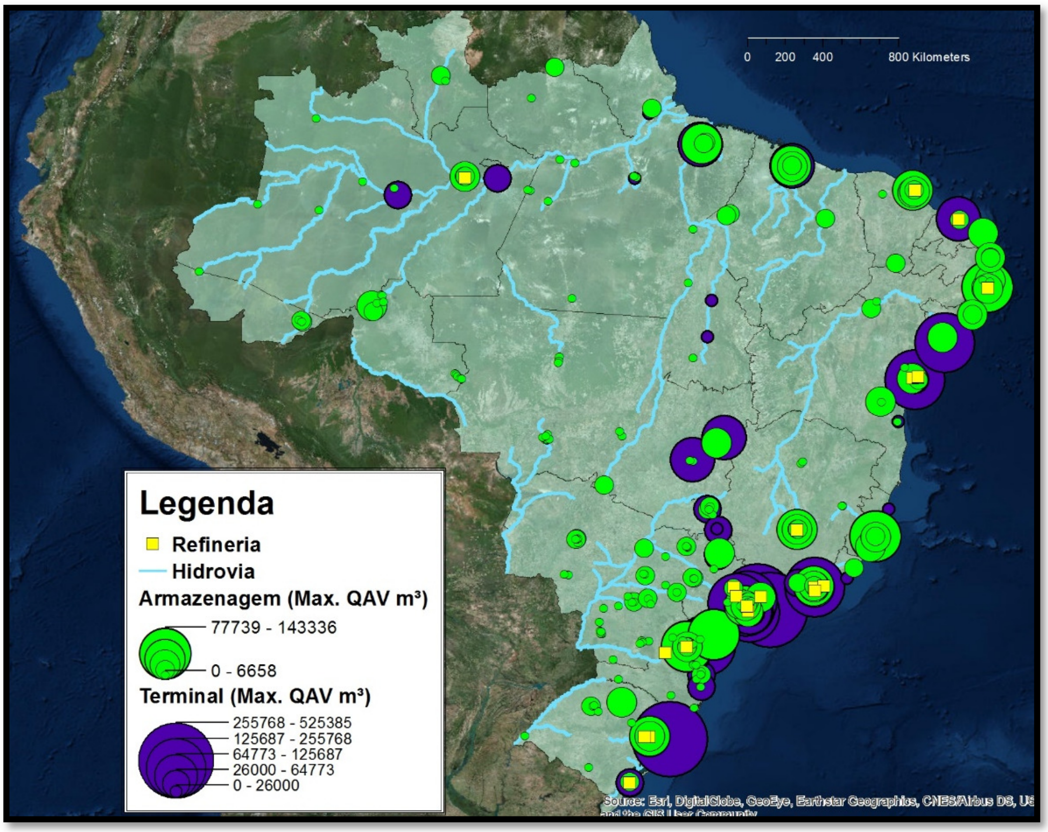

Figure 33: Distribution of QAV Deposits and Terminals Indicating Maximum Storage Capacity
Source: EPE - WEBMAP (2018)

The maximum storage capacity of jet fuel is mainly concentrated along the coastline where important harbors and for QAV imports are located and in the south-east where most air traffic, thus high demand for QAV occurs. Also, is to notice a distribution of jet fuel storage facilities along the waterways mostly among the central land and the Amazonas to simplify jet fuel distribution among the country.

To compare the data of production and demand of QAV between the years of 2010 and 2026 according to EPE (2016), demand will surpass supply on the long term leaving a gap of 9 thousand cubic meters per day production shortage in 2026. From this year onwards, demand is expected to increase exponentially as production keeps steady the level of today. This aspect clearly calls for an extension of the Brazilian QAV production infrastructure or for actions taken to broaden the jet fuel production portfolio. As for instance, synthetic aviation fuel would be an excellent alternative. If no measures are taken, the oil dependency and thus the amount of QAV imports will continue to rise in the long run.

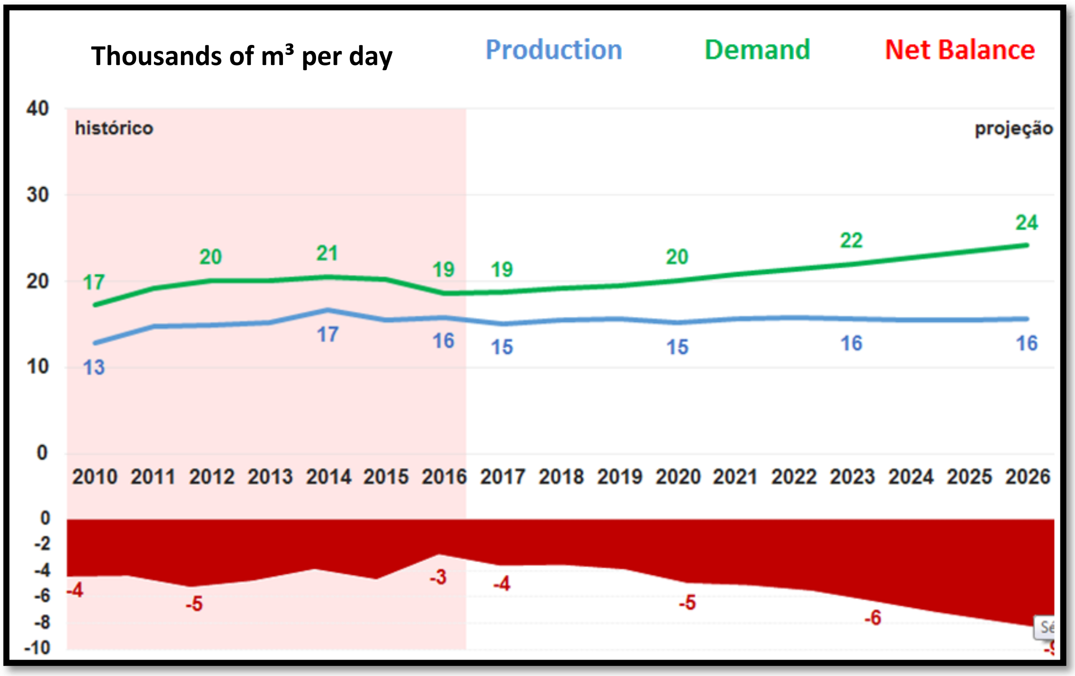

Figure 34: Balance of Supply and Demand QAV in Brazil: Today and forecast in Thousands of m^3 per day
Source: Empresa de Pesquisa Energética (2016)

However, the total energy demand of petroleum derivades QAV is recorded with 3,8 percent. Ethanol, gasoline and diesel are consumed the most in Brazil (EPE 2017). To demonstrate the development of the national consumption of QAV and the supply to international airlines from the 70´s on, figure 35 shows a clear and steady increase of consumption of QAV.

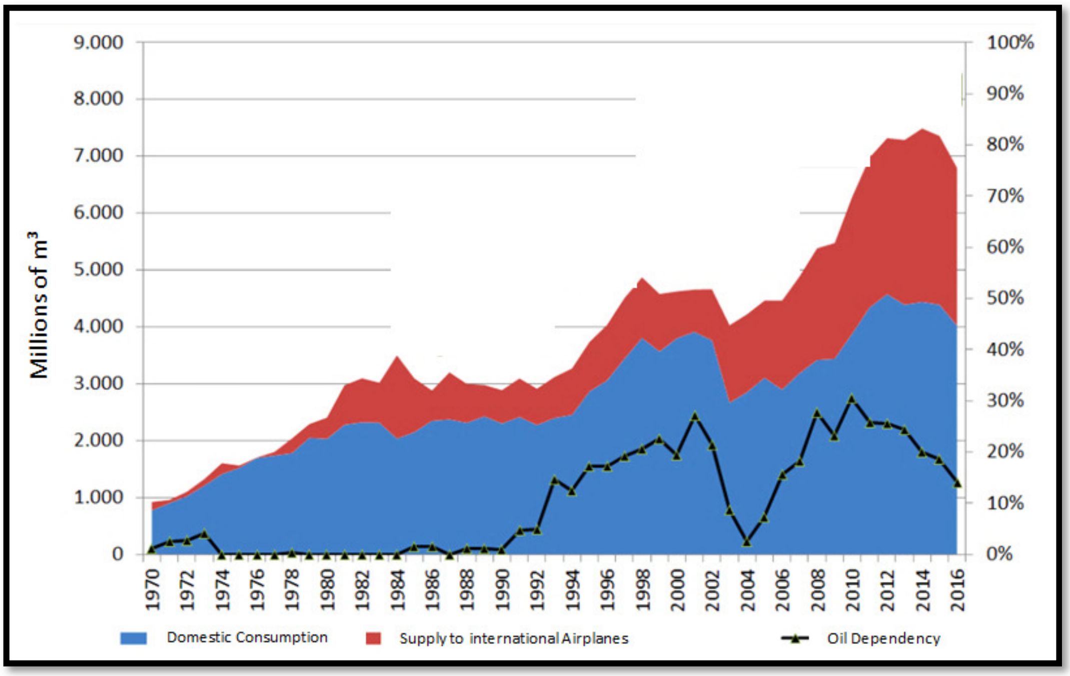

Figure 35: Evolution of domestic and international QAV consumption 1970 - 2016
Source: Empresa de Pesquisa Energética (2017) (Modified by author)

As shown, in 2016, 40 percent of all QAV is consumed domestically and another 30 percent is supplied to international operators reaching a figure of approximately 7.000 million of cubic meters QAV sold in that year. Under those circumstances, Brazil is required to import 12 percent of all jet fuel demand to satisfy total market request. Moreover, to illustrate the historical evolution of QAV in comparison to GAV, the following two graphs indicate the much higher production volume of aviation kerosene and the decline of aviation gasoline since 2014 respectively. In fact, the production of GAV is expected to fade out in near future due to a substitution of GAV powered airplanes by QAV powered ones.

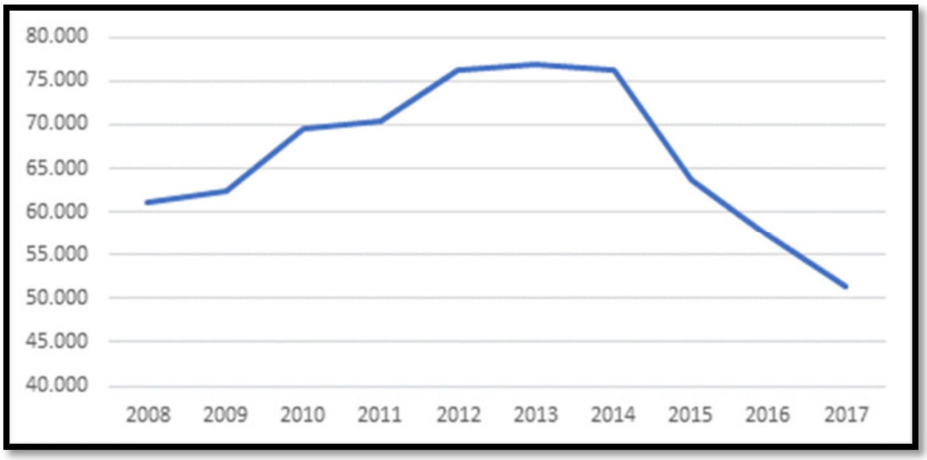

Figure 36: Evolution of Aviation Gasoline GAV Sold by distributors in liters (2016)
Source: SINDICOM (2017)

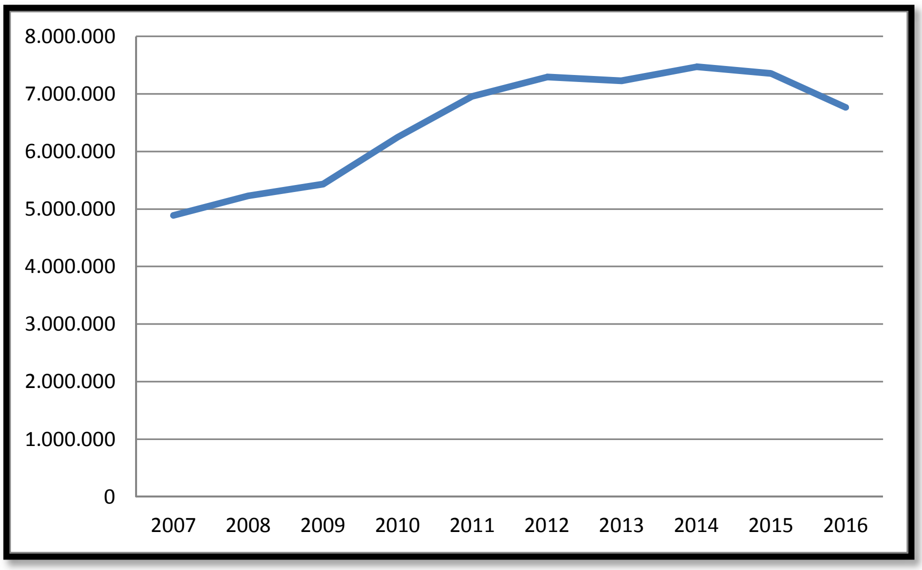

Figure 37: Evolution of Aviation Kerosene Sold QAV by distributors in m^3 (2016)
Source: ANP (2017) (Modified by the author) *(1m^3 = 1000 Liter)

Furthermore, figure 38 illustrates the interstate exchange of QAV stocks among points of importation and refineries. In comparison figure 39 shows a supply concentration in the heavy industrialized south-east region where also the most demand for the biggest Airports in São Paulo and Rio de janeiro is recorded the fuel is brought directly from nearby refineries to major airports via pipelines. To support production shortages for the relatively high demand of QAV compared to the local production output, in the northern region, aviation kerosene is imported and re-allocated from the states of Rio de Janeiro, São Paulo and Bahia towards remote locations either by coastal shipping, road or inland ship transportation. This reflects a tendency towards higher transportation costs for jet fuel to satisfy equally the countries QAV demand as dark blue represents states with excess capacities and light blue states with less production capacity than regional demand of QAV (SINDICOM 2017).

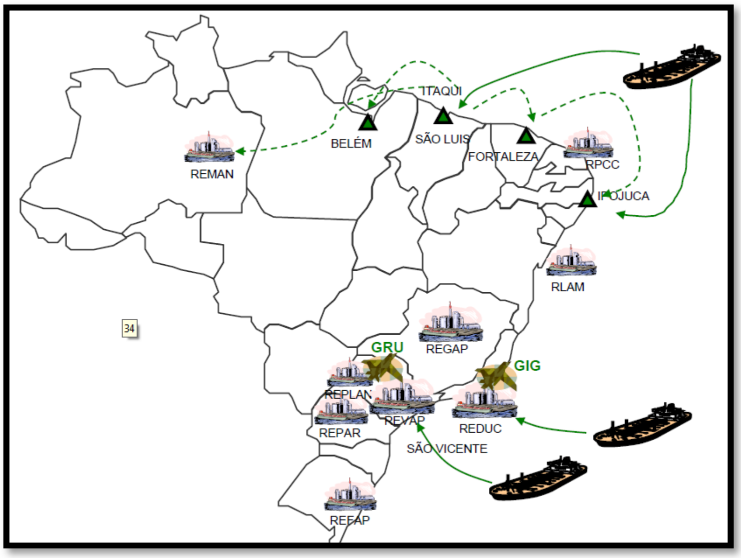

Figure 38: Import and reallocation of QAV by Petrobras
Source: Petrobras (2015)

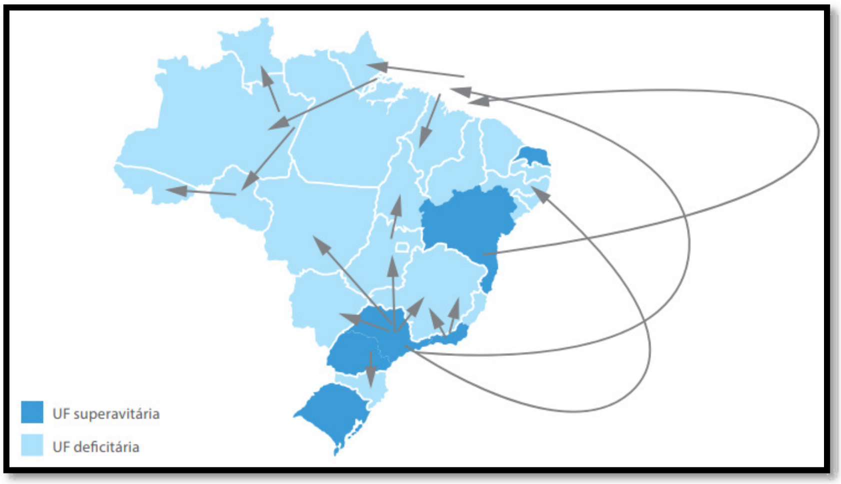

Figure 39: Re - distribution and shipping fluxes of QAV between regions
Source: ANP (2015)

3.5. REGULATORY BODIES, MARKET PLAYERS AND STAKEHOLDERS

Brazil´s aviation market is organized by several groups of actors and regulatory bodies. Hence the following chapter outlines the different participants along the QAV value chain, their functions and in which way do they interact with each other. At this, the importance for a support of the project Pro RQ for each stakeholder is described. Furthermore, a stakeholder map is provided illustrating the most important market participants dividing the players in three groups; the private, the science and the public sector.

Public Sector:

The Brazilian Ministry of Foreign Affairs (MRE) is responsible for implementing the Brazilian foreign policy and promoting Brazils bilateral relations in international organizations. Within the ministries structure, the Undersecretary for Environment, Energy, Science and Technology (SGAET) is responsible for energy-related topics. The secretariat incorporates the division for new and renewable resources (DRN), as part of the Department of Energy (DE), it helps to coordinate the ministry´s multilateral cooperation agreements. The Brazilian National Determined Contribution (NDC) reflects the vision of biofuels or other green technologies as a relevant way of reducing Brazil´s carbon footprint to play a leading role in the de-carbonization progress for global aviation in context of the COP21 goals. Considering the strategy for bio jet fuel in the energy agenda, the Ministry of Mines and Energy (MME) introduced the public policy initiative RenovaBio. This program aims to outline a common strategy to recognize the creation of market mechanisms to stimulate the capability of each biofuel to contribute to the reduction of emissions by certification and definition of emission targets. At this, the role of all types of biofuels in the energy matrix such as ethanol, biodiesel, bio methane, aviation biofuels and second-or-third generation fuels are developed comprising a long-term focus on energy security. The national Energy Research Office (EPE) is responsible for the execution of this policy. Created in 2004, the research organ is under the MME´s patronage and responsible for conducting studies, research for support of the planning and implementation of the national energy policy. Expertise are to be found in the fields of electricity, oil and its byproducts, natural gas, coal, renewable energy sources and energy efficiency. EPE does conduct studies and forecasts of the Brazils energy matrix trying to identify and quantify energy resource potential.

Further, the office supports plans for the expansion of environmental sustainable energy sources considering Brazil's energy sector framework for the implementation of new strategy programs introduced by the MME and the Ministry of the Environment (MMA). Similarly, the Logistic Planning Office (EPL), incorporates the same function as the EPE but is in charge of the logistic and transport sector in Brazil. The Institute of Applied Economic Research (IPEA) is a public institution that provides technical support to the federal government regarding public policies of fiscal, social and economic matters.

Moreover, the National Agency of Petroleum, Natural gas and Biofuels (ANP) is another institute linked to the Ministry of Mines and Energy. This federal government agency is responsible for the regulation of the oil sector and works closely together with the Energy Research Office towards common objectives introduced by the MME. These two operating bodies are crucial for the measure of viability of new energy technologies and can support the introduction of the project Pro QR into the Brazilian market as valuable research and development partner. The Ministry of Development, Industry and Foreign Trade (MDIC) oversees the National Bank for Economic and Social Development (BNDES), which has the potential for an investment partner to support the financial sustainability of the project.

The MRE also promotes the exchange of experiences and regulatory practices, building bridges between the government and the corporate sector, research institutions and international organizations. The Brazilian Electricity Regulatory Agency (ANEEL) provides favorable conditions for the electric power market to develop a balance between the agents and the benefit of society. The National Civil Aviation Agency (ANAC) is responsible for regulating and overseeing civil aviation activities, aeronautics and aerodromes infrastructure. Also, ANAC regulates the concessions of Brazilian airlines and approves Embraer aircrafts. Along with ANAC, the following organizations are part of the Brazilian Civil Aviation System; The Aeronautical Accidents Investigation and Prevention Center (CENIPA), subordinate to the Brazilian Air Force (FAB) and responsible for the prevention and investigation of accidents. The two entities are linked to the ministry of defense (MD). The Department of Airspace Control (DECEA) subordinated to the Brazilian Air Force, is responsible for strategic and systemic control of the country’s airspace. The Brazilian Airport Infrastructure Enterprise (INFRAERO), manages Brazil´s airport infrastructure and its service quality. The Civil Aviation Secretary (SAC) of the Presidency of the Federative Republic of Brazil is responsible for coordinating the civil aviation system in cooperation with the Ministry of Defense, when appropriate. This entity is subordinated under the Ministry of Transport, Port Terminals and Civil Aviation (MTPA). A main local partner for the Project PRO QR is the Ministry of Science, Technology, Innovation and Communication (MCTIC), which coordinates related activities and supports the project with coordination and political networking with further cooperation partner in Brazil and other actors. Linked to the MCTI is the national financier of studies and projects (FINEP) that promotes innovative science and technology projects, which might be an additional financial resource for the project PRO QR. The National Council of Scientific and Technological Development (CNPq), an agency of the Ministry of Science, Technology, Innovations and Communications (MCTIC), promotes scientific and technological research and encourage the formation of Brazilian researchers. It plays a leading role in the formulation and conduct of science, technology and innovation policies.

Academic Sector:

Besides the research potential of EPE and ANP as project partners, the academic sector of Brazil is crucial considering scientific investigation on alternative jet fuels during the initial phase of the Project PRO QR. The Brazilian Agricultural Research Company (EMBRAPA) is a technological innovation enterprise focused on generating knowledge and technology for Brazilian agriculture. The Brazilian Bioethanol Science and Technology Laboratory (CTBE) undertakes high-level research and develops technology in biofuels. The CTBE focuses on enabling economically feasible and scalable fuel production based on biomass with minimal impact on the food chain, water supply, land use and the environment. The Public Research

University (UNICAMP) from São Paulo and the Pontifical Catholic University (PUC) of Rio de Janeiro, the Institute for Technological Research (IPT) from São Paulo; the National Institute of Technology (INT) in Rio de Janeiro as well as the Technological Institute of Aeronautics (ITA) of São Paulo, contributing considerably to the scientific framework. The Leopoldo Américo Miguez de Mello Research & Development Center (CENPES), is an applied research and development complex of the national petroleum company Petrobras in Rio de Janeiro. It hosts simulation and process immersion rooms for the energy industry. The National Institute of Industrial Property (INPI) is the official government body responsible for industrial property rights being a federal autarchy of the Ministry of Industry, Foreign Trade and Services. This institution serves to register and accredit renewable jet fuel technology.

The Federal University of Rio de Janeiro (UFRJ) and the University of Brasilia (UnB) are higher education state of the art universities that support research & development institutions with various workgroups. Both in conceptual model, quality support as well as in technical support, the UFRJ provides a state of the art catalysis pilot plant center called PROCAT that realizes practical research along the steps of bio kerosene process and produces some amounts of biofuel and ethanol to jet fuel per day. COPPE is considered the best science institute for research and engineering in Latin America. The technology center counts with 12 strictly master and doctorate programs. Furthermore, the Federal University of Paraíba (UFPB) does provide a Laboratory of Technology and Processing of Biofuels (LTPB/ IDEP) whereas the Laboratory of Fuels and Materials (Lacom) develops drop in bio jet fuel research from regional raw material which present chemical composition within the range of bio jet fuel. Additionally, the Federal University of Minas Gerais (UFMG) operates a fuel laboratory in partnership with Boeing Research & Technology (LEC) that specializes on aviation fuel certification for the domestic aviation sector considering kerosene, bio kerosene and its blends in compliance with the ASTM 7566 standard. It executes research on different routes to convert raw material into Bio kerosene taking into account industrial process design and economic feasibility studies performed in simulators.

The Federal University of Maranhão (UFMA) employs a research group on bioenergy and bio products of the Maranhense Amazon (AMBio) conducting research on sustainable production of bio jet fuels from regional raw materials. The research is carried out in partnership with the Federal University of Paraíba and the federal University of Rio Grande do Norte and focuses mainly on the integral use of regional energy plants for the production of bio jet fuel and hydrocarbons. The Brazilian Department of Aerospace Science and Technology (DCTA) is the national military research center for aviation and space flight. The Institute of Aeronautics and Space (IAE) develops scientific-technological solutions to strengthen Brazilian aerospace power through research and innovation in order to launch operations and technological services regarding Brazil’s aeronautical, space and defense systems. These entities are subordinated under the Brazilian Air Force (FAB) and coordinate all technical and scientific activities declared by the Ministry of Defense. The Center for Strategic Studies and Management in Science (CGEE) promotes and carries out high-level prospective studies and research in the areas of education, science, technology in coordination with business sector. It develops further technical and logistic support activities for public and private institutions. The Center for Energy Research (Cepel), is a state funded electrical energy research institution by Eletrobras and its subsidiaries Chesf, Eletronorte, Eletrosul and Furnas. The center's mission is to deploy sustainable technology solutions for the generation, transmission and distribution of electricity by means of research, development and innovation activities for the Brazilian electricity sector. FAPESP is an independent public foundation with the mission to foster research and contribute to the technological development across the state of São Paulo. Its bioenergy research program aims to articulate public and private research and development by the use of academic and industrial laboratories to apply knowledge related to ethanol production in Brazil.

Private Sector:

A round table for almost all player mentioned in this paper offers the Brazilian Network of Bio Jet Fuel and Renewable Hydrocarbons for Aviation (RBQAV). Thus, it is responsible for a development and cross-sectorial innovation between research institutions, private companies and government institutions. The Network supports the creation of public policies and fosters the productions of bio jet fuel and renewable hydrocarbons considering the following aspects: Raw material, technological routes, quality control and certification, refinery structuring, life cycle analysis, logistics efficiency of supply as well as refueling and feasibility of the production chain. This concept might serve as a blue print pathway for a similar round table for renewable aviation blue crude fuel. Furthermore, the private Brazilian airlines (GOL, LATAM, AZUL, AVIANCA) play a considerable part and must be included in a stakeholder analysis as major final consumer of jet fuel next to the military. A common council for these airlines provides the Brazilian Association of Airline Companies (ABEAR). It is to be understood as a unit of communication, promotion and relationships within the airline sector. Through committees formed by the associated airlines, ABEAR plans to introduce, implement, and support programs within the aviation industry to promote the growth of civil aviation in a consistent and sustainable manner for both, passenger and cargo transportation. Hence, GOL Airlines executed in 2013 the first commercial flight powered by bio kerosene and aims to build an environment for large scale sustainable aviation fuel production. The company is open to partnerships with bio- or renewable fuel producers offering off take agreements (UBRABIO 2017).

In addition, the joint research center (JRC) for sustainable Aviation Biofuels Research & Development between Embraer and Boeing based in São José dos Campos compares different routes for ASTM approved synthetic paraffinic kerosene jet fuel production considering various feedstock materials in Brazil. Also, the national petroleum company Petrobras, which basically holds a monopoly of the Brazilian fuel production market, embodies all parts of the QAV value chain. The Brazilian industry in general is represented by the National Confederation of Industry (CNI) representing over a thousand associated employer unions and almost 100,000 industrial establishments. CNI is a highly active organization in defense of the productive sector with the mission of defending and representing the industry. A related body is the Brazilian Biodiesel and Bio Jet Fuel Union (UBRABIO). An association that represents players involved in the whole production chain of biofuels across the country. The Brazilian Association of the Chemical Industry (ABQUIM) is a non-profit organization that brings together large, medium and small size chemical industries as well as service providers to the sector in the areas of logistics, transportation, waste management and emergency response. It promotes specific studies on the activities and products of the chemical industry, accompanies changes in legislation and advises associated companies in economic, technical and foreign trade matters. The Brazilian Industrial Development Agency (ABDI) implements industrial policy, in line with the policies of science, technology, innovation and foreign trade. Connected to the Ministry of Development, Industry and Foreign Trade (MDIC), it acts as a link between the public and private sectors, contributing to the country's sustainable development through action plans that increase the competitiveness of the industry. Aerospace Industries Association of Brazil (AIAB) the national trade association that represents Brazilian aerospace companies, networking, promoting and defending its common interests and objectives while congregating the industries of the aerospace sector and related activities. It also carries out studies and research for the member companies and government bodies.

Ergostech, a Brazilian company in the biotechnology industry, tries to bring innovation to the biotechnology sector, especially in renewable energy to produce bioenergy, specifically bio-hydrogen, bio-methane and bio-products from agro industrial waste. In addition, the National Union of Fuel and Lubricant Distributors (SINDICOM) represents Brazil´s main fuel and lubricant distribution companies: AirBP, Castrol, Chevron, Cosan, Ipiranga, Petrobras Distribuidora, Petronas

Lubrificantes, YPF, Raízen, Shell, Moove and Total. Its associates represent approximately 75 percent of Brazil's fuel sales. SINDICOM is associated with legal, tax, operational, supply, transportation, industrial safety, occupational health and environmental protection matters regarding the value chain of combustibles. Regarding the international cooperation of leading countries towards a carbon neutral aviation fuel industry, the Brazilian government proposed the multi-stakeholder initiative Biofuture Platform. It is supposed to function as the interim facilitator of the platform at launch by clean-energy related meetings and events that bring together the appropriate stakeholders. The program strives to find sustainable, immediately scalable solutions to reduce carbon emissions in the transport sector promoting policy coordination and raising the issue in the global agenda in relation to green diesel, drop-in fuels, algae and advanced aviation biofuels.

In addition, the roundtable on Sustainable Biomaterials (RSB) is another example of multi stakeholder approach towards a renewable bio economy consisting out of sustainable solutions and collaborative partnerships between businesses, NGO´s, academics, government and UN organizations to foster practices for reduction of global carbon emissions. Hence, 28 airlines are already committed worldwide to using RSB certified jet fuel and RSB has engaged in Brazil with various organizations to produce alternative jet fuel. Likewise, the Brazil Business Council for Sustainable Development (CEBDS) induced a collaboration platform named below50. It is the global unified voice of sustainable fuels that emits at least 50 percent less CO_2 and creates inter-sectorial Business to Business opportunities across supply chain of alternative jet fuel. Likewise, it addresses legislative and financial barriers to foster the production of these fuels demonstrating the economic, social and environmental importance of alternative aviation fuels.

3.6. STAKEHOLDER ANALYSIS

A stakeholder analysis reflects the relationship of market players between each other and their importance to the project. Basically, the entities can be divided into four categories weighted by the interest of stakeholders and the influence or power they have on the project PRO QR. Thus, the matrix is divided into groups of the following categories: Important status to meet their needs by consultancy, group of key players where to focus efforts of cooperation on, a group of least important that should be simply kept informed and those where to show consideration to bind them as potential supporters of the project.

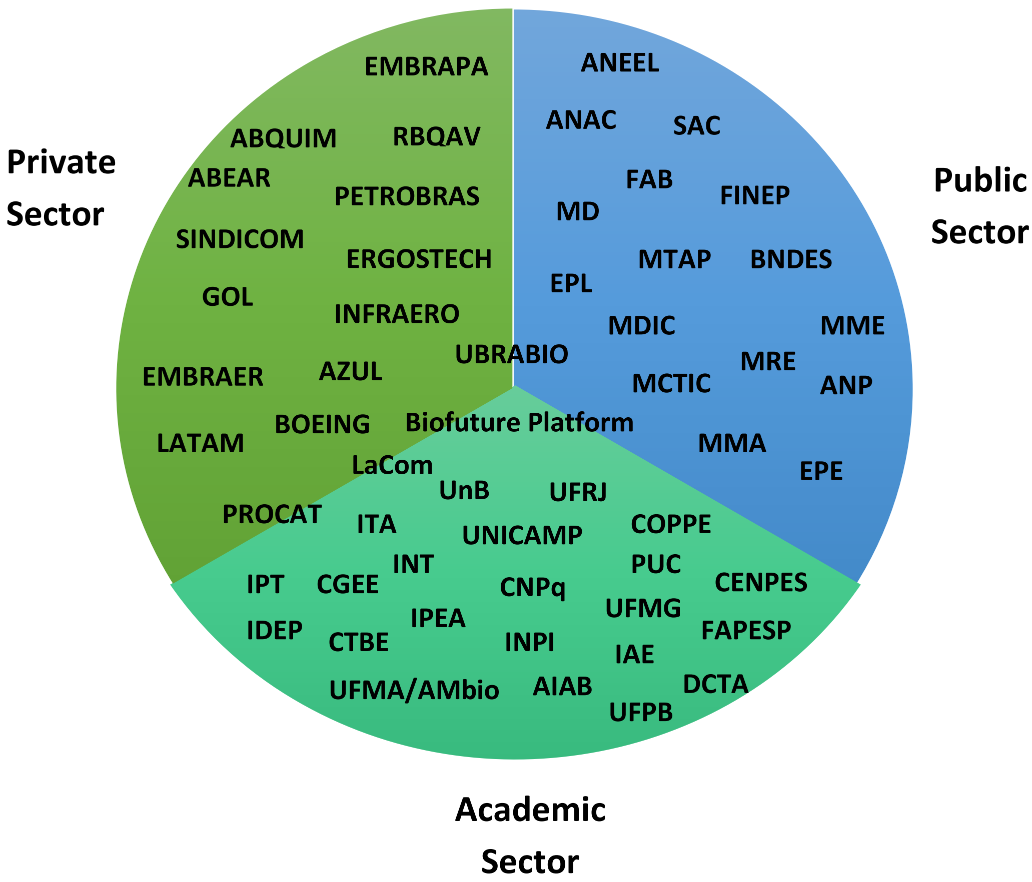

Figure 40: Stakeholder Map of the Project PRO QR; Source: Elaborated by the Author

Meet their needs (Increase Level of interest)	Key Player (Involve in governance and decision-making)
EPL, MD, FAB, RBQAV MTPA, INFRAERO, CENPES, LEC, IAE, FAPESP, GOL, AZUL, LATAM, JRC - Boeing/Embraer, Petrobras, AIAB, Ergostech	MCTIC, **MME (**EPE, ANP**), MMA, MDIC, ANAC, BNDES, SAC, FINEP, UFRJ, UnB, PROCAT, DCTA, SINDICOM**

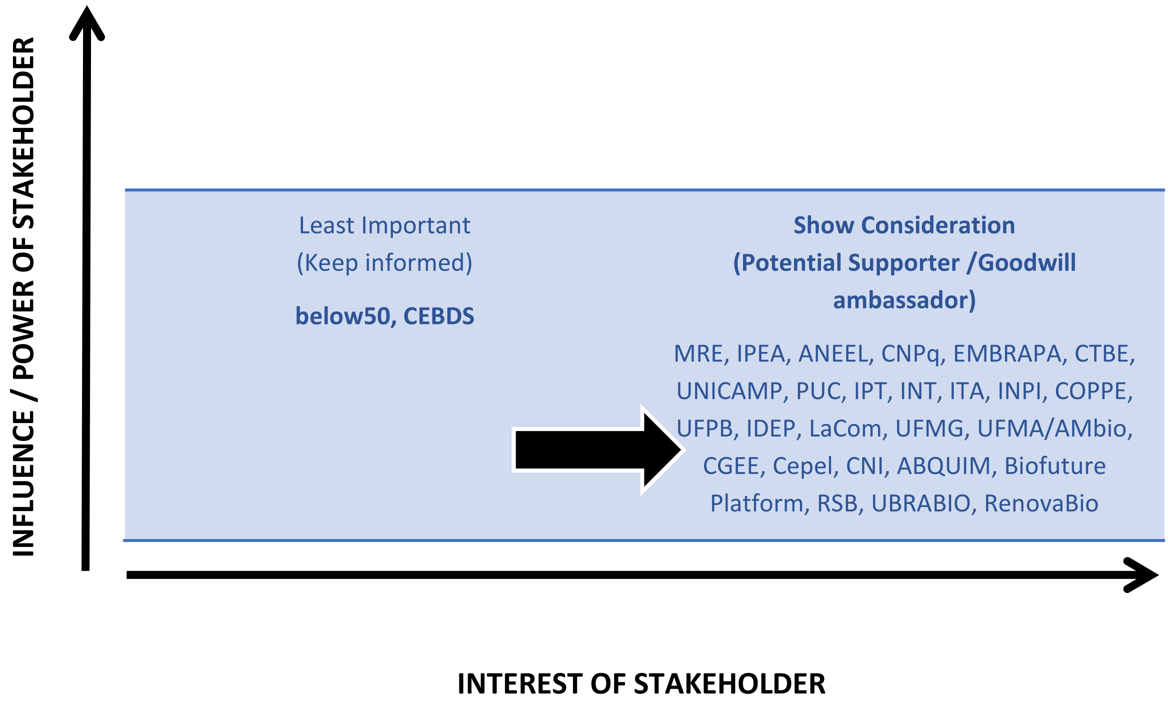

Figure 41: Stakeholder Matrix- Public, Academic and Private Market Player Project PRO QR l; Source: Elaborated by the Author

FINEP – Economic subsidy (Non-repayable)	**Use of resources directly to the companies to share the costs and risks inherent to the research, development, and innovation activities**
FINEP PAPPE – Economic subsidy (Non-repayable)	Program to support micro and small technology business, in partnership with foundations to support research or federations of the industries. Partners operate in a decentralized way.
FINEP PRIME - First enterprise (Non-repayable)	For emerging enterprises of high-aggregated value aiming to consolidate its initial phase, to cover for human resources and services of specialized consultancy.
BNDES-FUNTEC Technological Fund (Non-repayable)	Fund for technological and innovative development of strategic interest for the country, according to public programs and policies.
FINEP - Inova Brasil	Support to strategic investment plans for research, development and innovation projects. It assists enterprises of distinct sizes.
FINEP - Zero interest	Innovation projects of micro and small businesses with regional partners.
BNDES – Innovative capital	By acquisition of real estate assets in publicly traded enterprises. The focus is the enterprise, not the project. Centered in the company strategy and innovation.
BNDES - Technological Innovation	Financing research, development and radical innovation projects that represent technological risk and market opportunity.
BNDES - BNDES Card	To invest in products and processes of goods, inputs and services.

BNDES - Automatic	For implementation, expansion and modernization of venture projects, including investment in R & D and Innovation.
BNDES - Credit Limit	Rotated credit for the enterprise or economic groups that are already clients.
BNDES - Sectorial	Pro-R&D; Pro-pharmaceutical; Pro-software; Pro-plastic; Pro-aeronautics; Pro-engineering; PROTVD, BNDES PSI; BNDES Qualification.
Joint Action FINEP-BNDES	PAISS (sugar-ethanol sector); Inova Energy (energy sector); Inova Petro (suppliers of the productive chain of oil and natural gas); and Inova Health (innovation in the health sector).

Furthermore, there exist various financing instruments for support on new innovative projects from FINEP and BNDES as the following table outlines:

Figure 42: Non-Repayable and Repayable Financing Instruments for Technology Projects in Brazil
Source: Cirani et al. (2016)

In addition, tax incentives have direct impact on new research and development project as they could be beneficial to the Project PRO QR, especially in terms of support during the first research phase of the project when the demonstration and pilot plant is to be mounted. In the Brazilian research and development environment there are the following to consider:

PDTA and PDTI	**Program for the Industrial and Agricultural Technological Development (replaced by Lei do Bem, regulated by Decree 5,798/2006).**
Lei da Informática (Law n° 10,176/2001)	It grants tax incentives to companies that produce specific equipment. Reduction of IPI, as compensation for the investment in the R&D of products.
Lei do Bem (Law n° 11,196/2005)	It expands and simplifies the use of tax incentives by the enterprises, in compensation for the increase in the industrial technological park in Brazil, and consequently the improvement of national products.

Lei do MEC (Law n° 11,487/2007)	It allows enterprises to use tax incentives to finance projects conducted by universities and research centers.

Figure 43 Tax Incentives for Technology Projects in Brazil
Source: Cirani et al. (2016)

4. EXCURSION I: BRAZILIAN ROADMAP FOR BIO JET FUEL PRODUCTION

To provide a small excursion on the creation of Brazil´s bio kerosene industry, the development of a roadmap for domestically produced biofuels will be outlined further on. However, this roadmap could serve as a role model for the implementation of the synthetic jet fuel value chain and for the creation of an interdisciplinary network of technical experts, universities, private sector and institutions regarding the Power to Liquid – Synthetic Jet Fuel production pathway as an alternative aviation kerosene option for the Brazilian market.

According to the Brazilian association of aviation companies (ABEAR 2017), investments and sustainable practices across all links of the aviation industry value chain focus mainly on a development of production of sustainable aviation biofuel. A continuous review of air traffic control, airlines operational and administrative procedures is daily business. In effect, the concentration on reducing the environmental impact of air traffic is key. Further, it must be invested heavily in a comprehensive customer relationship management such as training, education and specialization of professionals working in air transportation and supporting industries. Brazilian airlines bear high operational costs that can account for up to 40 percent of total operational cost (GOL 2012). Thus, any difference in the aviation fuel prices instantly creates an impact on return of investment and a competitive position for the airlines. One main goal of the Brazilian aviation industry is to reduce CO2 emissions in alignment with the government´s climate combat goals. Hence, a transition in the next 20 to 40 years towards the use of sustainable biofuels in substitution of petroleum-based jet fuels will be introduced. During this phase, the production, transport and use of aviation biofuels will have to be more effective, efficient and climate neutral to cope with the global expansion of new technologies and accelerating competitiveness (Boeing/Embraer/ FAPESP and UNICAMP 2013).

A roadmap can help to identify gaps and barriers related to the production, transportation and use of fuels for aviation. Although some companies are already producing and selling biofuels to be used in mixture with conventional kerosene, aviation biofuels have not yet become a standard of the fuel supply as comprehensive commercial industry is still under development. The objectives of the industry are to develop a research and commercialization agenda resulting in a modern and innovative commerce along a sustainable aviation biofuels supply chain, producing biofuels for aviation with high greenhouse gas mitigation potential.

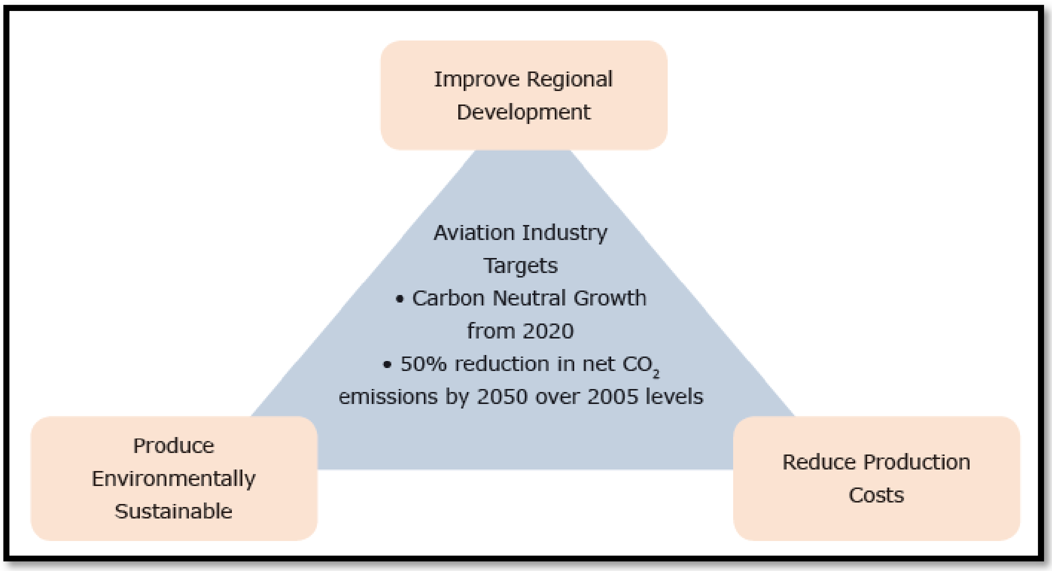

Figure 44: Roadmap targets and strategic objectives for Brazil ´s aviation industry for 2050
Source: (Boeing/Embraer/ FAPESP and UNICAMP 2013)

Through the Senate Law number 506 from the year of 2013 the creation of the so called National Program of Bio-Kerosene was initiated. The idea was to foster and support clean technology in terms of production of biofuel for use in national aviation through federal incentives to the environmental sustainability of Brazilian aviation in adequate proportion with aviation kerosene of fossil origin (Senado Federal Brazil 2017). Nevertheless, the initiation of a bio kerosene industry in Brazil implies some challenges ahead to sustainably scaling up the bio economy. For example, current uncertainty about policies and mandates, lack of recognition as well as a proper pricing of cellulosic and other advanced low carbon fuels. In addition, the volatile business environment regarding future demand of primary material and oil price fluctuations reflects a challenge to be confronted. Thus, scaling up 2nd generation and alternative low carbon advanced bio-or synthetic fuels will require determination and appropriate policies to create an enabling policy environment and a comprehensive roadmap to attract sufficient investments (Biofuture Platforms 2016).

5. TAXATION FRAMEWORK

As in every market, various taxes influence the price calculations along the value chain and shape the purchase price of jet fuel considerably. Nowadays, the following taxes must be considered in Brazil.

5.1. ICMS TAX RATE

Tax on Operations Related to the Circulation of Goods and on Services of Interstate and Intermunicipal Transport and Communication Services

The specific ICMS tax amount levied on petroleum derived fuels is collected by the refineries in form of a tax substitution. Hence, tax substitution is understood as a form of taxation in which the complementary law No. 87, also known as the Kandir Law, allows a taxpayer to be indicated as responsible for the collection of ICMS by other taxpayers and the rate is therefore shifted throughout the supply chain of jet fuel in a kind of forward mode. In detail, the refinery, designated as a substitute taxpayer, is responsible for collecting ICMS for subsequent operations. Considering tax substitution on interstate sales, the payment to the refinery that is based in the fuel producing state is taxed. According to Ribeiro (2016), the ICMS tax portion is then passed from the original refinery on to the state of consumption or retail of the jet fuel, with the presumed interstate profit margin set by the National Council of Finance Policy (CONFAZ). When the commercialization of jet fuel takes place within a state or between two states, defined internal tax rates cannot be lower than the interstate rates on jet fuel, except by a particular deliberation of the states, which must be executed by agreements of CONFAZ.

In relation to domestic sales, the tax substitution regime is applied differently depending on the fuel and the state. In the case of gasoline and diesel, the states adopt the regime of tax substitution in domestic sales, naming the refinery as a substitute taxpayer. In the case of hydrous ethanol, the tax substitution regime is usually made by appointing the distributor as a substitute taxpayer. In the case of ethanol for fuel purposes, unlike petroleum-derived fuels, the amount of ICMS collected is the responsibility of the producing state and not of the state of destination of the product. In the fuel ethanol commercialization chain, the collection of ICMS occurs in a different way from that prevailing for other fuels. The price of the product purchased by the distributors to the distilleries and plants already includes the ICMS. Thus, it is up to the distilleries and mills to collect them from the producing state. The distributors, when selling hydrous ethanol, collect the ICMS as taxpayers and as surrogate contributors, the portion related to the reseller points. When the distributor sells hydrated ethanol to a dealer located in another state, it collects the ICMS due to the producing State (Ribeiro 2016).

5.2. COFINS TAX RATE

Social Contribution for Social Security Financing PIS / PASEP Tax Rate: Contribution to the Programs of Social Integration and the Formation of the Patrimony of the Public Servant

According to (Ribeiro 2016), this tax rate consists of federal charges that are levied on company’s gross revenues. Like all Brazilian tax contributions, they do not affect revenues from exports. However, there is to differ between two regimes, the non-cumulative and the cumulative regime. In this context, law number 10.637 and law number 10.833 established a non-cumulative regime for legal entities that apportion income tax in the form of real income. According to article three of both laws, the taxpayer has the right to deduct, from the calculation basic amount, credits generated by the acquisition of inputs and other goods and services that are contained in a closed list. Hence, in the non-cumulative regime, the value of the contribution to the PIS / PASEP tax is determined by application of 1.65 percent on total revenues after credit discounts. In comparison, the tax contribution for COFINS, defines a rate of 7.6 percent on the same basis of calculation. Consequently, companies opting for presumed profit are more likely to remain in the cumulative tax regime defined by law No. 9.718. In this regime, the tax rates are defined as of 0.65 percent for PIS / PASEP and of 3 percent for COFINS on total revenue. This regime is characterized by the cascade incidence of tax contributions on each link throughout the production chain. In addition, the fourth article of that law defines the sort of ad valorem rates on top in percentages due to amounts generated by producers and importers of petroleum derived fuels. All companies however are bound to the Special System for Calculation and Payment of the Contribution for PIS / PASEP and COFINS named RECOB. However, for the case of aviation kerosene the tax rate is fixed on 0,0712 Reais $ per liter fuel sold.

5.3. CIDE TAX RATE

Contribution of Intervention in the Economic Domain

This tax is a contribution defined by law No. 10.336 levied on the importation and sale of petroleum and its derivatives as well as fuel ethanol, hydrated and anhydrous. The tax rate is charged on the total volume traded by the producer. However, the Cide tax is not levied on the sale of biodiesel. Currently, only the importation and the commercialization of gasoline and its chains as well as of diesel oil and their chains are charged. Aviation Kerosene is not affected by this tax form. As amended by Decree No. 8.395 in 2015, the specific rates of Cide-fuels are defined for gasoline: R $ 0.100 per liter and for diesel oil R $ 0.050 per liter. In addition, 29 percent of all tax income generated from Cide is destined for the states administration.

PRODUCT / TAX	PIS/PASEP	COFINS	CIDE	ICMS
Gasoline (per liter)	R$0,06794	R$0,31366	R$0,10	25 – 32 %
Aviation Kerosene	R$0,0712	R$0,0712	0	12 - 25 % (figure 46)
Producer (Aviation Kerosene)	R$0,0712	R$0,0712	0	R$ 0,00 (SP) R$ 0,2560 (RJ)
Distributor (Aviation Kerosene)	0	0	0	R$ 0,6044 (SP) R$ 0,0149 (RJ)
Diesel Oil (per liter)	R$0,04417	R$0,20383	R$0,05000	12 - 25 %
Biodiesel	R$0,02641	R$0,12159	0	Applied at Diesel Sales

Figure 45: Tax variations on different types of fuels in Reais SP = São Paulo RJ =Rio de Janeiro
Source: Ribeiro (2016)

Due to the fact that the ICMS tax rate on aviation fuel ranges from 12 to 25 percent, depending on the state of appliance as well as on the stage of the supply chain of jet fuel, a common practice for companies is to fuel up at locations the lowest tax liabilities are charged. This deliberate tax avoidance through this tanking planning becomes a common practice performed by scheduled airlines and executive aviation in order to achieve a reduction of costs in the total annual operations. Consequently, this practice leads to several negative consequences. Higher fuel consumptions increase pollutant gas emissions and operational inefficiencies are a daily reality. Moreover, this “tax rate war” reduces tax collection in states with higher rates and consequently air tickets become more expensive in these locations. In addition, network effects, such as minimizing the cost of all supplies over an aircraft's flight network scheduling in an integrated and simultaneous manner, are not well evaluated. Also, breakeven price analysis is not systematized and generally speaking fuel tanking operations are conducted in states where fuel prices are cheaper (ABEAR 2016).

In November 2017 a fix ICMS tax rate of 12 percent on kerosene and gasoline for airplanes was requested to the Brazilian Senate but was rejected by it later. This measure would have made the cost of QAV in Brazil more competitive and hence end the practice of "tanking", increase competitiveness of remote destinations and make routes to these locations more efficient and cost logical. Furthermore, interstate and intrastate ICMS tax rates should be leveled and brought down by the government to a reasonable amount to lower the final cost of QAV for domestic flights (Senado Federal Brazil 2017).

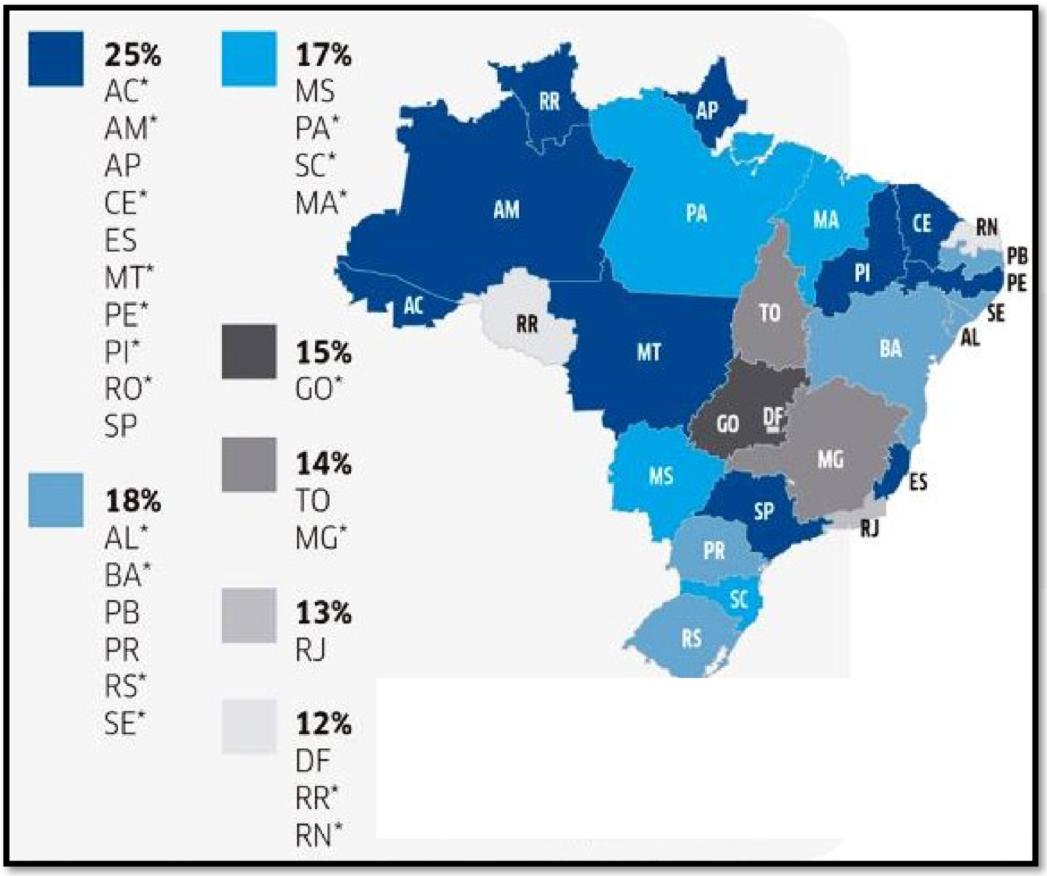

Figure 46: ICMS tax rates levied on QAV among Brazilian States 2017
Sources: ABEAR and SINDICOM in Diario do Nordeste (2017)

Taking into consideration that the Airports of the states of Distrito Federal (DF), Minas Gerais (MG), Parana (PR), Rio de Janeiro (RJ), and São Paulo (SP) account for 64 percent of all annual domestic air traffic, the figure 46 visualizes the wide spread differences of tax rates in Brazil. Herewith, the states of São Paulo and Parana have a considerably high rate of 25 and 18 percent respectively. Thus, the majority of flight operations bear a high ICMS tax rate on the relatively high costs on QAV for the Airlines.

6. METHODOLOGY

To elicit quantitative primary data, a coherent survey was realized by means of questionnaires as information source. This research method was chosen as an appropriate tool because it allows the researcher to receive significant and compound data on different subjects in relatively short time. Thus, the survey was carried out sending questionnaires on the one hand to the administration and management of Brazilian airport infrastructure, namely Infraero and the Civil Aviation Secretary – SAC, responsible for political and quality aspects on civil aviation in Brazil and on the other hand, to jet fuel supplier companies such as Petrobras, Raizen and AirBP, as mentioned in chapter 3.4. To both was also send a digital letter (ANNEX A1) presenting the structure of the questionnaires and the research idea. However, the data received during the research is collected the first time in this way. Hence, the outcomes were supposed to deliver detailed data on QAV transport fluxes, numbers for the QAV supply among transport routes within and between federal states. Also they should give an idea about specific figures on QAV demand at the airport Infrastructure. These scientific data results imply an added value in a more sophisticated way in comparison to the secondary information that exists nowadays among the Brazilian aviation consensus. Unfortunately, the response rate of the sample group was rather low to nonexistent so that most data for the empiric part of the present paper had to be obtained by examining secondary data sources. Briefly, figure 47 illustrates all steps that have been considered when interpreting data among the research phases. Here, it is to notice that the scope of the research is limited to the phase of the illustration of empiric outcomes by cost mapping and diagrams. The comparison of the base versus benchmark case scenarios is subject to further research for the project PRO QR.

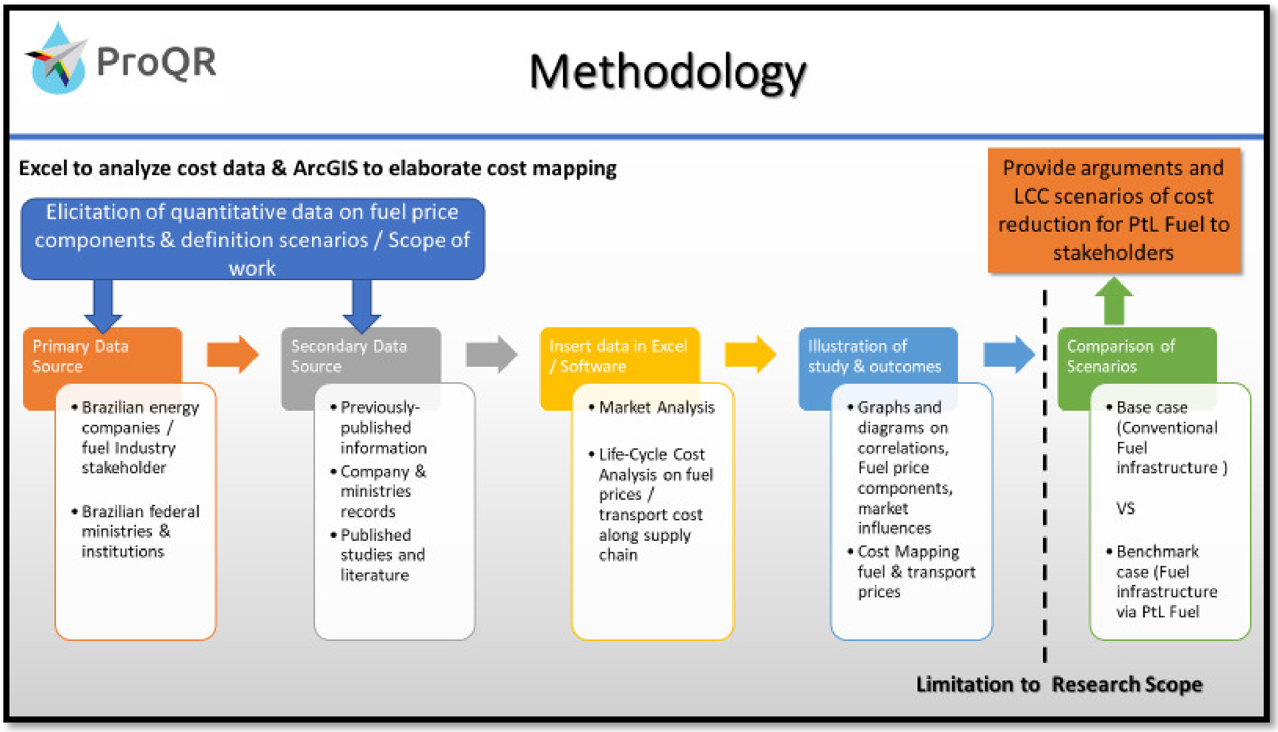

Figure 47: Research Methodology and Phases of Research Scope
Sources: Elaboration of the author

6.1. THE QUESTIONNAIRES

A logically structured questionnaire is a valuable tool for successful data research. It should be kept as simple as possible and must include concise questions to collect most relevant data. Furthermore, questions should be formulated in an objective, understandable and accurate way to not overcharge the respondents knowledge and aim appropriately for the information linked to the research questions of the paper. The questionnaire includes three specific objectives. Firstly, it must translate the information needed into a set of specific questions which the respondent can and want answer. Secondly, a questionnaire must uplift, motivate and encourage the respondent to cooperate and to avoid boredom and thirdly, it should minimize response errors due to a misunderstanding of research questions. The researcher must keep asking himself during the elaboration of the survey: What is to find out by the question sets? Moreover, the type of response options is to define by choosing standardized or not standardized questions, open or closed questions, qualitative question or demographic ones. Thereby, it is to consider that the easiest to create are open questions, the easiest to analyze are closed types of questions. Hence, the two questionnaires in ANNEX A2 were tried to be elaborated as accurate as possible. Subsequently, one asks question about the specific jet fuel demand at Brazilian airports, flight operations, airplane types in operation, storage infrastructure and means of QAV transport to the airports. The other questionnaire in ANNEX A3 tries to obtain quantitative data about the jet fuel supply towards Brazilian airports considering the value chain of QAV and figures about fuel transportation. Here, transport frequencies, specific routes and challenges for the aviation fuel supplier are investigated on regarding each federal state.

7. EXCURSION II: THE SPECIFIC CASE OF AMAZONAS

The region of the amazon rainforest accounts for the largest part of Brazilian territory. Seven states share this northern area. Distances are vast and signs of civilization are wide spread across the states and often far away from each other. Thus, transportation on land can be a major challenge, especially during the rainy season December to April. This is when transporting heavy cargo on poorly conditioned infrastructure becomes sometimes an impossible task. Frequently, roads are impassable and shut down for weeks. Therefore, passengers and cargo traffic are realized mostly by airway with small, medium or commercial airplanes from minor airfields or by waterway with boots throughout the river basin that can be combined with road transportation as they have capacity for truck loads. Subsequently, this pushes costs for kerosene or aviation gasoline across the amazon states, not just for commercial and private aviation but also for the supply and cargo of the military bases located in remote areas.

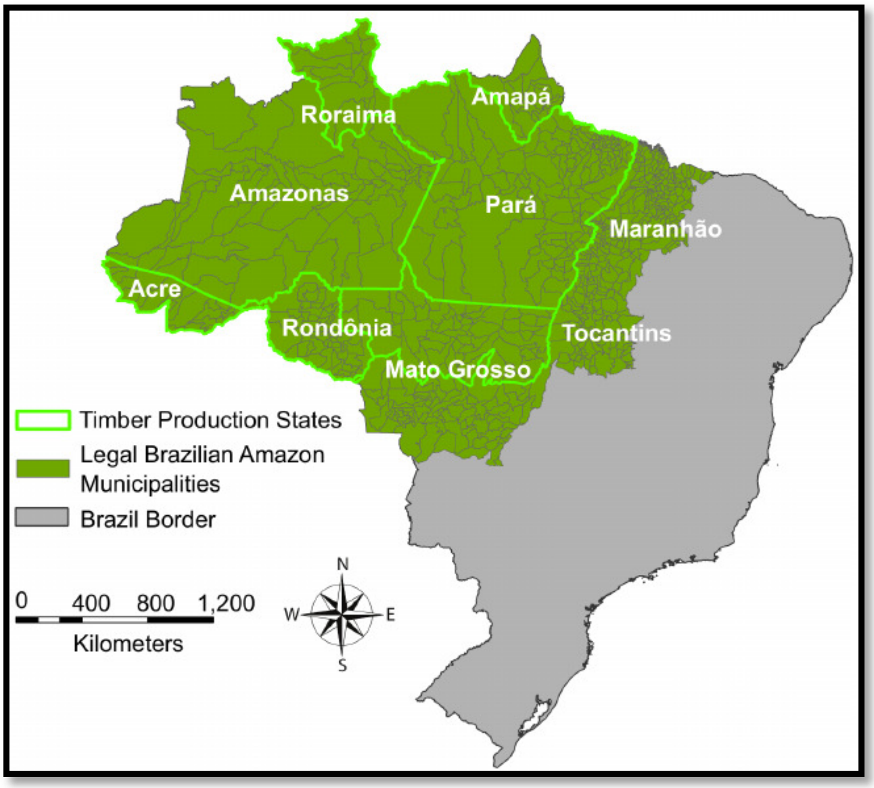

Figure 48: Brazilian Amazon region and its federal states
Source: Hahn et. al (2014)

To specify the regional airfield network, QAV supply infrastructure and transport system, the next chapter will emphasize detailed maps by zooming in this region. Indications about the total jet fuel demand of these airfields per month or per year, can give estimations about how much synthetic fuel is needed to produce to satisfy the regional demand for aviation fuel. Furthermore, the means of transport for QAV between point of production at the refinery in the capital Manaus, point of distribution at the cities Tefé and Itacoatiara and point of consumption at one of various airports in the region, is analyzed. Here, major difficulties for QAV transport between very remote areas give an idea about inefficient transport ways and therefore market entry points for a synthetic aviation fuel production line. As figures 49 and 50 illustrate, the demand for jet fuel is concentrated at two areas, in the state of Roraima at the very north of Brazil and in the state of Mato Grosso at the central land. Moreover, it sticks out that the distribution of airfields is not equal and the network consists of vast areas without any airport. In addition, some airfields are located at very remote areas. Regarding the transport of jet fuel to the points of consumption, most of the supply is done by waterway via the amazon basin. Thus airports, terminals and fuel deposits are located along the rivers and allow transshipment of the cargo. Correspondingly, the road infrastructure is developed to an extend that the most remote fuel bases in Porto Velho, Rio Branco and Cruzeiro do Sul can be reached by trucks on paved roads. However, seasonal difficulties due to heavy weather minder the quality of transport links or restrict the access at all.

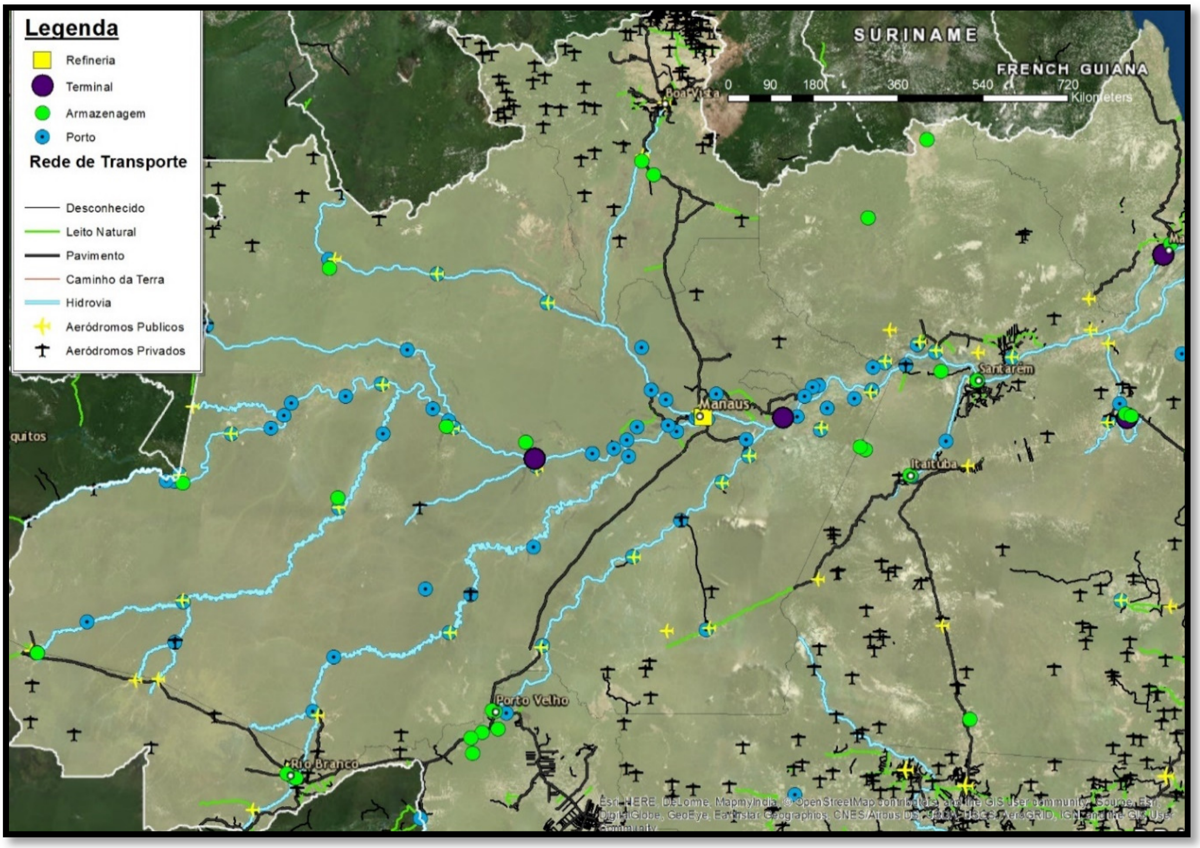

Figure 49: Transport and QAV Supply infrastructure in the Amazonas
Source**:** ANAC (2017) / DIVA / IBGE / EPE

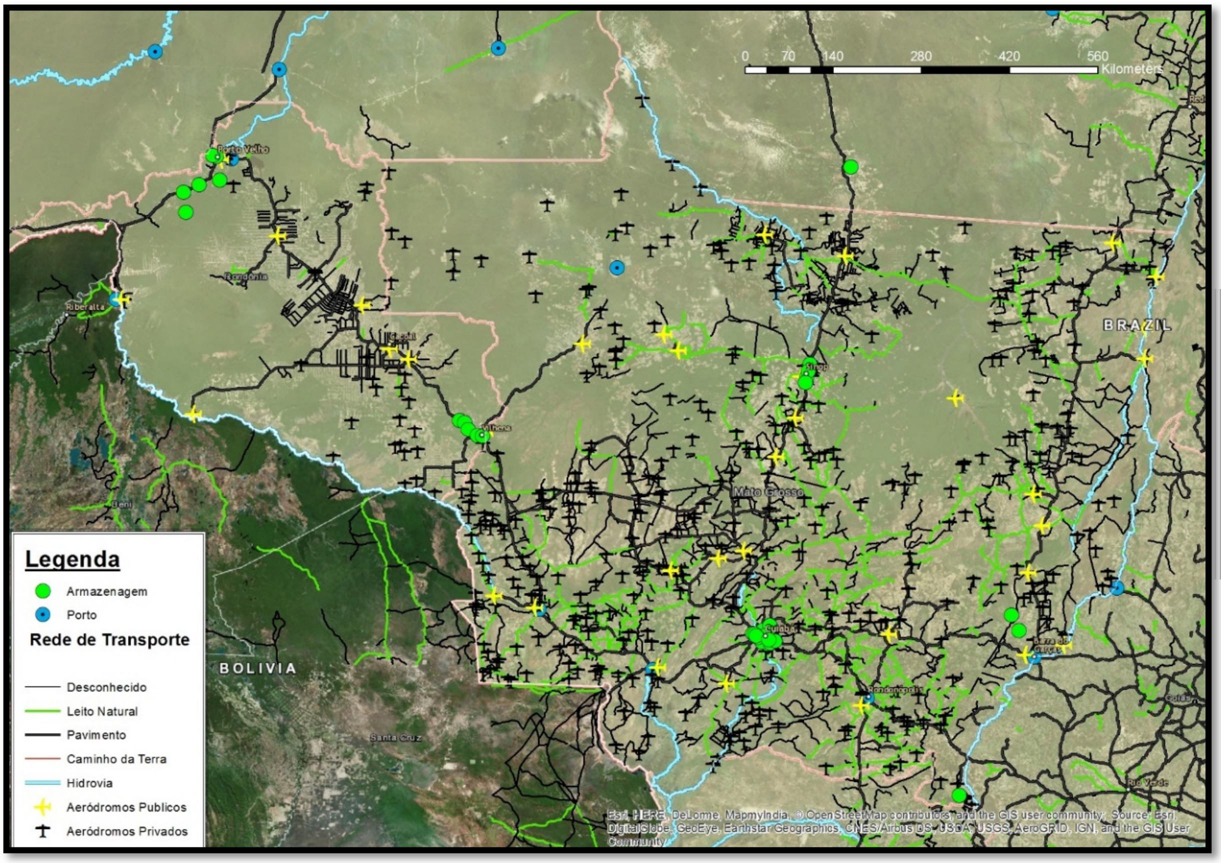

Figure 50: Transport and QAV Supply infrastructure in the State Mato Grosso
Source: ANAC (2017) / DIVA / IBGE / EPE

8. LCCA – LIFE CYCLE COST ANALYSIS

Therefore, a total cost of ownership analysis about the cost composition for QAV is necessary to adequately determine, allocate and compare all cost throughout the whole life cycle. To obtain a realistic measure of the market price of one-liter kerosene, several cost drivers must be considered and weighted throughout all stages of the supply line. A coherent cost analysis takes into account cost factors along the upstream and downstream line. This means from point of extraction or importation of crude oil (cradle) to the point of production of jet fuel at the refineries (gate), via the distribution and storage at terminals or fuel deposits until the point where an airplane is refueled at an airport and the fuel is burned during a flight (grave). The transport factor, depending on the means of transport and the road infrastructure given at a certain location, next to the cost of crude oil on the international market, are the most volatile cost forces. Furthermore, the ICMS tax rates for QAV vary heavily between different Brazilian states and represent an immense cost burden throughout the whole value chain, thus reflecting a major influence on the final jet fuel price for distributors. In this regard, the following illustration shows the different cost drivers that must be considered when calculating the purchase price for a fuel supplier.

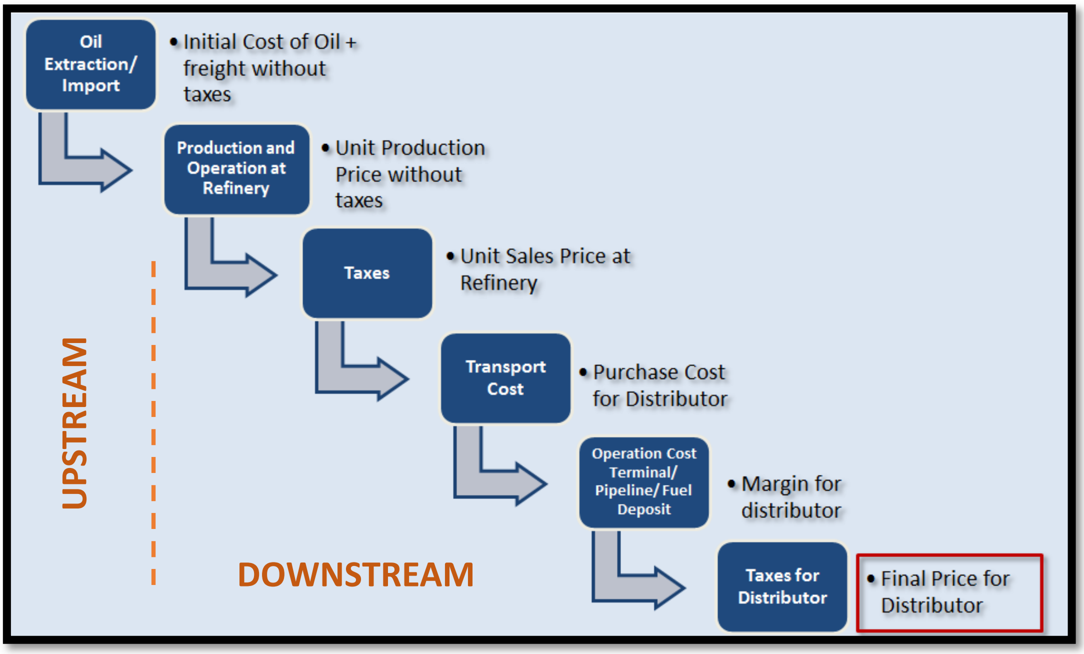

Figure 51: Cost Drivers throughout the supply chain for the determination of the Purchase Price for Kerosene in Brazil
Source: Elaborated by the Author

To clarify in detail the cost calculation among the Brazilian value chain, figure 52 indicates the structure and methodology of QAV price calculation in Brazil from point of production as well as distribution onwards. However, margins of a distributor or reseller (J) are matter of the supplier company's internal price policy and therefore subjective. Nevertheless, an estimate is calculated by subtracting the sales price at refinery including taxes by the production price of a refinery. Furthermore, it is to consider the fact that the following price structure for calculating the purchase price of one-liter QAV is subject to a theoretical approach as practiced among the Brazilian scientific consensus and does not necessarily reflect real purchase prices of QAV in remote areas as described further on throughout the present paper.

	Price Composition from Point of Production onwards
A	Production Price (without taxes and on FOB terms)
B	Tax Rate Cide
C	Tax Rate PIS/Pasep e Cofins
D	**Price at Refinery without ICMS D = A + B + C**
E	Tax Rate ICMS Refinery E = [(D / (1 - ICMS%)] - D
F	**Sales Price at Refinery including ICMS F = D + E**
	Price Composition from Point of Distribution onwards
G	Freight Cost from Fuel Base onwards
H	Purchase Costs for Distributor H = F + G
I	Freight Cost from Point of Reselling
J	**Margin Distributor F - A**
K	Tax Rate PIS/Pasep e Cofins for Distributor
L	**Price for Distributor without ICMS L = H + I + J + K - E**
M	ICMS for Distributor M = [(L / (1 - ICMS%)] - L - E
N	**Final Price Distributor N = M + L + E**
R	Margin for Reseller R = S - N
S	**Final Price Reseller S = R + N**

Figure 52: Calculation of Final Price for Distributor / Reseller throughout Jet Fuel Supply Chain in Brazil
Source: ANP 2017

Anyway, major cost factors are taxes (B / C / E / K / M), transport (A /G / I) and production (A). These have the biggest impact on the final kerosene price and are the most volatile and depend of where the QAV is produced and of the point of consumption. As the ICMS tax rate on aviation fuel ranges from 12 to 25 percent, depending on the state of appliance as well as on the supply chain stage. Costs for transportation, for example from refinery or fuel terminal onwards, fluctuate because of poorly conditioned infrastructure in the Amazonas and further because of the switch of transport mode from roadways to waterways or even to air transport. Subsequently, these impacts shape the price of jet fuel. In the following, the purchase price calculation considers all steps of the value chain for one-liter of jet fuel. Hence, this scheme was used by the author as a basic structure for the calculation of the purchase price for kerosene taking into account externalities like volatile transport conditions due to geographic variances and varying tax impacts linked to unequal political frameworks between Brazilian states.

To begin with the unit cost Reais per liter QAV, at upstream production line, at the extraction or import crude oil from the international market to Brazil, the National Petroleum Agency (ANP) released values without taxes and government intervention on its website as follows.

A: Cost of Extraction Crude Oil (2017)		*R$ / liter*
Brazil - without Taxes		0,27686
Extern - without government intervention		0,12786

The next step along the supply line is the cost for processing and production of QAV as a direct derivate from crude oil under conditions at any domestic refinery (REPEC 2017). The pure unit price is the result from dividing the total cost of production per month by the total output per month and comes down to a value of 1,30 Reais $ per liter. In addition to that, the unit price at incoterm ex-works refinery, which includes the factory´s margin is calculated to 1, 83 Reais $ per liter (REPEC 2017 and ANP 2017).

Processing Cost for Production at Refinery 2016	**CAPEX**	**OPEX**	
	R$	*R$ / liter*	*Liters*
Total Production Output per Month			**74.730.000**
Total Cost for Production	**97.270.348**		
Unit Processing Cost		**1,3016**	
Unit Production Cost (Extraction + Processing)		**1,5785**	
Unit Production Cost (Importation crude oil + Processing)		**1,4295**	
D: Unit Price at Refinery without taxes		**1,8302**	

Next, the portion of the tax PIS/COFINS, as a uniform allocation, and the ICMS tax rate in percent differing among brazilian states are added. From this point on the costs of one liter QAV will be distinct from one state to another and must be calculated according to the particular tax rate of each state. Consequently, the unit sales price at refinery including taxes ranges between 2,16 Reais $ per liter, for example in Brasilia (DF) to 2,53 Reais $ per liter in the state Amazonas (AM).

C: PIS/Cofins		0,0712
E: ICMS States	%	R$
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	25%	0,6338
AL, BA, PB, PR, RS, SE	18%	0,4174
MS, PA, SC, MA	17%	0,3894
GO	15%	0,3355
TO, MG	14%	0,3095
RJ	13%	0,2841
DF,RR,RN	12%	0,2593
F: Unit Sales Price at Refinery with taxes		
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP		2,5352
AL, BA, PB, PR, RS, SE		2,3188
MS, PA, SC, MA		2,2908
GO		2,2369
TO, MG		2,2109
RJ		2,1855
DF,RR,RN		2,1607

Furthermore, the cost driver transport cost was elaborated bottom-up taking into consideration the means of transport road truck, ship and railway among different regions of Brazil. Hence, an average unit cost X Reais $ per one-liter QAV is calculated by means of the method explained in the following chapter 8.1. Then, to illustrate the evolution of costs by distance of medium transported, the unit costs from 100 to 1000 kilometer are elaborated. Subsequently, the total purchase cost for a fuel distributor is the unit sales price from refinery plus the costs for transport of one-liter jet fuel. As the sales price is subject to different state ICMS tax rates, the following prices differ correspondingly and vary between ship and road transportation.

	Kilometers of Cargo QAV from Point of Refinery / Terminal									
G / I: Average Transport Cost (Road Transportation)	100	200	300	400	500	600	700	800	900	1000
Average cost R$ (m³) per KM	R$ 43,20	R$ 69,29	R$ 95,39	R$ 121,48	R$ 147,58	R$ 173,67	R$ 199,77	R$ 225,86	R$ 251,96	R$ 278,05
Average cost R$ / liter per KM	**R$ 0,0432**	**R$ 0,0693**	**R$ 0,0954**	**R$ 0,1215**	**R$ 0,1476**	**R$ 0,1737**	**R$ 0,1998**	**R$ 0,2259**	**R$ 0,2520**	**R$ 0,2781**
H: Purchase Cost for Distributor										
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 2,5784	R$ 2,6045	R$ 2,6306	R$ 2,6567	R$ 2,6828	R$ 2,7089	R$ 2,7350	R$ 2,7611	R$ 2,7872	R$ 2,8133
AL, BA, PB, PR, RS, SE	R$ 2,3620	R$ 2,3881	R$ 2,4142	R$ 2,4403	R$ 2,4664	R$ 2,4925	R$ 2,5186	R$ 2,5446	R$ 2,5707	R$ 2,5968
MS, PA, SC, MA	R$ 2,3340	R$ 2,3601	R$ 2,3862	R$ 2,4123	R$ 2,4384	R$ 2,4645	R$ 2,4906	R$ 2,5167	R$ 2,5428	R$ 2,5689
GO	R$ 2,2801	R$ 2,3062	R$ 2,3323	R$ 2,3584	R$ 2,3845	R$ 2,4106	R$ 2,4367	R$ 2,4628	R$ 2,4889	R$ 2,5150
TO, MG	R$ 2,2541	R$ 2,2802	R$ 2,3063	R$ 2,3324	R$ 2,3585	R$ 2,3846	R$ 2,4107	R$ 2,4368	R$ 2,4629	R$ 2,4890
RJ	R$ 2,2287	R$ 2,2548	R$ 2,2809	R$ 2,3070	R$ 2,3331	R$ 2,3592	R$ 2,3853	R$ 2,4114	R$ 2,4375	R$ 2,4636
DF,RR,RN	R$ 2,2039	R$ 2,2300	R$ 2,2561	R$ 2,2822	R$ 2,3083	R$ 2,3344	R$ 2,3605	R$ 2,3865	R$ 2,4126	R$ 2,4387

Transport Cost R$ (m³) per KM Ship Transport - High Restriction	R$ 17,52	R$ 24,84	R$ 32,16	R$ 39,48	R$ 46,80	R$ 54,13	R$ 61,45	R$ 68,77	R$ 76,09	R$ 83,42
Average Transport Cost R$ / liter per KM Ship Transport - High Restric	**R$ 0,0175**	**R$ 0,0248**	**R$ 0,0322**	**R$ 0,0395**	**R$ 0,0468**	**R$ 0,0541**	**R$ 0,0615**	**R$ 0,0688**	**R$ 0,0761**	**R$ 0,0834**
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 2,5527	R$ 2,5600	R$ 2,5674	R$ 2,5747	R$ 2,5820	R$ 2,5893	R$ 2,5967	R$ 2,6040	R$ 2,6113	R$ 2,6186
AL, BA, PB, PR, RS, SE	R$ 2,3363	R$ 2,3436	R$ 2,3509	R$ 2,3583	R$ 2,3656	R$ 2,3729	R$ 2,3802	R$ 2,3876	R$ 2,3949	R$ 2,4022
MS, PA, SC, MA	R$ 2,3340	R$ 2,3157	R$ 2,3230	R$ 2,3303	R$ 2,3376	R$ 2,3450	R$ 2,3523	R$ 2,3596	R$ 2,3669	R$ 2,3743
GO	R$ 2,2545	R$ 2,2618	R$ 2,2691	R$ 2,2764	R$ 2,2837	R$ 2,2911	R$ 2,2984	R$ 2,3057	R$ 2,3130	R$ 2,3204
TO, MG	R$ 2,2285	R$ 2,2358	R$ 2,2431	R$ 2,2504	R$ 2,2577	R$ 2,2651	R$ 2,2724	R$ 2,2797	R$ 2,2870	R$ 2,2944
RJ	R$ 2,2030	R$ 2,2104	R$ 2,2177	R$ 2,2250	R$ 2,2323	R$ 2,2396	R$ 2,2470	R$ 2,2543	R$ 2,2616	R$ 2,2689
DF,RR,RN	R$ 2,1782	R$ 2,1855	R$ 2,1928	R$ 2,2002	R$ 2,2075	R$ 2,2148	R$ 2,2221	R$ 2,2295	R$ 2,2368	R$ 2,2441

These outputs lead further down the life-cycle-cost calculation to the cost stage where a certain margin of the distributor is added. Mostly, the margin rate is defined by internal price policy of the fuel distributor company to a value of between 10 – 15 percent and can be calculated regarding the fuel calculation structure of ANP subtracting the unit sales price at refinery with taxes by the unit price at refinery without taxes. The result is a margin between 0,33 and 0,70 Reais $ and a mean value of 0,44 Reais $ per liter jet fuel.

J: Margin Distributor	
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 0,7050
AL, BA, PB, PR, RS, SE	R$ 0,4886
MS, PA, SC, MA	R$ 0,4606
GO	R$ 0,4067
TO, MG	R$ 0,3807
RJ	R$ 0,3553
DF,RR,RN	R$ 0,3305

The tax rates mentioned above are applied again for the distributor because in Brazil taxes apply two times, firstly between federal states and secondly at each stage throughout the supply chain. Likewise, the tax accumulated costs are calculated for kilometers of QAV transported, here for the example of road transportation, and for each state of ICMS rate applied.

	Kilometers of Cargo QAV from Point of Refinery / Terminal (Road Transportation)									
L: Price for Distributor Without ICMS	100	200	300	400	500	600	700	800	900	1000
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 3,1640	R$ 3,2162	R$ 3,2684	R$ 3,3206	R$ 3,3728	R$ 3,4249	R$ 3,4771	R$ 3,5293	R$ 3,5815	R$ 3,6337
AL, BA, PB, PR, RS, SE	R$ 2,9476	R$ 2,9998	R$ 3,0520	R$ 3,1041	R$ 3,1563	R$ 3,2085	R$ 3,2607	R$ 3,3129	R$ 3,3651	R$ 3,4173
MS, PA, SC, MA	R$ 2,9196	R$ 2,9718	R$ 3,0240	R$ 3,0762	R$ 3,1284	R$ 3,1806	R$ 3,2328	R$ 3,2850	R$ 3,3372	R$ 3,3893
GO	R$ 2,8657	R$ 2,9179	R$ 2,9701	R$ 3,0223	R$ 3,0745	R$ 3,1267	R$ 3,1789	R$ 3,2311	R$ 3,2833	R$ 3,3354
TO, MG	R$ 2,8397	R$ 2,8919	R$ 2,9441	R$ 2,9963	R$ 3,0485	R$ 3,1007	R$ 3,1529	R$ 3,2051	R$ 3,2573	R$ 3,3094
RJ	R$ 2,8143	R$ 2,8665	R$ 2,9187	R$ 2,9709	R$ 3,0231	R$ 3,0753	R$ 3,1275	R$ 3,1796	R$ 3,2318	R$ 3,2840
DF,RR,RN	R$ 2,7895	R$ 2,8417	R$ 2,8939	R$ 2,9460	R$ 2,9982	R$ 3,0504	R$ 3,1026	R$ 3,1548	R$ 3,2070	R$ 3,2592

M: ICMS for Distributor	Kilometers of Cargo QAV from Point of Refinery / Terminal (Road Transportation)									
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 0,4209	R$ 0,4383	R$ 0,4557	R$ 0,4731	R$ 0,4905	R$ 0,5078	R$ 0,5252	R$ 0,5426	R$ 0,5600	R$ 0,5774
AL, BA, PB, PR, RS, SE	R$ 0,2296	R$ 0,2411	R$ 0,2526	R$ 0,2640	R$ 0,2755	R$ 0,2869	R$ 0,2984	R$ 0,3098	R$ 0,3213	R$ 0,3328
MS, PA, SC, MA	R$ 0,2086	R$ 0,2192	R$ 0,2299	R$ 0,2406	R$ 0,2513	R$ 0,2620	R$ 0,2727	R$ 0,2834	R$ 0,2941	R$ 0,3048
GO	R$ 0,1702	R$ 0,1794	R$ 0,1886	R$ 0,1978	R$ 0,2070	R$ 0,2162	R$ 0,2254	R$ 0,2346	R$ 0,2439	R$ 0,2531
TO, MG	R$ 0,1528	R$ 0,1612	R$ 0,1697	R$ 0,1782	R$ 0,1867	R$ 0,1952	R$ 0,2037	R$ 0,2122	R$ 0,2207	R$ 0,2292
RJ	R$ 0,1364	R$ 0,1442	R$ 0,1520	R$ 0,1598	R$ 0,1676	R$ 0,1754	R$ 0,1832	R$ 0,1910	R$ 0,1988	R$ 0,2066
DF,RR,RN	R$ 0,1211	R$ 0,1282	R$ 0,1353	R$ 0,1425	R$ 0,1496	R$ 0,1567	R$ 0,1638	R$ 0,1709	R$ 0,1780	R$ 0,1852

Lastly, one can determine the final price the distributor sells the aviation fuel to the consumer. For this, the price indicators L and M from figure 52 are simply totaled to obtain a price range between 3,70 Reais $ and 4,84 Reais $ for one-liter jet fuel at point of consumption. However, these results include an average transport cost and leave out extensive costs for transport in remote areas, where final fuel prices can increase to an amount at least twice that high as explained further on.

	Kilometers of Cargo QAV from Point of Refinery / Terminal (Road Transportation)									
N: Final Price Distributor (Road Transport)	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**	**900**	**1000**
AC, AM, AP, CE, ES, MT, PE, PI, RO, SP	R$ 4,2187	R$ 4,2882	R$ 4,3578	R$ 4,4274	R$ 4,4970	R$ 4,5666	R$ 4,6362	R$ 4,7058	R$ 4,7754	R$ 4,8449
AL, BA, PB, PR, RS, SE	R$ 3,5946	R$ 3,6582	R$ 3,7219	R$ 3,7855	R$ 3,8492	R$ 3,9128	R$ 3,9765	R$ 4,0401	R$ 4,1038	R$ 4,1674
MS, PA, SC, MA	R$ 3,5176	R$ 3,5805	R$ 3,6434	R$ 3,7063	R$ 3,7692	R$ 3,8320	R$ 3,8949	R$ 3,9578	R$ 4,0207	R$ 4,0835
GO	R$ 3,3715	R$ 3,4328	R$ 3,4943	R$ 3,5556	R$ 3,6171	R$ 3,6784	R$ 3,7399	R$ 3,8012	R$ 3,8627	R$ 3,9240
TO, MG	R$ 3,3020	R$ 3,3627	R$ 3,4234	R$ 3,4841	R$ 3,5448	R$ 3,6054	R$ 3,6661	R$ 3,7268	R$ 3,7875	R$ 3,8482
RJ	R$ 3,2348	R$ 3,2948	R$ 3,3548	R$ 3,4148	R$ 3,4748	R$ 3,5348	R$ 3,5948	R$ 3,6548	R$ 3,7148	R$ 3,7747
DF,RR,RN	R$ 3,1699	R$ 3,2292	R$ 3,2885	R$ 3,3478	R$ 3,4071	R$ 3,4664	R$ 3,5257	R$ 3,5850	R$ 3,6443	R$ 3,7036

Expressed by means of a bar diagram, the proportional distribution of the cost composition for one-liter QAV is defined as follows in figure 53. Remarkably, there clearly stick out three major cost drivers, production (28 %), transport (26 %) and taxes (29%). However, the cost portion for transport is calculated here as an average cost for a return trip on road transportation between refinery and airport for 1000 kilometers. This cost is subject to change as geographical differences and variation of transport network apply among Brazil as to compare in the next chapter.

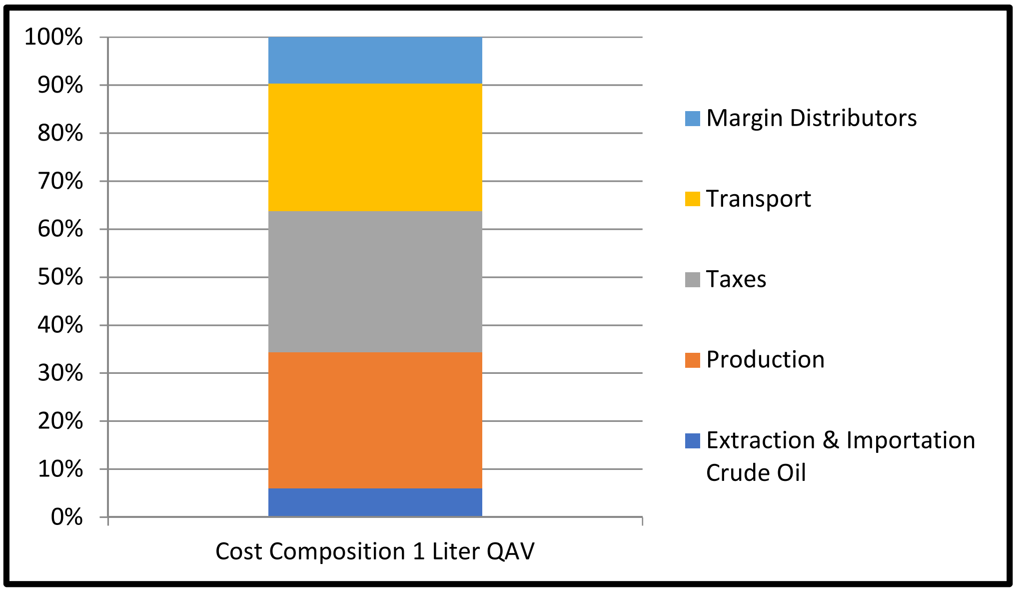

Figure 53: Cost Composition of 1 Liter QAV in Percentage
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

8.1. TRANSPORT COST

Particular attention is drawn to the impact of QAV transport cost on the life-cycle-cost-calculation between refinery, fuel terminal and airport. At this, distances between points of jet fuel production at refineries, points of storage or distribution at fuel terminals and depots or points of consumption at airports when refueling airplanes, must be considered. Furthermore, the mode of transport, the quality of transport infrastructure and the total unit cost of transport for the overall transport cost per kilometer must be examined. Hence, the following parameters are taken into consideration to determine the value of:

Unit Transport Cost of 1 Liter QAV Cargo per Day in R$ / Liter QAV

Road Transportation	
Average Speed	Km/h
Cost of Gasoline / Diesel	R$/Liter
Cargo Transported	Liter QAV / Mean Value
Truck	*Liter QAV Max. Cargo*
Truck 1 Trailer	*Liter QAV Max. Cargo*
Truck 2 Trailer	*Liter QAV Max. Cargo*
Distance return trip Refinery - Airport	Km
Fuel Consumption	Liter/Km
Unit Cost of Transport (Sum all costs for Transport per Km)	R$ / KM

Figure 54: Indicators for calculation of unit transport cost 1 Liter QAV – Road Transportation
Source: Elaborated by the Author

Ship Transportation	
Average Speed	Km/h
Cost of Fuel	R$/Liter
Cargo Transported	Liter QAV / médio
Nominal Value Cargo	*Liter QAV / Average Load per Month*
Efective Value Cargo	*Liter QAV / Actual Load*
Load Factor	*%*
Distance Cargo Transported	Km
Fuel Consumption	Kg/BHP/hora
Ship In Movement	*Kg/BHP/hora*
Ship In Halt	*(Kg/hora)*
Unit Cost of Transport (Sum all costs for Transport per Km)	R$ / KM

Figure 55: Indicators for calculation of unit transport cost 1 Liter QAV – Ship Transportation
Source: Elaborated by the Author

In order to achieve a realistic determination of the transport cost for each mode, the following cost formula is applied on both, road and ship transportation taking into account indicators from figures 54 and 55.

$$\boldsymbol{CT_{ik}} = \sum \boldsymbol{T_{ik}} * \boldsymbol{CU_{ik}} * \boldsymbol{DM_{ik}}$$

Whereas:

CT_{ik}:	Total Cost of Transport of i type of cargo and k mean of Transport (R$ / Liter QAV transported)
T_{ik}:	Weight of Cargo of i type of cargo and k mean of Transport (Liter of QAV)
CU_{ik}:	Unit Cost of Transport per km (Sum all costs R$/KM)
DM_{ik}:	Distance of Cargo Transported (Km QAV Load)

To elaborate a coherent transport cost calculation, the following steps are taken: First, all cost parameters listed in Annex A4, which occur for any company in Brazil that realizes jet fuel transport by road or waterway, is analyzed and resumed. Then, the corresponding cost data for each parameter is collected. Further, all costs are summed up and divided by the amount of kilometer one desires to express the cost of transport on. Hence, the obtained result is the unit cost of transport expressed in Reais $ per kilometer. An additional indicator is the actual distance a truck or a boat takes to deliver aviation fuel to airfields. In the present study a refinery of QAV within a state is taken as a central location of distribution. However, a capital of a given municipality or a fuel terminal can also serve as point of reference. Now, the distance in kilometers to a fuel terminal, fuel deposit or airport is measured and serve as reference locations for jet fuel distribution. At this, the distance of the return trip is significant as the sum of transport costs includes all costs that occur for a company, independently of the cargo load. Thus, cargo in liters QAV and distance in kilometers are two variables that are subject to fluctuation depending on the jet fuel supply of each airport or fuel terminal. So, the amount of QAV cargo expressed in liters can vary depending on the size of a vessel transporting fuel. In general, a mean value of average load in liter QAV per month is calculated by multiplying the maximum load capacity by a load factor expressed in percent. Taking into consideration these variables, the overall unit transport cost of one-liter QAV cargo per day can be determined.

For simplicity of reproduction of the transport cost per kilometer, the figures 56 and 57 illustrate radar maps, which emphasize how much must be paid for transporting one liter of QAV every 200 kilometers. Of course, freight costs in the Amazonas are higher as the mean value elsewhere in Brazil due to high restrictions. Thus, cost data here differs to the transport costs calculated in the life-cycle-cost-structure because a cost variation coefficient for externalities of 35 percent is applied that takes into account additional costs that occur uniquely in the Amazonas due to the following: Seasonality, costs for ships in halt and waiting hours for trucks because of impassable transport ways, costs for changing cargo from one mode of transport to another or damages of material due to an improper road network among others.

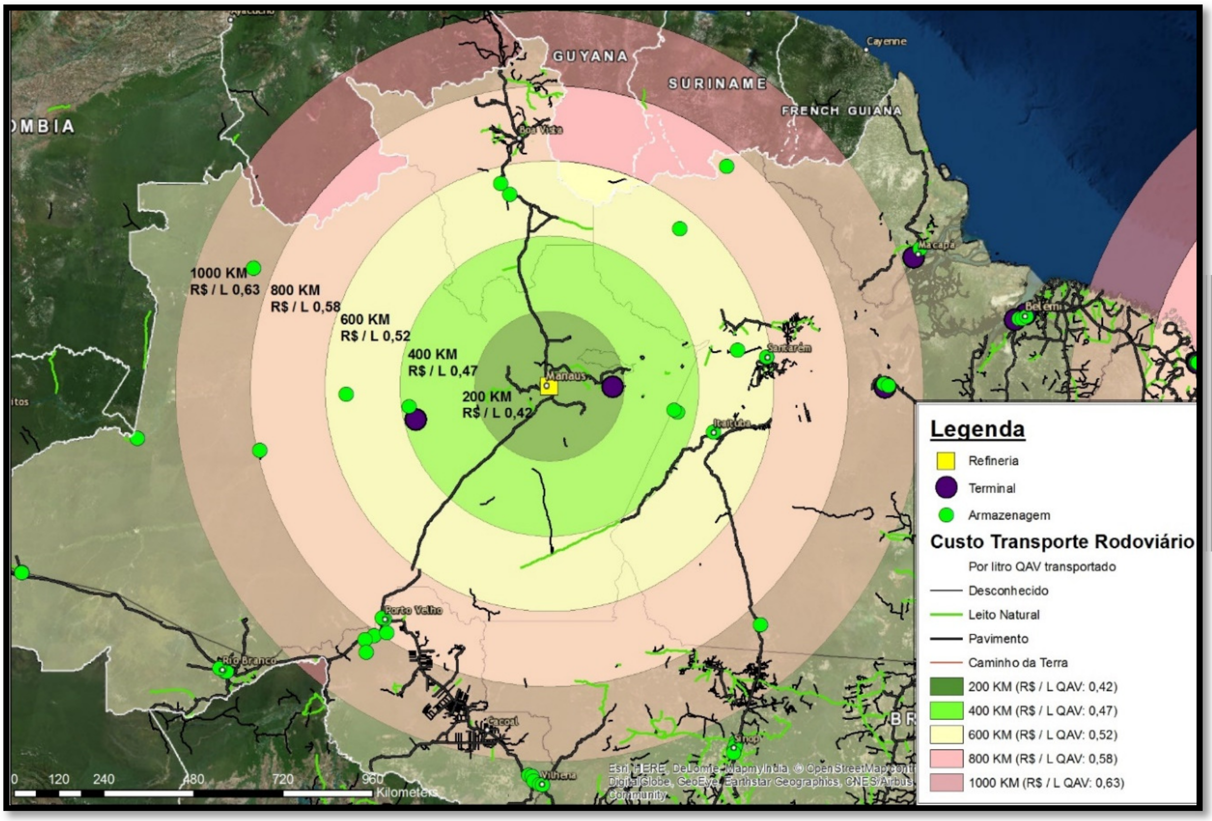

Figure 56: Radar Map of unit transport cost of 1 Liter QAV in 200 KM frequencies – Road Transportation
Source: Pioneiro Combustíveis (2017) and EPL (2017)

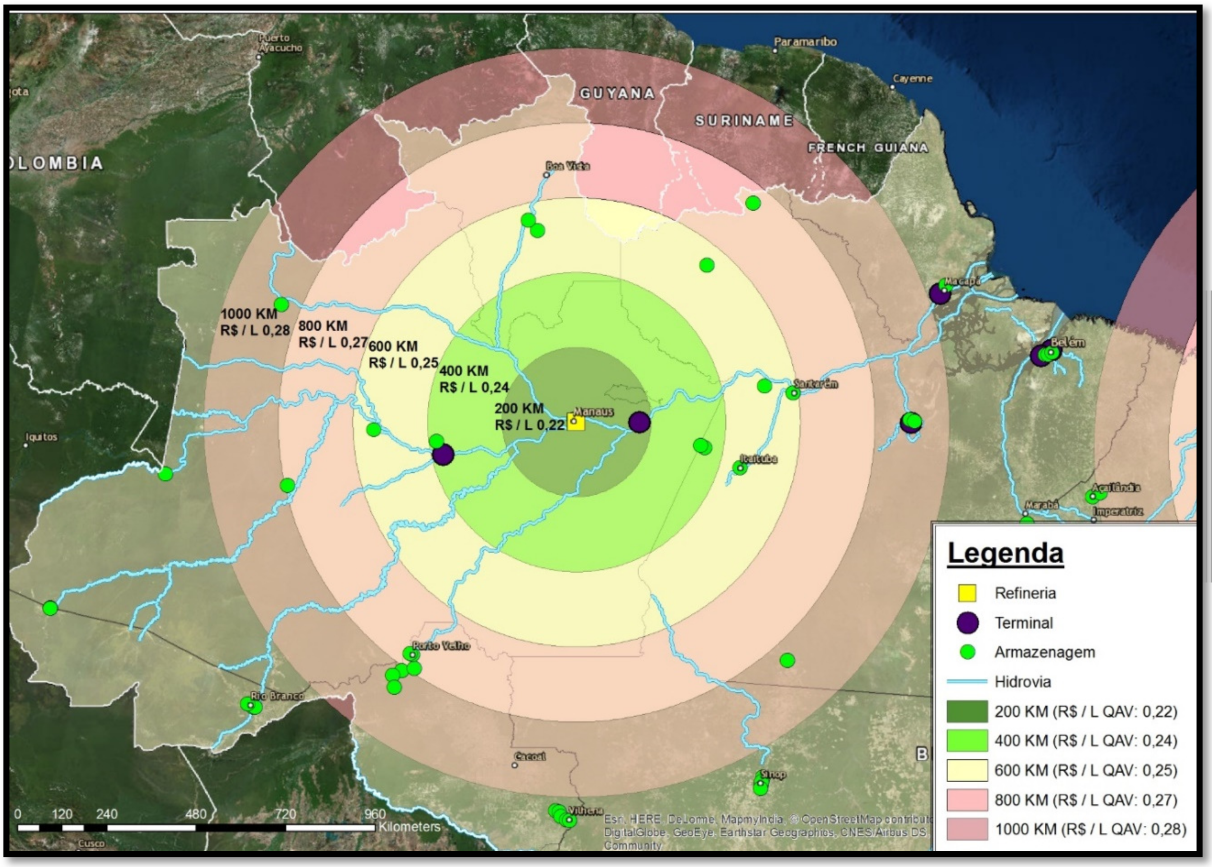

Figure 57: Radar Map of unit transport cost of 1 Liter QAV in 200 KM frequencies – Ship Transportation
Source: Pioneiro Combustíveis (2017) and EPL (2017)

8.2. TRANSPORT COST SCENARIOS

A significant cost driver for the determination of a purchase price of one-liter jet fuel is the unit transport cost. Thus, it makes sense to examine the means of transport as well as the transport network among various locations in greater detail. For this reason, four scenarios have been elaborated indicating the correlation between the unit transport cost, the distance from point of production to point of consumption and the final purchase price of one-liter QAV by municipality. Therefore, figure 58 shows the return transport route by road transportation from the refinery REMAN in Manaus via Porto Velho and Rio Branco to the city of Cruzeiro do Sul at the Border to Peru. Distances between the landmarks are indicated by text and fuel prices are highlighted in distinct colors. Furthermore, fuel deposits are passed along the transport route thus indicating the fuel distribution and storage network of that area. On basis of the life-cycle-cost-analysis explained in chapter 7, for each liter aviation fuel delivered on a 4000 Kilometer return trip to Cruzeiro do Sul, 1,20 Reais $ must be paid. For this reason, the final prices of jet fuel are highest in most remote municipalities.

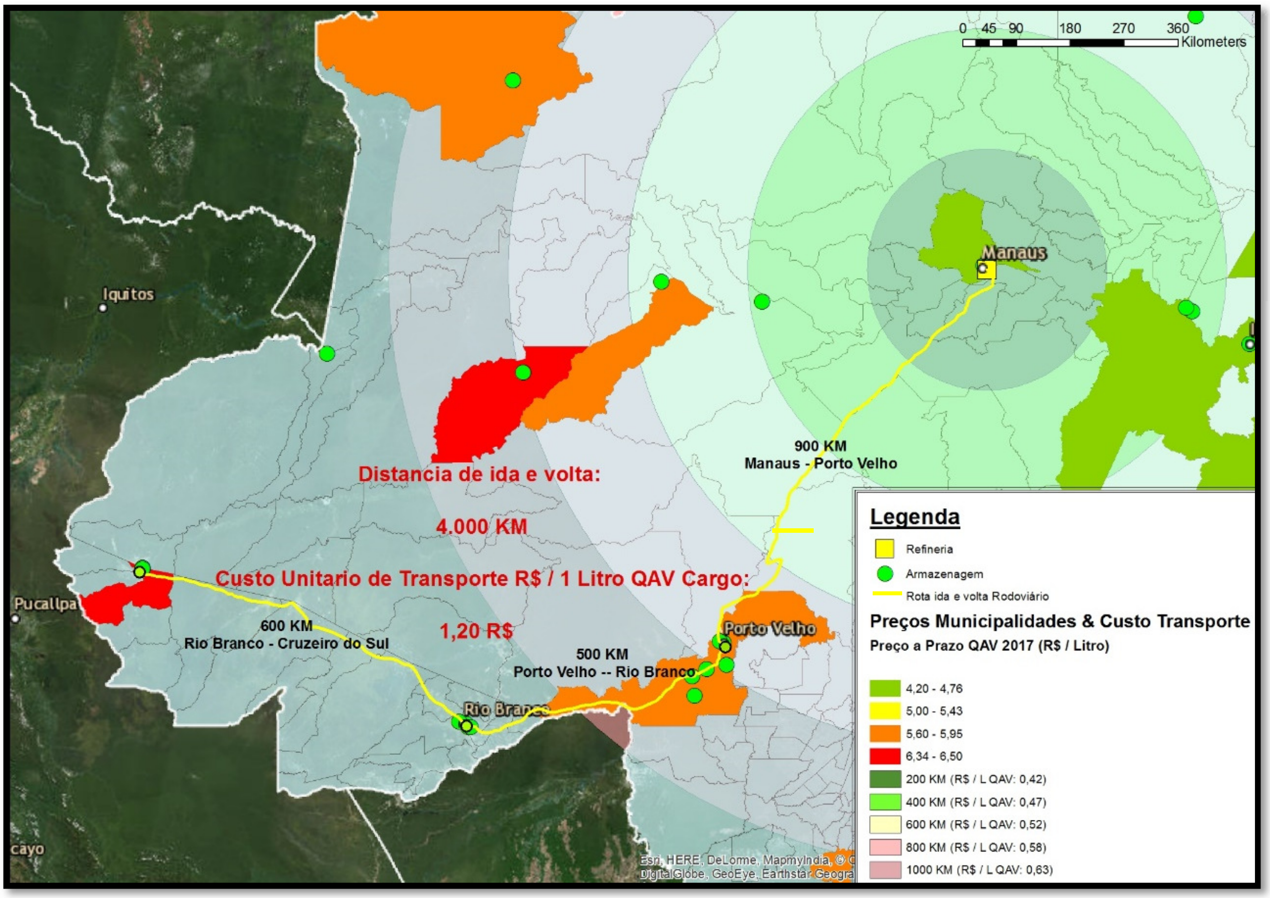

Figure 58: Scenario 1: Correlation of Distances, Unit Transport Cost and Final Price of QAV by Municipalities in the Amazonas
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

In comparison, the transport network between Manaus, the states of Rondonia and Mato Grosso is integrated to a further extend as the scenario of figure 59 highlights. The picture indicates the QAV value chain including refinery, terminal and fuel deposit as well as the plain unit cost of transport of one-liter QAV. However, in this illustration the cost of transport regarding road and ship transportation is stressed without an added cost coefficient for externalities. For instance, aviation fuel can be delivered from Manaus to Porto Velho by both means of transport but QAV transport by ship reflects a cost benefit, if the ships load cargo factor is high and therefore efficient. Further, the interconnectivity of transport modes and the kilometers between each fuel deposits are emphasized. Hence, transport of aviation fuel can be executed in Mato Grosso in several ways within a more compact network, that decreases the total cost of one-liter QAV in that region.

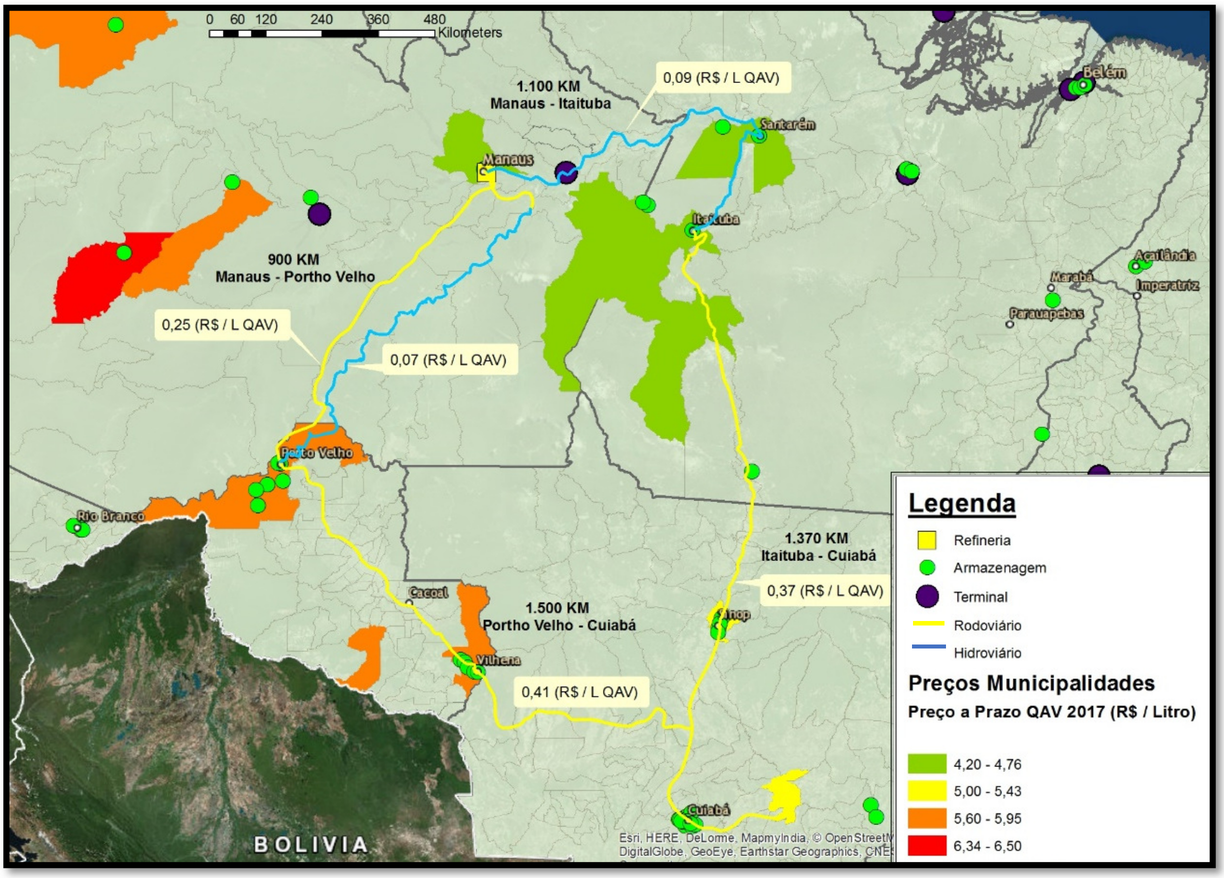

Figure 59: Scenario 2: Correlation of Distances, Unit Transport Cost and Final Price of QAV by Municipalities in the Amazonas, Rondonia and Mato Grosso
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

Also, jet fuel can be transported to the central land on alternative ways. For instance, the relatively well-developed railway transport network in the south-east region facilitates the transport of jet fuel from the principal QAV refinery in Campinas, São Paulo to the cities of Brasilia, Cuiaba and Campo Grande at the interior land. Therefore, the following map shows the rail and ship network of that region as well as its connection to the road network of Mato Grosso. Hence, the airports in the state of Mato Grosso do not necessarily rely on the delivery of aviation fuel from the refinery in the Amazon but can benefit from the interconnectivity to road and ship transportation from the south-east of Brazil.

Those factors bring down the unit cost for transport considerably and reduce total price of QAV in that region.

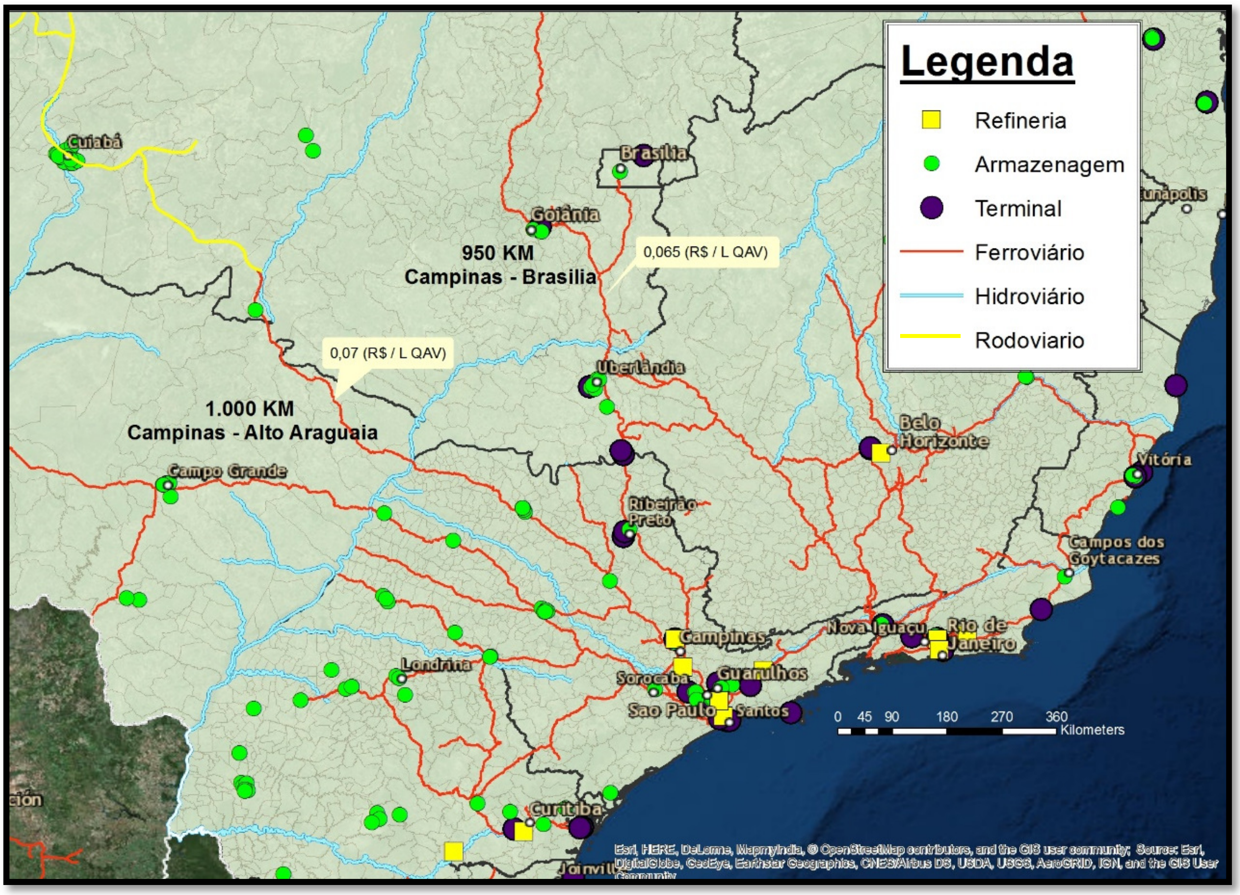

Figure 60: Scenario 3: Correlation of Distances, Unit Transport Cost and Mode of Transport South-East Region
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

To outline an extensive transport scenario across the whole country, figure 61 indicates the carriage of aviation gas by road and ship from the only refinery, named RPBC that produces the fuel and is located next to the city of São Paulo, to the destination Boa Vista in the very north of the country. The total distance is calculated to 5.200 kilometers that reflect a unit transport cost of 2,10 Reais $ per liter fuel transported. Notably, the transport cost is the sum of the cost within the states of the Amazonas, as 1,20 Reais $ per liter fuel (figure 58). According to Pioneiro Combustíveis (2017), the cost of QAV transport on the route between São Paulo and Belém is calculated to 0,90 Reais $ per liter fuel transported. Hence, the distance is not necessarily decisive for the overall transport cost rather than the relative weight of operating expenditures regarding the parameters of the transport cost per kilometer cargo transported as explained in the chapter transport costs of the present paper.

Figure 61: Scenario 4: Correlation of Distances, Unit Transport Cost and Mode of Transport
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

9. RESULTS

9.1. HEAT MAPPING: JET FUEL PURCHASE PRICE

All outcomes, which have been calculated by means of inputs and the life-cycle-cost-analysis explained throughout the present paper, are now expressed visually by heat maps. These graphics indicate various key figures with regard to both, final prices of QAV and the transport cost of aviation fuel. In the light of purchase prices for jet fuel, the following figure 62 illustrates the aviation fuel prices by federal state. However, it must be taken into consideration that those amounts are mean values that include all costs along the QAV supply life cycle and reflect an average price within a particular state. Consequently, final prices are subject to variation considering unit transport costs and the ICMS tax rates between each state. For that reason, jet fuel is most expensive among the Amazonas states, at the north-east states and in the state of São Paulo. Surprisingly, the aviation fuel in the state of Rondonia is one of the most inexpensive due to the theoretical price calculation including the lowest ICMS rate of 12 percent. Under those circumstances, the strong correlation between the cost driver taxes and the final purchase price of one-liter QAV can be proven.

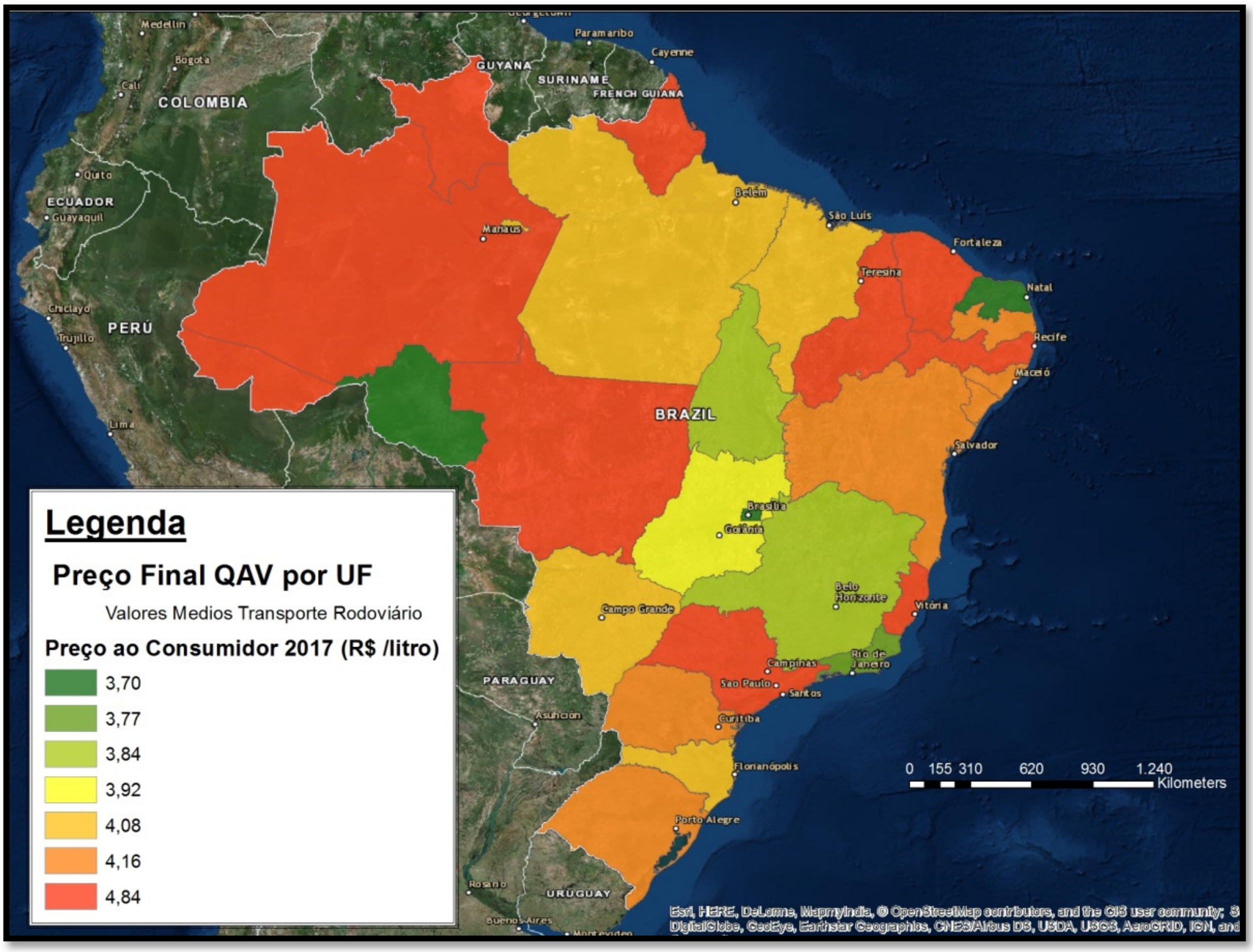

Figure 62: Final Price of QAV by federal State – Mean values Road Transportation
Source: ANP (2017), EPL (2017), Pioneiro Combustíveis (2017), REPEC (2017)

Additionally, the purchase price of one-liter aviation fuel a distributor sells to its customers can be broken down by municipality. With focus on a detailed map section of the Amazonas, figure 63 illustrates the only refinery REMAN based in Manaus as a center point, the transport network such as road and ship transportation as well as the purchase price of one-liter QAV distributed among municipalities. Noticeably, the price for QAV increases the greater the distance from the refinery and determines remote areas such as Cruzeiro do Sul and Carauri as the most expensive ones for buying aviation fuel. However, the final purchase prices in figure 63 are values obtained directly from a transport company named Pioneiro delivering QAV in the Amazonas. Hence, these prices comprise additional transport costs and further margins in contrast to the prices shown in figure 62 calculated by a theoretical life-cycle-cost calculation as explained before in chapter 7.

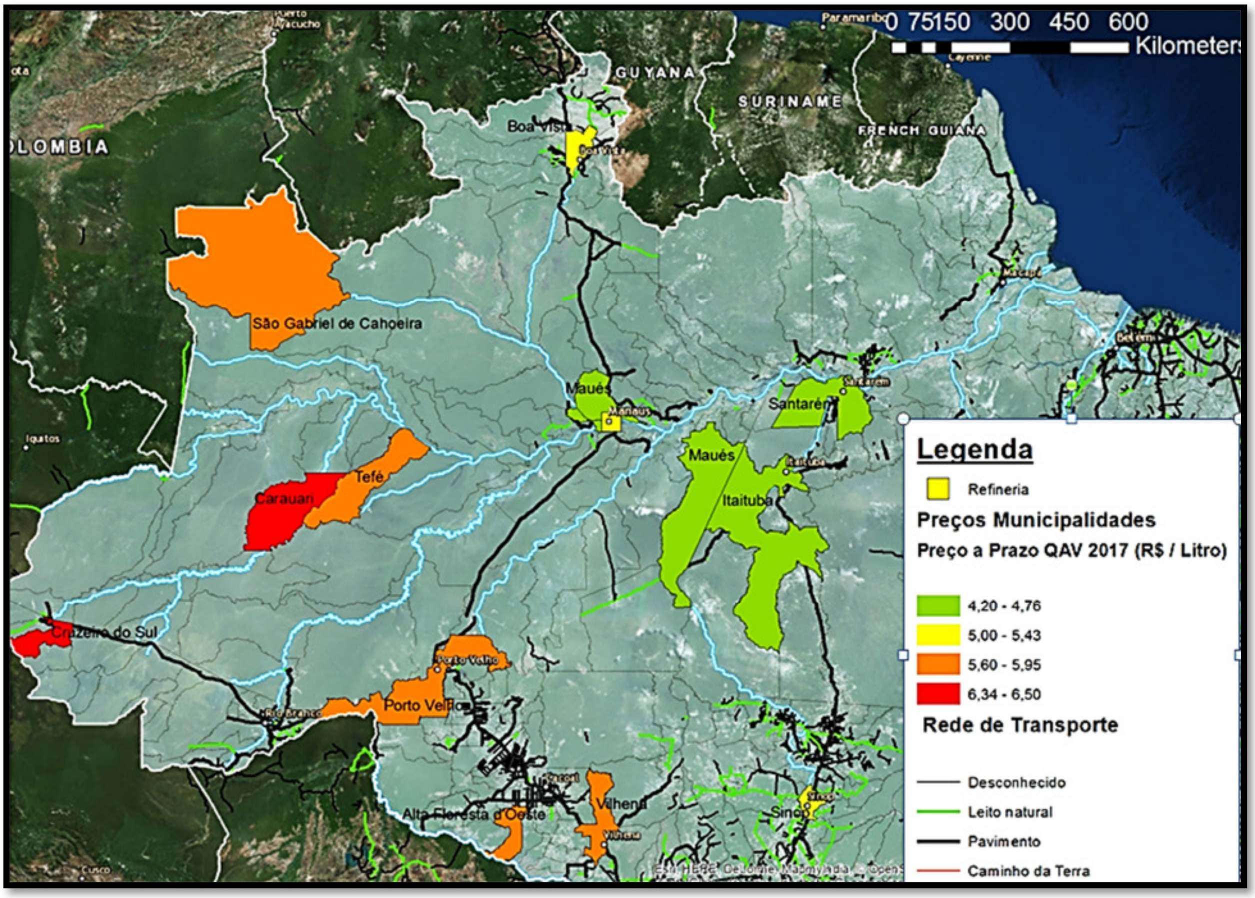

Figure 63: Final Price of QAV by Municipalities in the Amazonas
Source: Pioneiro Combustíveis (2017)

In further detail, the transport coefficient explained in the mentioned chapter can be applied to the most remote airports located at the municipalities which are directly connected to a road or ship transport network or those located at an area with very restrictive access. Hence, the unit cost of transport increases and has a direct influence on a much higher purchase price for jet fuel that is calculated to a maximum figure of 9,36 Reais $ per liter QAV. Again, it must made clear to the reader that the number values shown in figure 64 are based as well on the scientific approach of the life-cycle-analysis described throughout this paper and might vary in practice given the fact that jet fuel distribution companies apply certain margins or extraordinary add on transports costs may apply in remote areas.

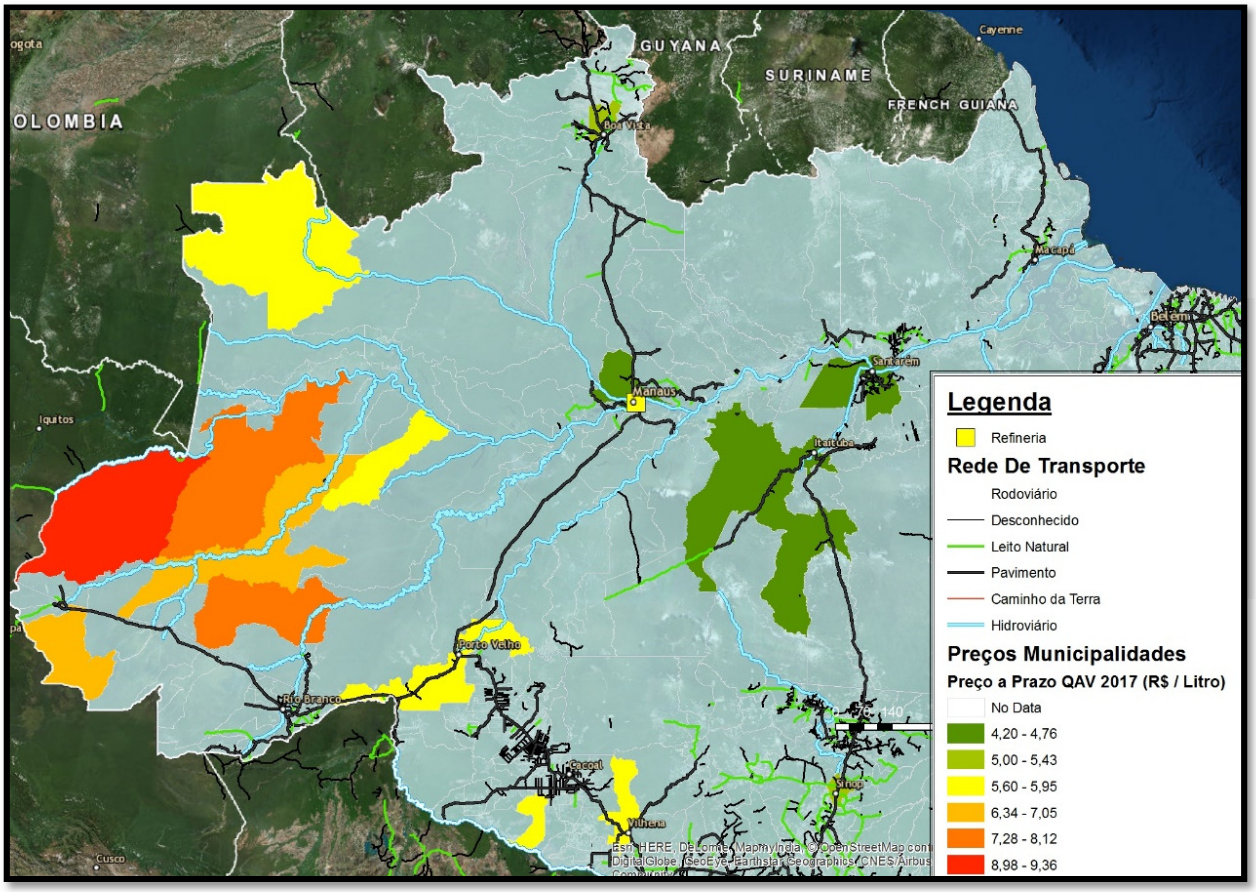

Figure 64: Final Price of QAV by very remote Municipalities in the Amazonas
Source: Pioneiro Combustíveis (2017) and calculation of the author

10. DISCUSSION

As the results of the research indicate, the combination of the transport modes ship, rail and road transportation create a more compact and integrated system and results in a considerable decrease of the total unit transport cost in Reais $ per liter QAV transported. Mostly, the domestic tax framework and an inefficient transport distribution, shape the final fuel price to an extraordinary extend. Strategies towards an expansion of Brazil´s jet fuel production portfolio by an implementation of a decentral synthetic aviation fuel production line besides the already upcoming Bio-QAV industry, would support on the one hand the decrease of dependency on oil imports and prevent jet fuel price fluctuations. On the other hand, the transport of jet fuel would become more predictable, direct and structured due to more compact distribution patterns. In this context, a more integrated and decentral network of fuel production hubs among the Amazonas could create valid alternatives to the costly and challenging re-distribution, coastal shipping and transport of aviation fuel into remote areas. Unequal distribution of the QAV production line across the country and the concentrated airport network among the south-east region, intensify these challenges. Overall, the outcomes of the present paper give an idea about challenges of jet fuel transport across remote areas in the Amazonas and show that aviation fuel purchase prices can be extraordinarily high in specific cases. Hence, the question of economic viability of a power to liquid synthetic renewable aviation fuel production line is linked directly to the extent of transport costs for jet fuel produced in Brazil and of course to the whole life cycle costs of a conventional jet fuel production. Regarding to the outcomes of the present paper, there is a market entry chance of the new technology in very remote areas where the production and distribution of QAV is costly as to compare in figure 64 QAV prices among municipalities, where prices of QAV nearly reach the 10 Reais $ per Liter. In these niches, at remote areas and where challenging and costly distribution patterns exist, the commercialization of synthetically produced jet fuel would economically make sense.

11. CONCLUSION

To summarize, the strongest cost drivers responsible for the extraordinary high portion of jet fuel of 30 percent on operational cost, are high tax rates and transport costs among remote areas. For instance, the value of 30 – 50 percent of higher cost for jet fuel transport within the Amazonas region underlines that argument. Combined with the fact that the domestic aviation fuel price is linked directly to the international oil prices, which influences the final purchase price of jet fuel along the value chain. In short, viable niches for an implementation of a synthetic aviation fuel production plant considering cost factors can be defined as follows. Remote Areas among municipalities, located distant or in medium range to the transport network within the states of Roraima, Acre and Amazonas due to the high transport cost of more than 1, 20 Reais $ per liter QAV applied plus a maximum rate of 25 percent for ICMS taxes charged. Ultimately, the mentioned parameters bring down the overall fuel price of one-liter QAV sold by the distributor to the consumer at an airport to more than Reais $ 6,50 in those remote municipalities depending on the coefficient of high transport costs in remote areas.

Recommendations for further research and next steps regarding the evolution of the project PRO QR are a detailed bottom - up study on QAV storage volumes and respective costs for storage as well as a study about sources and locations of carbon dioxide, renewable energy and water resources. In addition to this, an environmental impact assessment, indicating externalities and social impacts as well as costs of the projects alternative fuel technology. Furthermore, a life-cycle-cost analysis for the benchmark scenario value chain synthetic aviation fuel production must be executed. This should be realized in combination with a coherent socio-economic and financial analysis to examine the break-even point and to define at which point grid parity between the life-cycle-costs of the baseline case conventional QAV and the benchmark case alternative jet fuel occur. The essential outcome of this comprehensive research is the levelized cost of electricity (LCOE) for both production lines.