

IS THE TILTROTOR WORTHY FOR CIVILIAN TRANSPORTATION BETWEEN GREAT CITIES? A CASE STUDY INVOLVING BRAZILIAN IMPORTANT CITIES

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Abstract

Brazilian executive transportation has grown significantly facing the challenge of avoiding the traffic jam of great cities and lack of satisfactory airport infrastructure. There are travel ranges which are too far for helicopters and too close for fixed-wing aircrafts, where the tiltrotor-type solution, that now enters the civilian market, may bring better relation between time and cost to the user. The objective of this study is to examine the tiltrotor's feasibility and its worthiness against other available market options for executive transportation between Brazilian great cities. Tiltrotors are supposed to use the large helicopter landing sites, sometimes far from cities airports. Therefore, the IFR (Instrument Flight Rules) operation is a concern because of the transition to the VFR (Visual Flight Rules) and the following flight to the landing site that, if performed at low speed, will raise the specific fuel consumption because the engines would not be completely tilted forward. Today, the tiltrotor speed would be limited to 80 knots inside some helicopters visual corridors of these cities. The tiltrotor would flight more economically in the fixed-wing corridors, unless the rules for the helicopter corridors are adapted to it. That's why the certification and safety issues are analyzed. ANAC (Brazilian Civil Aviation Agency, under the Civil Aviation Secretariat, a species of Ministry directly attached to Brazil's Presidency) is set to play a major role in definition of the requirements to certify or accept the FAA (Federal Aviation Administration) certification of tiltrotors because, rigorously, it does not fit in any of the present standards. Meanwhile, DECEA (Brazilian Airspace Control Department, under the Air Command, which is linked directly to the Defense Ministry) is expected to define the IFR and visual corridors rules. Typical flights departing from São Paulo city (Capital of São Paulo State) and arriving in many Brazilian great cities are simulated. These cities are 46 to 658 NM apart and there are roads and airways connecting them. Shorter distances represent an advantage to helicopters while bigger distances would be more adequate to fixed-wing aircraft. To compare the tiltrotor with its competitors it was chosen one jet aircraft, one helicopter and one car "competing" with the tiltrotor Agusta Westland AW-609. The simulation considers departure and arrivals in places that have landing sites that support the operation of the AW-609 and helicopters with similar gross weight. For the jet aircraft solution, the time and costs data are added with the taxi transportation between the leaving and arriving points and the closest airport in each city. Aircraft manufacturer data, such as specific fuel consumption and cruise speed, are used for the comparison whose results are based on the necessary time and cost to perform this travel carrying seven passengers. The cost of the fuel is based on the rates used in Brazil in the beginning of 2012. As conclusion one verifies that the tiltrotor solution is a fast option, thanks to the ability of performing point-to-point transportation at a cruise speed significantly higher than the helicopters' currently available in the market, though the tiltrotor be an expensive option, even taking into account its optimum range. The car is the cheapest solution but takes more time to reach destination. The jet aircraft had its time extended because of the need of taxi support in departing and arriving cities. The helicopter showed itself cheaper than the tiltrotor but significantly slower. The minutes to be saved with the tiltrotor option and the associated extra costs are to play the key role in defining the worthiness of this transportation according to the customer needs.

1. INTRODUCTION

The exponential increase of traffic caused by the excess of cars in big cities has brought a big waste of time in transportation within cities and between them.

Meanwhile, the long waiting period on the aircraft taxiways also represent a significant waste of fuel, bringing financial concerns to users, environment and society.

In this scenario, point-to-point air transportation involving helicopters and rotary-wing aircraft from heliports or helipads becomes more attractive due to their speed and convenience. Hence, significant and

continued growths in the number of helicopters, in great Brazilian cities like Sao Paulo, have been observed since 1993.

However, when it comes to transportation between cities that are apart a few hundred nautical miles, the fixed-wing aircraft shows capable of developing higher cruise speed than a helicopter with relatively low consumption of fuel. Therefore, there is a need to adopt an efficient means of transport between cities, facing the lack of satisfactory Brazilian airport infrastructure. This technological solution already exists and is on the industries' boards of the major manufacturers, being in some cases, on the verge of being certified for use in civil aviation. Its name is tiltrotor.

The concept of an aircraft with engines installed in the wing tips, assuming a vertical position for the VTOL (Vertical Take-Off and Landing) operation, was patented in September 1930 by George Lehberger. During the World War II and the postwar period, several prototypes have been developed due to tactical needs, but none of the projects succeeded due to the complexity of the flight control and propulsion systems required for the transition between the tilting positions the engines assume. In the following decades, the flight safety for take-off and landing operations (NASA, 2000) gained importance and brought complexity to the projects.

Since 1981, generically speaking, all the accumulated knowledge on tiltrotors in several projects were concentrated in one, called V-22 Osprey, which was the first large-scale production tiltrotor. His first flight was in 1989 and its first employment in action was in 2007 (BELL HELICOPTERS, 2011).

Now, with mature solutions for the complexities of flight control, the field is open for civilian usage, whose certification processes are more demanding on safety than military's. When these aircraft come into operation in our cities, it will be a solution for the transport, which seeks more economy and agility.

That said, one can bring the main problem of this work, i.e., identifying the feasibility of using a tiltrotor aircraft for executive transportation between Brazilian state capitals. To answer it, this article aims to identify the advantages, disadvantages and concerns involving the logistical launching of this new means of transportation which will soon be flying over our cities. This goal is achieved by analyzing a tiltrotor against its natural competitors, considering problems to be found about safety, air traffic control and IFR (Instrument Flying Rules) operation.

2. THE SIMULATION

There are several VTOL models under development, most of them smaller than the V-22 Osprey though their performance characteristics are similar to the former's. According to the scope of this work, one adopts the AW 609 (AGUSTA WESTLAND, 2010a) to analyze the implementation of a civilian tiltrotor, operating between two cities. Table 1 compares the AW 609 with the V-22 Osprey.

Table 1 - General Characteristics - AW 609 vs V-22 (AGUSTA WESTLAND, 2010a; BELL HELICOPTERS, 2011b)

	Trip/Pax	Ceiling	Cruise Speed
AW609	2/9	FL 250	275 kt
V-22 Osprey	4/24	FL 250	250 kt

The Agusta Westland 609 is a tiltrotor under development and is planned to get to the market by 2016. The AW 609 is projected to several uses, from government to rescue missions. Considering the problem of this work, the simulated configuration is the executive's. The three views and dimensions of this model are found in Figures 1 and 2. The latter shows the AW 609 executive interior layout.

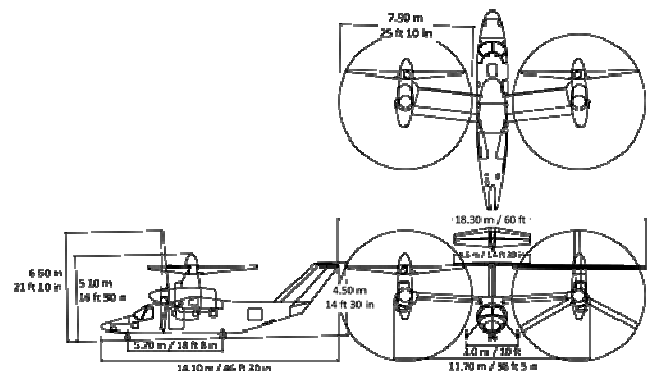


Figure 1 – AW 609 Dimensions (AGUSTA WESTLAND, 2010a)



Figure 2 – 6 passengers executive configuration (AGUSTA WESTLAND, 2010b)

Initially, it is assumed that the user profile for this type of aircraft be constituted of executives, business owners, politicians and personalities from the arts and sports circle. Transportation for this target-public have the time as a significant variable. Thus, the options of train and bus are discarded because they represent an option for people with different priorities.

The comparative analysis covers the performance of four vehicles in this particular task. The AW 609 is compared to a car, an airplane and a helicopter, checking their advantages and disadvantages in a simulated trip performed by an executive, leaving the Faria Lima Financial Center (FLFC) in Sao Paulo and arriving in residential places that have helipads in five different cities. Their distance to São Paulo are presented in Table 2.

Table 2 – Destinations

Destinations	Distance from São Paulo (NM)
Campinas	46
Rio de Janeiro	181
Belo Horizonte	279
Brasília	461
Salvador	658

A severe restriction to tiltrotors lives in the fact that more than half of the Brazilian helipads are over buildings and restricted to a maximum weight of 5 ton. The AW 609 will have an expected empty weight of 5,125 kg. The origin-city and the five destinations have helipads and surroundings that support a safe operation of the AW 609 and helicopters of the same gross weight.

Heretofore the tiltrotor maintenance data are not completely defined by the manufacturer. So, the analysis of maintenance costs of all means of transport chosen are not detailed herein. Garage and pilots or drivers costs are discarded. Only the fuel consumption is included in the cost analysis. The chosen vehicles carry seven to nine passengers with the comfort that the target audience requires. For this comparison the transport media are shown in Figures 3 to 6.



Figure 3 – Mercedes Benz Sprinter – executive version (MERCEDES, 2012)



Figure 4 – Embraer Phenom 300 (EMBRAER, 2008)



Figure 5 – Agusta Westland 109 Power (AGUSTA WESTLAND, 2012)



Figure 6 – Agusta Westland AW 609 (AGUSTA WESTLAND, 2012)

Table 2 shows characteristics of the four competitors.

Table 2 – Transport capabilities (AGUSTA WESTLAND, 2010; EMBRAER, 2008; MERCEDES BENZ, 2012)

Vehicle	Model	Data	
		Pax	Cruise Speed (kt)
Automobile	MB Sprinter	9	60
Airplane	Phenom 300	8	383
Helicopter	AW 109 Power	7	147
Tiltrotor	AW 609	9	275

The MB Sprinter would leave Faria Lima Financial Center in São Paulo (FLFC) and arrive at the residential neighborhoods of each city, as, for example, the well-known Lagoa Rodrigo de Freitas in Rio de Janeiro, a high profile place in that city.

The AW 109 Power and the AW 609 would take off from the FLFC's helipad, fly through visual corridors and airways and land on the destinations helipads.

The Phenom 300 option would need to consider ground transportation between the departure/arrive addresses and the executive airports in both cities. This distance could be covered with a private car and driver. For costs calculation it is considered the taxi fees. Therefore, the trip is divided in 3 sections. Section 1 involves the stretch from the FLFC in São Paulo to Congonha's airport. The flight of the Phenom 300 between SBSP and the destination airport is section 2. The taxi from the destination airport to the residential destination is the final section.

In São Paulo, the FLFC is 4,1 NM far from Congonhas airport and the standard taxi fee is USD 3,06 per nautical mile traveled (TARIFA DE TÁXI, 2012). Then, the Phenom 300 would require USD 12 more than the AW 109 and the AW 609 needs for land transportation in São Paulo. The time needed to drive this stretch is 14 minutes (GOOGLE, 2012) with no traffic.

The five destinations have cheaper taxi fees, but the distance from their airport to the best residential neighborhoods are about 6,5 NM and takes about 15 minutes to be performed. One considers for all these cities that the Phenom 300 users would need USD 17 more than the AW 109 and 609 users.

The distance between the chosen points and airports that support the Phenom 300 in these cities is considered as an average, because the client could work near the Congonha's airport, but live in the suburb of the destination, facing even more traffic.

For all the flying options it was considered 15 minutes as step up time. The figure 7 shows the time that the contenders would take to reach the five destinations

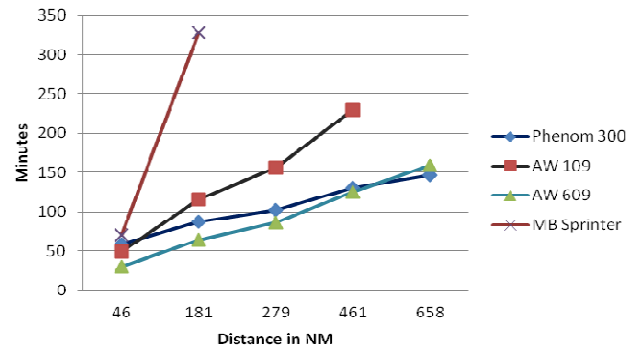


Figure 7 – Time to destinations (based on GOOGLE MAPS, 2012; EMBRAER, 2011; AGUSTA WESTLAND, 2012)

The flights within the terminals are considered with 180 kt for both the Phenom 300 and the AW 609 and with 80 kt to the AW 109 due to traffic sequencing and Brazilian corridors speed limits.

The ground transportation and the speed restrictions explain why the jet is slower than the tiltrotor and the helicopter in the 46 NM trip. In the range between 181 and 461 NM, the jet is faster than the helicopter, but still takes more time than the tiltrotor. Only in the 658 NM trip the jet speed could recover the 29 minutes lost in ground transportation.

The time that the MB Sprinter takes for distances over 181 NM are included in Figure 7, but it takes over 6 hours to Belo Horizonte, 12 hours to Brasília and 22 hours to Salvador.

The AW 109 was not considered an option for Salvador, since its maximum range doesn't reach that far.

The cost is calculated using only the fuel consumption in cruise regime, according to each manufacturer. In the tiltrotor case, Agusta Westland Brazil responded that performance data are not available yet. To perform the match, it is considered the hypothesis that the fuel flow of the tiltrotor's PT6C-67A engine in maximum cruise speed at ISA (International Standard Atmosphere) has the same value found in the AW 139 which uses the PT6C-67C engine.

Figure 8 presents the results in USD spent on fuel to each mile traveled by the four transport media.

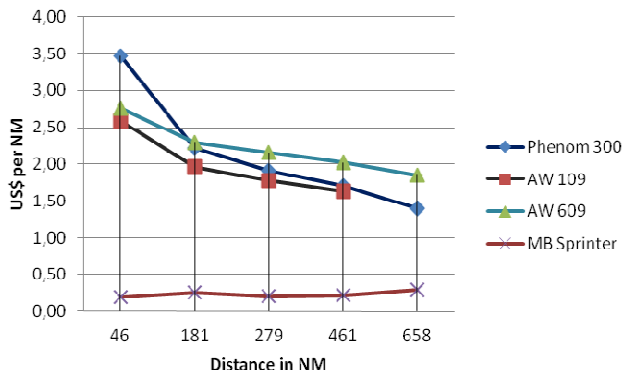


Figure 8 – Cost per mile to each destination (based on GOOGLE MAPS, 2012; EMBRAER, 2011; AGUSTA WESTLAND, 2012)

From Figure 8, one can say that the car solution is, by far, the most affordable, followed by the AW 109. The short trip to Campinas is cheaper in the tiltrotor than in the jet, but for the other destinations the AW 609 is the most expensive option.

The cost of the tiltrotor is higher than the second more expensive in 3% to Rio de Janeiro, 13% to Belo Horizonte, 19% to Brasília and 32% to Salvador.

Summarizing both time and cost variables, one can see that the car option is the cheapest by far, but requires an amount of time that people with expensive working hours usually are not up to spend. The only distance where the car should be considered is the Campinas destination, where the whole trip would take 71 minutes.

The helicopter is the cheapest flight solution, but needs significantly more time than their counterparts for trips over 181 NM.

The jet solution has its flight time much hampered by the necessity of using additional land transportation in both cities. It is noteworthy that, even adding the fuel consumed by aircraft with a value of two taxi rides, the final cost for the set (taxi + plane + taxi) is cheaper than the tiltrotor's.

The tiltrotor has up to 32% higher cost than the second most expensive option, but accomplished the objective faster than any other for distances shorter than 461 NM.

In the presented analysis, traffic delays are not computed, but it is known that the rush hour would affect seriously the car and jet solutions, mainly when within the cities, bringing stress to the client.

Likewise, the Brazilian deficient airport infrastructure would result in difficulty about getting a slot to take off with the Phenom 300, and a delay in the flight authorization before taxi, traffic in the taxiway and flight at slow speeds for traffic sequencing within the terminals are highly probable to be present.

Maximum speed can not be used by the car because the highway speed is limited to 120 km/h. Both jet and tiltrotor are limited to a speed of 180 kt inside the visual corridors and a similar speed during approach. The helicopter's speed using their visual corridors are to be limited to 80 kt.

Therefore, the tiltrotor is the most appropriate option for those who need to move quickly and can afford a higher cost in distances up to 279 NM. In travels farther than that, jets can perform them cheaper spending the same time.

The value that the target audience gives to their time and other individual needs of the users will define if the time savings will worth the additional cost of this new type of transportation.

3. SAFETY

There are no statistics of safety with civilian tiltrotors yet but they are expected to be similar to those of other aircraft, fixed or rotary-wing, since it will be certified by the same regulatory agencies.

This goal will be achieved only if the training of flight and maintenance crew is properly implemented.

It must be proved that there are no additional risks associated with the tiltrotor operations on high helipads (on the tops of buildings) as compared with those currently done with helicopters.

The consequences of a crash of a tiltrotor over the city must be also studied by the CENIPA (Centro de Investigação e Prevenção de Acidentes Aeronáuticos), the Brazilian aeronautics investigation and accident's prevention center. CENIPA will define the best method for the initial action after an accident involving this new type of aircraft happens.

Essentially, in safety terms, the car option is more vulnerable than the aircrafts analyzed herein, according to the Brazilian statistics of accidents on the air or in federal highways (SEADE, 2011).

4. AIR SPACE

Assuming that the tiltrotor option can take advantage over the other aircraft, i.e., avoiding the three airports of São Paulo city, using helipads already approved for the operation of helicopters that have its same gross weight, an analysis of airspace in the São Paulo's Terminal area (Figure 9) must be done. This terminal has Instrument departing (SID) and arrival (STAR) profiles (ICEA, 2011) and the visual corridors must avoid the IFR path.

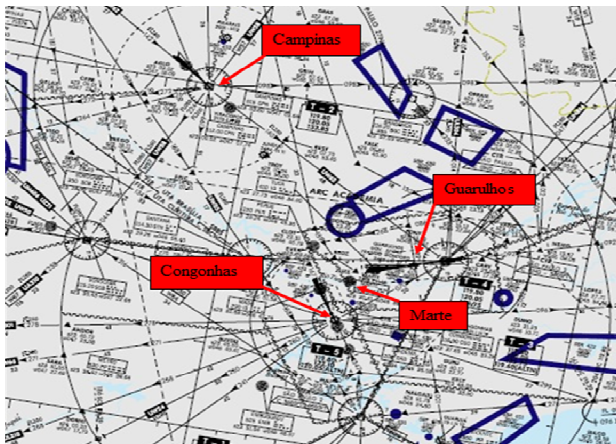


Figure 9 - São Paulo's Terminal (BRASIL, 2011)

That's why this terminal also has:

- REA - Visual Aircraft Routes (Figure 10): Trajectories of VFR (Visual Flight Rules) supported by geographical points and visual landmarks, listed as a reference for the guidance of VFR aircraft, arranged so as not to interfere in the IFR (Instrument Flight Rules) procedures of Congonhas, Guarulhos and Campinas (BRAZIL, 2010).

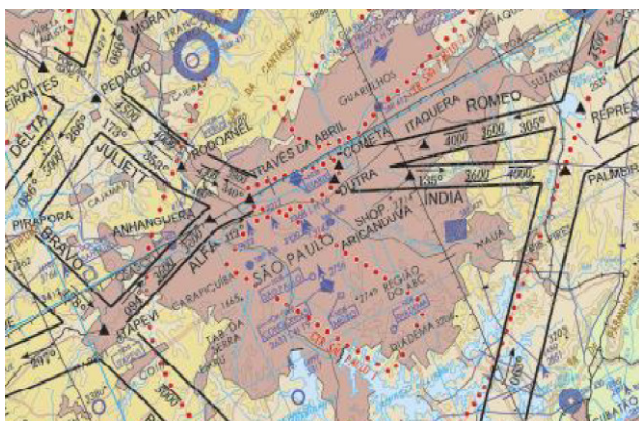


Figure 10 – Airplane corridors (BRASIL, 2010)

- REH - Special Helicopters Route (Figure 11): It is an established route for the purpose of allowing VFR flights of helicopters under specific conditions (BRAZIL, 2010), including the restriction to 80 kt as maximum speed. Near Congonhas airport, there is a unique system called Helicontrol, that is and station

at the control tower exclusive for helicopters traffic. Every take-off from helipads in this area need to be authorized and demands a transponder code.

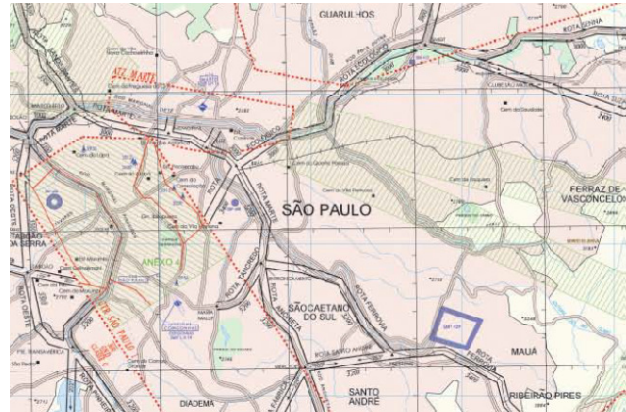


Figure 11 – Helicopters visual corridors (BRASIL, 2010)

In the case of instrument approximation and landing, the tiltrotor could approach to an airport in IFR and, when in visual meteorological condition (VMC), there could be a transition to VFR, following the visual corridors.

It is expected that the creation of specific corridors for the tiltrotor would be impossible in a dense airspace like São Paulo's.

Therefore, the tiltrotor would use the existing helicopter or fixed-wing aircraft corridors. Flying in the REH would reduce its efficiency because the engines would not be completely tilted forward.

On the other hand, the great versatility of tiltrotors brings difficulty in the division of visual corridors with other fixed-wing aircraft because they will operate from helipads and the corridors leads to airports.

Initially, the tiltrotors would use the REA to avoid the restrictions of the REH, but it would fly directly from the helipad to the closest visual reference on the visual corridors. In this case, it should change the radio frequency from the Helicontrol to the common control in this transition.

A discussion is needed on the standards for VFR flight, which can be provided in the ICA 100-12 – Regras do Ar ou Serviços de Tráfego Aéreo (BRASIL, 2009) - or in the ICA 100-4 - Regras e Procedimentos Especiais de Tráfego Aéreo para Helicóptero (BRASIL, 2007), the first applied to fixed-wing aircraft and the other to helicopters. These two instructions treat differently the separation between aircraft, weather minima and distance to obstacles along the routes.

The National Civil Aviation Agency – Agência Nacional de Aviação Civil (ANAC) and the Department of Airspace Control – Departamento de Controle do Espaço Aéreo (DECEA) will study the standards set by the FAA, including specific rules and limits for tiltrotors flying over residential areas, due to the blast of the rotors and the noise emission.

5. CONCLUSION

This study compares the tiltrotor, which will soon enter in the business aircraft market, with its main competitors in the task of executive transportation between the city of São Paulo and other five great Brazilian cities.

The study shows that the tiltrotor option can perform the path chosen in less time for distances up to 461 NM, having, on the other hand, a higher fuel cost as compared to the other transportation options with similar capacity, leaving to the consumer prioritization between time and cost.

It is also found that the flying rules that the tiltrotor will obey must be defined by ANAC and DECEA in order to guarantee the effective use of the tiltrotor.

Once the statistics of civil tiltrotor aircraft operations are available, data about the flight safety, pilot training and operational and maintenance cost will strengthen the analysis presented here.

6. REFERENCES

1. AGUSTA WESTLAND. <http://www.agustawestland.com/product>. 06-27-2012
2. AGUSTA WESTLAND. Mediagallery. <http://www.agustawestland.com/mediagallery/> 06-26-2012.
3. BELL HELICOPTERS. V-22 Osprey Guidebook (2011). http://www.bellhelicopter.com/mungoblobs/919/124/en_v-22_guidebook.pdf. 11-19-2011.
4. BRASIL. Departamento de Controle do Espaço Aéreo. Aic n 05/10. Circulação VFR de aeronaves nas CTR-SP1, CTR-SP2, CTR-KP, ATZ-MT e sob a projeção vertical da TMA São Paulo. Rio de janeiro, 2010. 35p.
5. BRASIL. Departamento de Controle do Espaço Aéreo. Aip Map. Carta de área Rio/São Paulo. Rio de janeiro, 2011.
6. BRASIL. Departamento de Controle do Espaço Aéreo. ICA 100-4. Regras e Procedimentos Especiais de Tráfego Aéreo para Helicóptero. Rio de Janeiro, 2007. 31p.
7. BRASIL. Departamento de Controle do Espaço Aéreo. ICA 100-12. Regras do ar e Serviços de Tráfego Aéreo. Rio de Janeiro, 2009. 283p.
8. EMBRAER. PHENOM 300 (2012). <http://www.embraerexecutivejets.com.br/portugues/content/aircraft/phenom300_home.asp>. 06-27-2012.
9. Estados Unidos. National Aeronautics and Space Administration (NASA) . The history of the XV-15 tilt rotor research aircraft: from concept to flight. Washington, 2000. 211p.
10. GOOGLE. Google maps (2012). <<http://www.google.com.br/maps>>. 06-27-2012.
11. INSTITUTO TECNOLÓGICO DA AERONÁUTICA. OPERAÇÃO COM *TILTROTOR* EM CAPITAIS BRASILEIRAS. São José dos Campos (2011).
12. SÃO PAULO. Fundação Sistema Estadual de Análise de Dados (2011). <<http://www.seade.gov.br>>. 11-20-2011.
13. TARIFA DE TÁXI. Calculador de tarifa de táxi (2010). <<http://www.tarifadetaxi.com>> 03-13-2012.