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Assessing Electric Vertical Take-Off and Landing for Urban Air Taxi Services: Key Parameters and Future Transportation Impact

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Abstract: Urban air mobility (UAM) enabled by electric vertical take-off and landing (eVTOL) aircraft presents an innovative transportation system for mega-cities. An analysis of the techno-economic feasibility of eVTOL air taxis can provide insights into the development and potential impacts of this emerging mobility solution. This study examines eVTOL configurations and proposes a conceptual model for eVTOL air taxi services. A generic cost–revenue model is developed to evaluate the economic feasibility using the rate of return-on-investment approach. Two critical parameters are identified—maximum voyage and price per kilometer. The modeling analysis shows that eVTOL air taxis can achieve a positive rate of return given realistic assumptions on the critical parameters. Reductions in operating costs and increases in maximum voyage range improve financial viability. With technological advancement, eVTOL air taxis are expected to transform urban transportation by increasing capacity and flexibility. The techno-economic analysis provides useful implications for urban planning and policy regarding this innovative mobility mode.

Keywords: urban air mobility; air taxi service; techno-economic feasibility; generic revenue; operating cost modeling; urban transportation; mobility solution

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1. Introduction

Urban transportation is facing severe challenges due to rapid urbanization, population growth, and increasing vehicle ownership. In mega-cities such as Beijing, Shanghai, Hong Kong, and London, traffic congestion has become a major problem, leading to longer travel times, reduced safety, environmental pollution, and decreased quality of life for urban residents. Moreover, the capabilities of emergency services, such as medical rescue and fire-fighting, are also compromised by congested roads [1]. According to a report by the Texas A&M Transportation Institute, traffic congestion in the United States caused an estimated 8.8 billion hours of delay and 3.3 billion gallons of wasted fuel in 2019, resulting in a total cost of USD 179 billion [2].

Efforts to alleviate urban traffic congestion through innovations in ground and underground transportation, such as building "cloud rail", placing shared bikes, and expanding metro lines, are limited by various factors, including the original geographical environment of the city, urbanization, economic development, time consistency in human activities, outdated road facilities, and insufficient parking spaces [3–6]. To address these limitations, governments and companies are exploring the potential of urban air mobility (UAM) using electric vertical take-off and landing (eVTOL) aircraft [7].

eVTOL aircraft combine the vertical lift capabilities of helicopters with the efficient cruise performance of fixed-wing aircraft, enabling flexible and efficient urban air commuting [8]. These vehicles use electric vectored thrust for vertical take-off and landing, as well as transitioning from vertical to horizontal thrust [9]. The development of eVTOL technology is driven by advancements in distributed electric propulsion, batteries, and automation systems. Currently, over 200 companies worldwide are working on the development of eVTOL vehicles for passenger transportation, often referred to as UAM or advanced air mobility (AAM) [7].

The adoption of eVTOL as an emerging transportation mode offers several advantages over traditional ground transportation, including reduced travel time, lower infrastructure requirements, increased travel safety, improved talent flow, and operational benefits [10]. eVTOL aircraft can choose shorter and more flexible routes in complex urban air traffic networks, operating at different levels to ease congestion, reduce delays, and ensure timely arrival. Figure 1 summarizes the main changes in urban transportation between the current traffic age and the eVTOL age.

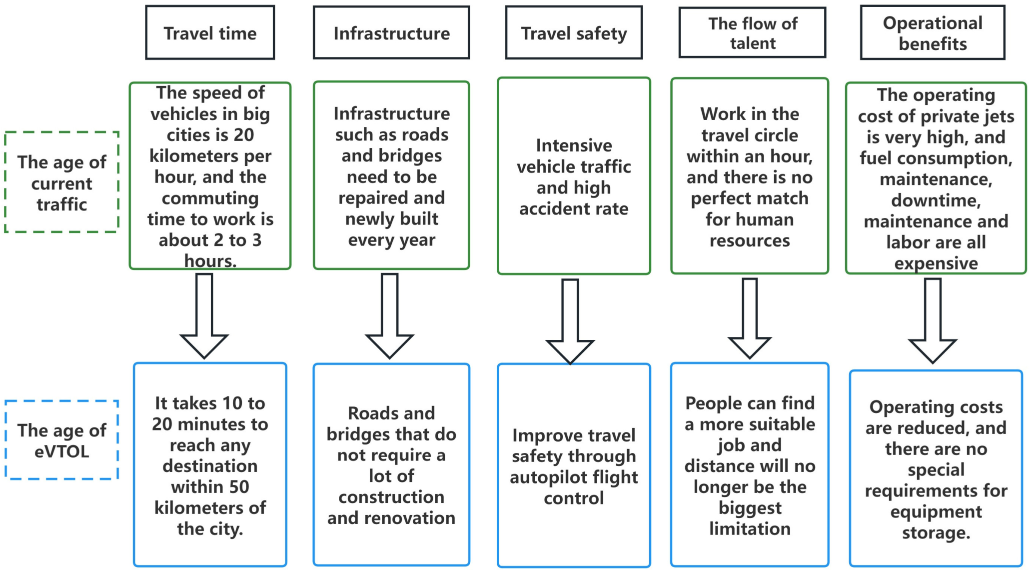


Figure 1. The main changes from current traffic age to the eVTOL age.

However, the deployment and adoption of eVTOL for UAM face several potential barriers and challenges. The technology has not been fully verified, and eVTOL aircraft cannot spin down if they lose power [11]. Additionally, battery capacity limitations result in shorter range and endurance, as well as lower load capacity [11]. While eVTOL technology has the potential to reduce the cost of design, manufacturing, and operation due to its distributed electric propulsion technology, its development is limited by the current level of battery technology and application environment [11].

The study addresses the following research questions. RQ1: How does the potential effect of eVTOL compare to that of helicopters and car taxis when applied to urban transportation in the future? RQ2: What are the characteristics of existing eVTOL configurations, and how can we establish a model and system by screening according to these characteristics? RQ3: Using numerical simulations and realistic assumptions on parameter values, how can we establish a quantitative analysis of the economic feasibility of eVTOL based on the equations for the rate of return on investment (ROI)?

The workflow of the study is shown in Figure 2.

The remainder of this study is structured as follows: Section 2 discusses the related work and how our work differs. Section 3 presents the model and results, mainly focusing on determining the maximum range and take-off and landing price. Section 4 discusses the implications of the findings. Finally, Section 5 summarizes the research with conclusions.

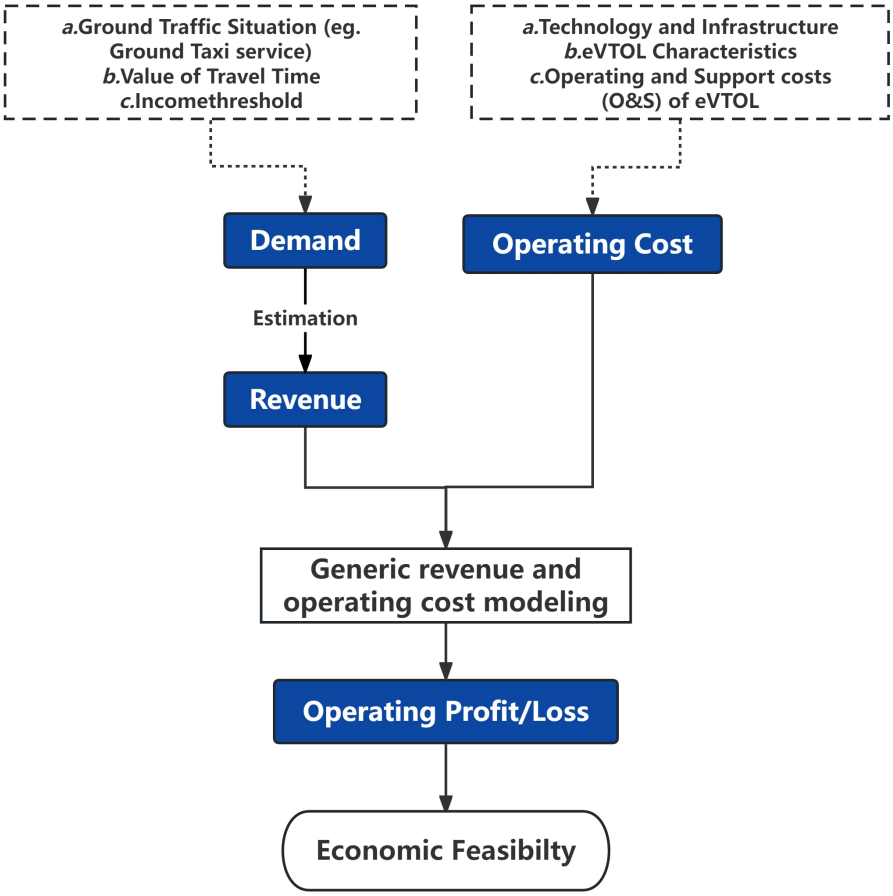


Figure 2. The workflow of the study.

2. Literature Review

2.1. Establishing a New Transportation System in Upper Urban Space

Establishing a new transportation system in upper urban space holds promise for addressing major urban transport challenges. Due to the mobility revolution, urban transport faces issues like emission reduction, congestion, and noise pollution. While alternatives to road vehicles, such as metro systems [2,12] and shared bicycles [13,14], and optimization of the existing road vehicle operations through intelligent traffic signal systems [15,16] have been proposed, these ground-based solutions face constraints due to the saturation of urban surface and underground spaces [1,6]. Few studies fundamentally solve the limitations of ground transportation space. Therefore, utilizing new space in the urban sky through modern transport technology, particularly electric vertical take-off and landing (eVTOL) aircraft, is a promising approach to establishing an upper urban space transportation system.

2.2. The Potential Effect of eVTOL

Questions regarding the actual application effect, potential hurdles, and economic and technical constraints of eVTOL remain to be explored [17–19]. Studies have shown that the potential of urban air mobility (UAM) to improve travel conditions is limited in urban areas with extensive road infrastructure and public transport networks, but it could offer more benefits in particular areas such as mountainous, island, and densely populated urban agglomeration regions [20,21]. Additionally, the introduction of UAM may lead to welfare gains for high-income households but welfare losses for low-skilled households [22,23]. Currently, eVTOL is a developing urban travel model, more akin to a customized service similar to tailored taxi services. There are insufficient data and literature support for the claim that eVTOL can alleviate urban traffic pressure and solve urban traffic congestion [24] (Figure 3).

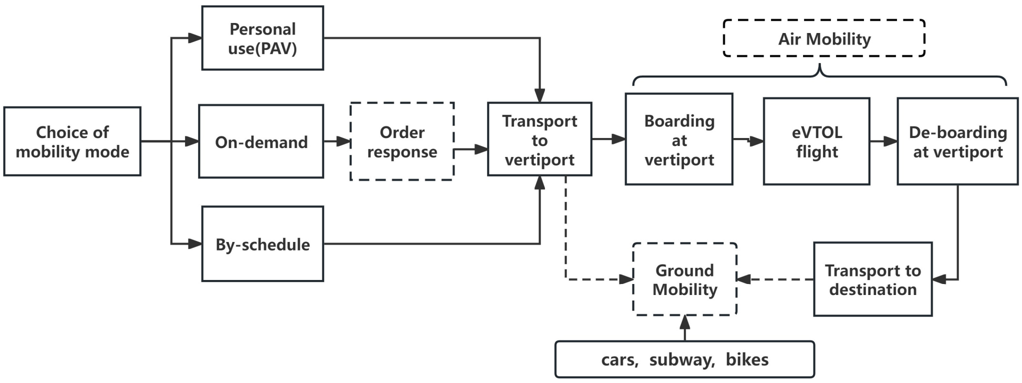


Figure 3. Total process of customer journey using the eVTOL aircraft.

2.3. Engineering Application and Economic Feasibility

Most of the literature analyzes eVTOL feasibility from an engineering perspective, proving that eVTOL aircraft can operate under certain technical conditions [25–31]. However, economic feasibility relies on mathematical modeling [32–38]. A deeper understanding of these parameters is needed to combine engineering feasibility with cost–benefit analysis and provide a more accurate and objective economic analysis [36].

2.4. Modeling of eVTOL Configurations

eVTOL configurations can be classified based on lift characteristics [39] or time to market, travel speed, and routes [10]. The optimal eVTOL configuration depends on the mission [40]. While some research has modeled eVTOL configurations, the analyses are not comprehensive enough due to non-uniform classification methods, limited modeled configurations, and insufficient data. More comprehensive modeling is needed to truly understand optimal configurations for different missions.

2.5. eVTOL Flying Mechanisms

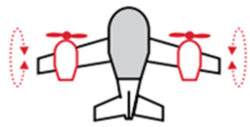
eVTOL aircraft can be distinguished based on their flying mechanisms, which have been analyzed by various organizations and researchers [10,36,39]. In the future, eVTOL aircraft could undertake both intracity and city-to-city transportation missions, with different characteristics and competitors for each type of mission [10]. The comparison between eVTOL's intracity transportation and its future expansion and application to city-to-city transportation can be summarized as in Table 1.

Table 1. Intracity and city-to-city trips of eVTOL aircraft.

Type	Intracity	City-to-City
Graphical representation		
Flight distance	About 20 km–50 km	About 100 km–400 km
Aircraft	Vertical take-off and landing	Vertical take-off and landing and short take-off and landing
Competitors	Taxi, car, urban public transport	Car, train, plane

eVTOL aircraft can be distinguished based on their configuration. The American Vertical Flying Society (VFS) [39] and Porsche Consulting [10] distinguish eVTOL configurations based on their flying mechanisms. The full set of flying mechanisms has been analyzed by VFS, Porsche Consulting, and Rajendran [36]. Table 2 characterizes and illustrates four flying mechanisms.

Table 2. Flying mechanisms.

Flying Mechanisms	Description	Illustration
Vectored thrust	An aircraft has wings, and any other vector thruster provides both lift and cruising. The methods of achieving vector thrust include but are not limited to tilting wings, tilting rotors, and tilting ducts	
Lift and Cruise	An aircraft has organic wings, and independent propellers provide lift and help cruise. When cruising, the aircraft relies on the wings instead of the propellers to provide lift	
Multi-copter (Multi-rotor)	An aircraft has multiple rotors, no wings, or short wings, and the aircraft also relies on propellers to provide all or part of the lift when cruising.	
Single-copter (Single-rotor)	An aircraft has a single rotor, no wing, or short wing. The aircraft also relies on the propeller to provide full lift when cruising, such as an electric helicopter or an electric auto rotor	-

3. Results

3.1. Determining Total Operating and Support Costs

The study determines the total operating and support costs (O&S) of an air taxi service by using eVTOL based on the total Cost Per Flight Hour (CPFH) metric, which is derived by dividing the total O&S costs by the aircraft utilization [23] and operation cost parametrically estimated by Bell Helicopter Textron, Inc. [41] and Financhill [42]. The categories of O&S in this study are divided into two objective parts: direct and indirect, which based on the classification result provided by Villa [43]. The cost drivers of the direct operating cost category are fuel (for eVTOL, it is electricity), maintenance, aircraft ownership or lease, landing fee, and aircraft insurance. The costs budgeted under the indirect category include costs incurred by the airline that are not directly related to the flight activities but those that must still be paid to ensure success and profitability [43]. These costs include marketing, ground staff at airports served, and other administrative costs. Figure 4 shows the categories of O&S that will be explored in this study.

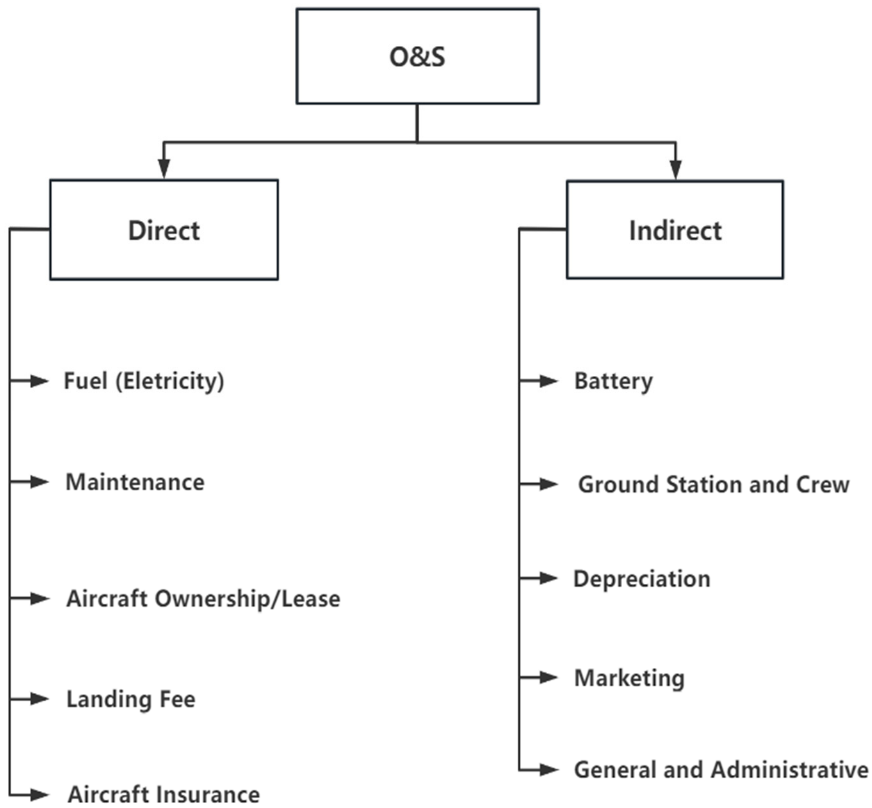


Figure 4. O&S Categories.

3.2. Generic Revenue and Operating Cost Modeling

The research object of the economic assessment in this study is intracity urban air mobility (single flight mission range is roughly 20–50 km) by using eVTOL. As for the city-to-city transportation (single flight mission range is roughly 100–400 km) of eVTOL, it is not considered within the scope of this assessment. The rate of return on investment (ROI) refers to the ratio of the total net revenue of the investment scheme in a normal year after reaching a certain designed production capacity to the total investment of the scheme. It is a static indicator for evaluating the profitability of an investment scheme, indicating the annual net income created by the unit investment in the normal production years of the investment scheme.

In this study, the economic feasibility refers to the same amount of money if the rate of return on investment in an air taxi service is higher than the rate of return on the savings service in investing the money directly to the risk-free government bonds, then it can basically prove that the air taxi service is profitable, that is, it is economically feasible.

The model for the profit rate of return on investment in an air taxi service by using eVTOL aircraft is based on the equations for the rate of ROI in economics as shown in Equation (1).

$$\omega_{eVTOL} = \frac{revenue_{eVTOL} - Cost_{Dirct} - Cost_{Indirect}}{Cost_{Total}} \times 100\%. \quad (1)$$

In the equation, ω_{eVTOL} is the value of ROI of an air taxi service by using eVTOL aircraft; $Cost_{Direct}$ is the direct O&S of an air taxi service by using eVTOL; $Cost_{Indirect}$ is the indirect O&S of an air taxi service by using eVTOL; $Cost_{Total}$ is the total cost of investing in an air taxi service by using eVTOL aircraft; and $revenue_{eVTOL}$ is the operating revenue of air taxi services by using an eVTOL aircraft.

An air taxi service (ATS) is an aerial on-demand transport mode for a single passenger or a small group of passengers, which aims to transform the method of everyday commutes [36]. The role that eVTOL aircraft play is similar to the traditional ground taxi service.

However, since the eVTOL aircraft is still in the initial testing stage, it has only been tested in a small range in some large airshows and specific areas and has not been commercially put into use.

Consequently, it is very difficult to directly predict the value of $revenue_{eVTOL}$ by using the operational data of eVTOL aircraft. Therefore, alternative methods should be used for analysis in forecasting.

$$revenue_{eVTOL} = \lambda W M_p, \tag{2}$$

where

$$\mathrm{M}_p = \frac{price_{eVTOL}}{price_{car}}, \tag{3}$$

$$\lambda = \frac{Flow_i}{\sum_{i=1}^{n} Flow_i}, \tag{4}$$

λ is the ratio of high-speed rail passenger flow to the total railway passenger flow between two points; W is the total revenue of ground taxi services at a certain area range; M_p is the ratio of the price of an eVTOL service per flight to the price of a car taxi service per trip; $price_{eVTOL}$ is the price of eVTOL per kilometer; and $price_{car}$ is the price of a car taxi per kilometer.

$$Cost_{up-front} = Cost_{vehicle} + Cost_{Infrastructure}, \tag{5}$$

$Cost_{vehicle}$ is the money spent on purchasing or leasing the eVTOL aircraft and spare parts matched to them; $Cost_{Infrastructure}$ is the total cost of the infrastructure development in investing in the air taxi service by using eVTOL aircraft; and $Cost_{up-front}$ is the up-front investments required to complete the air taxi service.

More specifically, the study defines $Cost_{Direct}$ and $Cost_{Indirect}$ into several categories for subsequent processing based on the classification of Figure 4. The model would become two versions there.

3.2.1. Model Version 1

The model version 1 is based on the specific data of the eVTOL configuration and the equation of the model is shown below:

$$Cost_{up-front} = Cost_{vehicle} + Cost_{Infrastructure}, \tag{6}$$

In the Equation (6), $Cost_{Direct}$ is represented by $Cost_{Flight}$. $Cost_{Flight}$ is the direct O&S of eVTOL flights within a period; $Cost_{Indirect}$ is considered as three objective categories in this study, which are $Cost_{Crew}$, $Cost_{Battery}$, and $Cost_{Depreciation}$. $Cost_{Depreciation}$ is the total depreciation cost of the total vehicle fleet; $Cost_{Crew}$ is total wages for the eVTOL ground crew within a period; and $Cost_{Battery}$ is the battery acquisition cost of typical eVTOL batteries to fulfill the needs of the flight missions within a period.

As for $Cost_{Flight}$, MIT16.887-EM.427 [35] created the specific mathematics model based on the Breguet Range Equation. The model considers the relationship among the cost per hour of crew wages supporting the air taxi service, an amortized unit cost, and the energy cost of the flight, and the specific form is shown in Equation (7).

$$Cost_{Flight} = \frac{Cost_{vehicle}}{n \cdot lifetime \cdot flights} + Cost_{crew/hr} \cdot (t_{take-off} + t_{landing} + \frac{V_{cruise}}{R_{trip}}) + Cost_{energy} \cdot E_{flight}, \tag{7}$$

where

$$E_{flight} = \sqrt{\frac{\frac{T^3}{T_i}}{2\rho A}} \cdot \left[t_{take-off} + t_{landing} + \frac{R}{\eta_{total} \frac{1}{g} \cdot \frac{L}{D} \cdot \frac{m_{battery}}{m_{total}}} \right], \tag{8}$$

In the two equations above, E_{flight} is the specific energy consumption of the battery system, η_{total} is the overall efficiency, L is lift, D is drag, m is mass, T is thrust, T_i is a scaling factor depending on propulsor type, ρ is air density, and A is the disk actuator area.

Equation (1) expresses the investment return rate of using eVTOL, then we substitute Equations (2)–(7) back into the original rate of return-on-investment Equation (1), and it can be turned into

$$\omega_{eVTOL} = \frac{\lambda W M_p - Cost_{Flight} - Cost_{Crew} - Cost_{Battery} - Cost_{Depreciation}}{Cost_{Total}} \times 100\% \quad (9)$$

3.2.2. Model Version 2

Because eVTOL aircraft have only been tested at international aviation exhibitions and in individual regions, there is no real precedent for actual commercial operation, and it is difficult to directly obtain the specific data of certain eVTOL configurations. Fortunately, the direct O&S has already been estimated by other reports.

Therefore, the model version 2 could be shown below.

$$\omega_{eVTOL} = \frac{\lambda W M_p - Cost_{Direct} - Cost_{Crew} - Cost_{Battery} - Cost_{Depreciation}}{Cost_{Total}} \times 100\% \quad (10)$$

where

$M_p = \frac{price_{eVTOL}}{price_{car}}$,

$\lambda = \frac{Flow_i}{\sum_{i=1}^{n} Flow_i}$,

$Cost_{Total} = Cost_{up-front} + Cost_{Flight} + Cost_{Crew} + Cost_{Battery} + Cost_{Depreciation}$.

In the Equation (10), $Cost_{Direct}$ is the direct O&S of an air taxi service by using eVTOL. The parameters of $Cost_{Crew}$, $Cost_{Battery}$, and $Cost_{Depreciation}$ have the same meaning as in Equation (6).

3.3. Model Processing

Since this study lacks the eVTOL configuration-specific data required for calculation of Equations (7) and (8), the model version 2 is used for processing in this section.

3.3.1. Estimating Revenue

The study will select the region of North America, where Uber has the most extensive business coverage density and the most mature service model [44], as the example for calculation.

The revenue of Uber in North America was USD 2.142 billion in Q1 of 2020 [45]. According to the statistics on Uber's official website, there are 289 cities served by Uber in the United States and Canada. As the operating revenue of a specific city has not been found, the study will use the average operating revenue of the region of North America for calculation: the average operating revenue is USD 7,400,000 [46]. The proportion of revenue from the ride-sharing service revenue (USD 2,475,000) as a percentage of total revenue (USD 3,543,000) was calculated as 76%. Therefore, in one city in the area of North America, the revenue from this ride-sharing service is calculated by the ratio of USD 5,624,000 within one quarter.

The price for UAM consisting of a kilometer fee is from 1.75 EUR/km to 5.00 EUR/km [47]. Close to 15% of the respondents always chose eVTOL in the stated preference section of the survey of 2500 commuters living and working in the Atlanta, Boston, Dallas-Ft. Worth, San Francisco, and Los Angeles areas [18], which shows that the revenue to be calculated is a conservative estimate. Table 3 can be obtained by combining the above information and data.

Table 3. Model parameters in a quarter.

Notation	Description	Value	Literature	Source
$price_{eVTOL}$	Price of eVTOL per km.	5.1 USD/km	1.75 EUR/km to 5.00 EUR/km (1.8 USD/km to 5.1 USD/km)	[47]
$price_{car}$	Price of car taxi per km	3.7 USD/km	1.17 USD/km to 3.73 USD/km	[48]
W	Average operating revenue of car taxi in a certain city in North America	USD 5,624,000	USD 5,624,000	[46]
λ	See preference section of the survey	15%	15%	[18]
M_p	Ratio of the price of eVTOL per flight to the price of car taxi per trip	USD 5.1/USD 3.7		[47,48]

According the data and information in Tables 2 and 3, applying Equation (2), $revenue_{eVTOL}$ can be calculated as below,

$$revenue_{eVTOL} = \lambda W M_p = 15\% \times \$5.624 \times 10^6 \times \frac{\$5.1}{\$3.7} = \$1{,}162{,}800 \tag{11}$$

3.3.2. Estimating O&S

For this assessment, the up-front investment of the air taxi service by using eVTOL aircraft was assumed to be USD 1,200,000 [35]. The repeatability of flights will be significant to maximizing throughput and profit, and the vehicle must be able to operate continuously for at least 3 h while flying 25-mile (about 40 km) missions at the end-of-life state of the battery to achieve 10 times the missions [45]. Based on mission's flight requirements, eVTOL could complete multiple flight missions in a certain period of time. This study assumes that eVTOL would fulfill mission requirements for 18 h (the other 6 h are for daily overhaul and maintenance) and the cumulative number of flights per day is 60. A designed single-leg mission of a UAM service with an emergency diversion segment is shown in Figure 5.

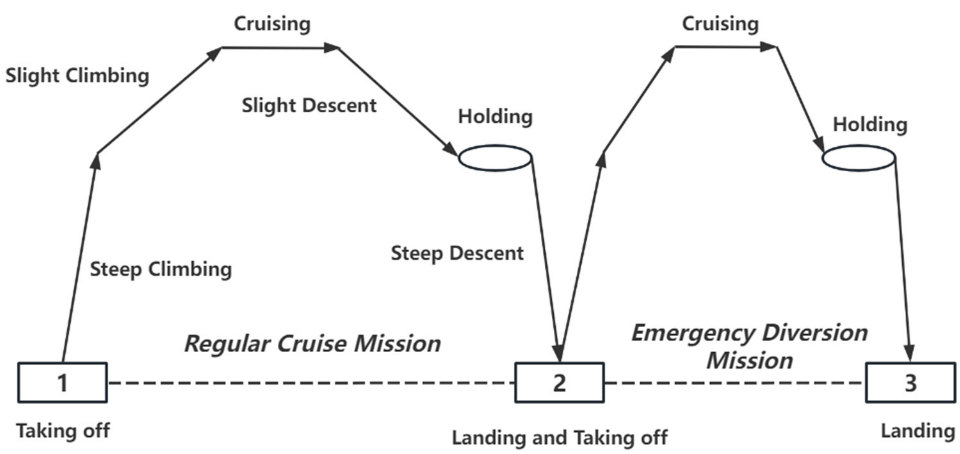


Figure 5. Leg design of mission of a UAM service with emergency diversion segment.

Combining the diagram of Figure 5 and mission flight requirements [45], the time allocation for a single regular cruise flight mission can be summarized in Table 4.

Table 4. Time allocation for single regular cruise flight mission.

Mission Stage	Cost of Time
Taking-off	About 1 min
Cruising	About 10 min
Landing	About 1 min
Positioning/Plug-in electric	About 0.5 min
Recharging on the ground	About 6 min
Battery pull/Positioning	About 0.5 min
Overall	About 19 min

According to Table 4, the ground crew is working during all the periods of the mission except the period of Cruising, with the working time of the mission being 9 min. Hourly wages for the eVTOL operator are assumed fixed at USD 150 [23].

$Cost_{Direct}$ has already been estimated, and at industry inception, the cost to travel by eVTOL aircraft in urban areas is likely to be greater than USD 2.5/km [49].

As for the $Cost_{Depreciation}$, the vehicle depreciation was assumed constant at 10% of the total vehicle fleet's asset value [24]. No other deprecation costs were modeled.

As for the $Cost_{Battery}$, the battery acquisition cost based off the 140 kWh rating for a typical eVTOL aircraft in Uber Elevate [24] is priced at 400 USD/kWh for batteries with a year-on-year 4% cost reduction over the time-frame. Due to the limitation of the maximum range of the eVTOL aircraft, in order to complete the flight mission, the battery needs to be swapped to ensure the repeatability of flight missions. Therefore, this study calculates the additional number of batteries to fulfill the requirements of flight missions, and the calculation equation is shown below:

$$N = \frac{400 - Range_{eVTOL}}{Range_{Mission}}, \tag{12}$$

Notes:

eVTOL aircraft would undertake 10 missions to finish 400 km within 3 h.

N is the additional number of batteries to fulfill the requirements of flight missions (the results are rounded off); $Range_{eVTOL}$ is the maximum range of different eVTOL configurations; and $Range_{Mission}$ is the flying range per mission (40 km). The calculated value in this assessment is the cumulative number of flights within one-quarter of eVTOL.

3.4. Maximum Voyage of eVTOL Flying Mechanisms

The flight voyage per mission is an important parameter in the mathematical model. Therefore, this study uses the maximum voyage of eVTOL configurations as a variable parameter to analyze the adoption situation of three eVTOL flying mechanisms and substitutes the actual voyage data collected from Table 3 into Equation (10) to obtain the calculation results. As already explained in the model preliminary calculation (Section 3.3), the other parameter values remain the same value.

Figure 6 presents a scatter diagram with ROI as the horizontal axis and voyage (in kilometers) as the vertical axis. Exponential and linear regression analyses were conducted on the scatter diagram to investigate the relationship between ROI and the maximum voyage of different eVTOL configurations.

Based on the analysis of Figure 6, the following conclusions can be drawn:

(1) When adopting the average range of all eVTOL configurations currently on the electric aviation market, the modeling results preliminarily show that an air taxi service using eVTOL aircraft can be profitable after commercial operation. The return on investment is considerable, with an estimated ROI of about 0.8% in a quarter and 3.2% in a year.

(2) For vectored thrust and lift and cruise configurations, the average range yields an ROI greater than zero, indicating profitability. The lift and cruise mechanism demonstrates particularly good performance in commercial operation. The estimated ROI for

vectored thrust is 0.3% in a quarter and 1.2% in a year, while for lift and cruise, it is 4.6% in a quarter and 18.4% in a year. For these configurations, rapid battery charging technology could be applied to improve flight operation efficiency.

(3) For multi-copter and single-copter configurations, the ROI is lower than zero, suggesting a lack of profitability. The voyage range of the multi-copter eVTOL configuration is within 30 km to 55 km. To continue the 40 km per flight mission for multi-copters, battery swapping technology should be implemented after each single flight.

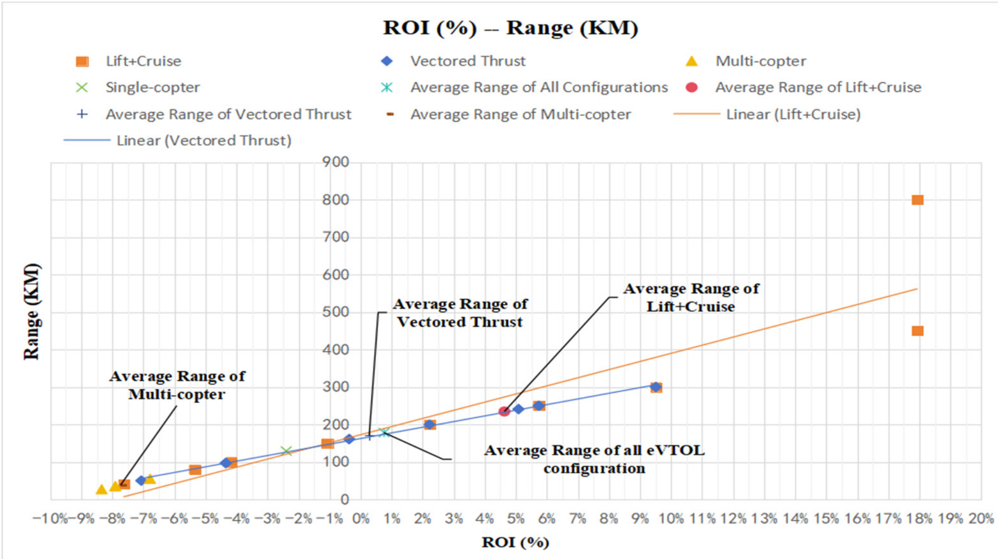


Figure 6. Analysis of the relationship between ROI and maximum voyage of different eVTOL configurations.

These findings provide valuable insights into the economic feasibility of different eVTOL configurations and their potential for adoption in urban air taxi services. However, it is important to note that these results are based on preliminary modeling and may be subject to variations depending on specific operational contexts and technological advancements.

3.5. Price of eVTOL per Kilometer

In this study, the price of eVTOL per kilometer will directly affect the parameter $revenue_{eVTOL}$ of the model. As already explained in the model preliminary calculation (Section 3.3), $price_{Car}$ takes the value in this section of 3 USD/km, and the other parameter values remain the same. Therefore, this study uses 1.8 USD/km to 5.1 USD/km as variable range values analyze the sensitivity of model to obtain the range values of $revenue_{eVTOL}$.

The study takes ROI as the horizontal coordinate axis and the price of eVTOL per kilometer as the vertical coordinate axis to establish the scatter diagram, and then it conducted linear analysis on the scatter diagram to obtain Figure 7.

After analyzing Figure 7, with the increase in the price of eVTOL per kilometer, the ROI is increasing. When the price is greater than 4.1 USD/km, the air taxi service starts to make a profit (ROI > 0). Meanwhile, when the price is less than 4 USD/km, the air taxi service basically has no profit or even has a loss (ROI < 0).

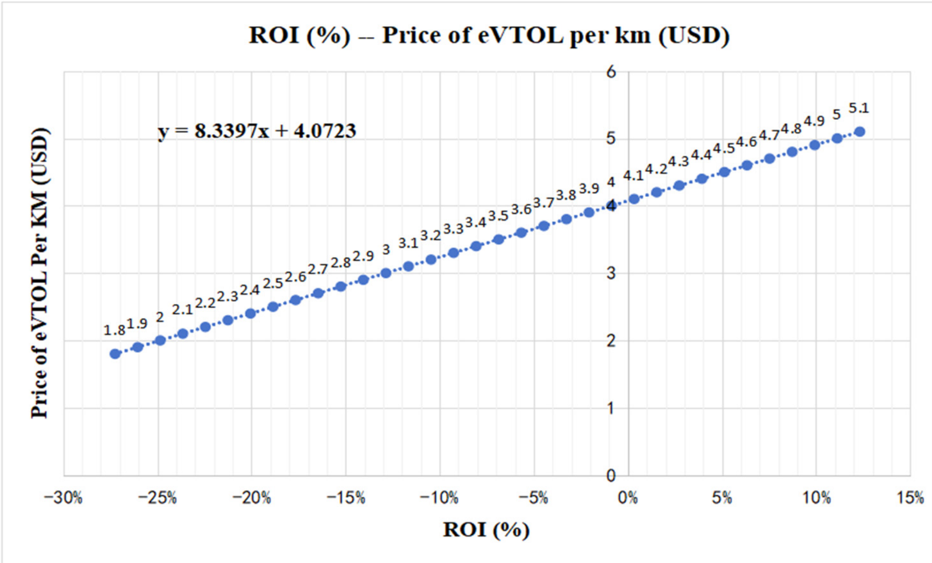


Figure 7. Analysis of the relationship between ROI and price of eVTOL aircraft per kilometer.

4. Discussion

The results of this study indicate that investing in air taxi services using eVTOL aircraft can be profitable, with an estimated ROI of 0.8% within a quarter and 3.2% in a year for the average range of all eVTOL configurations currently on the electric aviation market in a North American city. This finding aligns with previous studies that suggest that UAM could positively affect household welfare in cities [22] and attract investors with attractive returns on infrastructure investment [28,37,38]. However, it is important to note that the estimated ROI in this study may be higher than what can be realistically achieved due to several factors.

Firstly, the market share assumption of 70% for leading ride-hailing companies like Uber [44] might lead to an undervaluation of the revenue estimation in Equation (11). A more conservative market share assumption could provide a more reliable basis for revenue calculation. Additionally, there is a minimum eVTOL adoption rate of 15% among consumers, as estimated in Equation (11). Future research should incorporate a range of market share and adoption rate scenarios to assess the sensitivity of profitability estimates.

Secondly, the comprehensiveness of cost accounting in this study could be further improved. While the lowest estimation of USD 2.5/km is used, the air traffic line, space use, and operation fees that air taxi services would need to pay to relevant departments are not considered, which could be a significant part of future operating costs. Moreover, relevant taxes are not accounted for in this study. A more inclusive cost structure, as demonstrated in other work, would enhance the reliability of the profitability assessment. Future research should also investigate the potential impact of financing costs, such as bank loan interest, on the overall economic feasibility of eVTOL air taxi services.

Despite these limitations, this study makes valuable contributions to the understanding of eVTOL economics and UAM feasibility. The constructed generic assessment framework and the identification of key parameters, such as maximum voyage and price per kilometer, provide a solid foundation for future research. The profitability prospects revealed in this study, though preliminary, offer important insights for industry practitioners and policymakers interested in the development of eVTOL and UAM.

To further advance this research area, several directions are worth pursuing. Firstly, as eVTOL technology matures and commercial operations commence, future studies should aim to obtain empirical data on revenue, costs, and consumer preferences from real-world eVTOL air taxi services. Such data would enable more accurate and reliable economic assessments. Secondly, the external effects of eVTOL adoption, such as impacts on urban transportation networks, environmental sustainability, and social equity, should be thoroughly investigated to provide a holistic view of the benefits and challenges of UAM. Thirdly, the policy and regulatory environment for eVTOL operations should be closely examined to identify potential barriers and enablers for the scalable and sustainable development of UAM.

In conclusion, this study provides valuable insights into the profitability potential of eVTOL air taxi services, while highlighting the need for further research to refine the economic models and address the identified limitations. As eVTOL technology continues to advance, it is crucial for researchers, industry practitioners, and policymakers to collaborate closely in assessing the comprehensive impacts of UAM and designing strategies for its sustainable and equitable integration into urban transportation systems.

5. Conclusions

This study investigates the economic feasibility of air taxi services using eVTOL aircraft by employing generic revenue and operating cost modeling based on realistic parameter value assumptions. The results suggest that investing in eVTOL air taxi services can be profitable, with an estimated ROI of 0.8% within a quarter and 3.2% in a year for the average range of all eVTOL configurations currently on the electric aviation market in a North American city.

The main purpose of this study is to construct a generic techno-economic feasibility assessment framework and analysis paradigm, laying the foundation for subsequent research. This framework covers key factors affecting the economic feasibility of eVTOL, such as operating costs, revenue estimation, return on investment, etc., and proposes corresponding calculation methods and parameter settings. This provides an analytical approach and operational guidance for different cities to carry out empirical research.

The findings contribute to the growing body of literature on the potential impact of UAM on urban transportation and household welfare. However, the study also identifies several limitations, such as the lack of actual revenue data from commercial eVTOL operations, optimistic assumptions regarding market share and consumer preferences, and the exclusion of certain operating costs and taxes from the calculations.

In the future, we plan to select typical cities for case studies, collect actual operational data, and calibrate and optimize the model. We will consider the characteristics of different types of cities, conduct comparative analyses, and explore the application potential and limitations of eVTOL air taxi services in various scenarios. We will also continuously track the latest developments in eVTOL technology and update and expand the analysis framework in a timely manner.

Future research should focus on obtaining more accurate revenue data from specific manufacturers and eVTOL aircraft configurations operating in real-world settings, as well as incorporating a more comprehensive range of operating costs and financial considerations. Additionally, the impact of UAM on urban transportation networks, household welfare, and social equity should be further explored to better understand the potential benefits and challenges of widespread eVTOL adoption.

We believe that through the organic combination of framework construction and empirical research, constantly enriching and improving the economic feasibility study of eVTOL, we can provide more targeted and practical decision-making references for the industry and promote the innovative application of eVTOL in urban transportation.

In conclusion, while this study provides evidence for the potential profitability of air taxi services using eVTOL aircraft, more research is needed to refine the economic models and address the limitations identified. As eVTOL technology continues to develop and approach commercial viability, it will be crucial to carefully assess its economic, social, and environmental implications to ensure the sustainable and equitable integration of UAM into existing urban transportation systems.

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