iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** V **Month of publication:** May 2022

DOI: https://doi.org/10.22214/ijraset.2022.41953

Conceptual Design of 13-Seater STOVL Aircraft for Rural Air Mobility in Nepal *VAAYU YAAN*

Pradeep Kandel[1], Rakesh Kumar Shah[2], Dr. P. Karunakaran[3], Sumit Pandit[4], Ajay Kumar Yadav[5]
[1, 2, 4, 5]*Final Year Student, Department of Aeronautical Engineering, Excel Engineering College (Anna University), Tamilnadu, India*
[3]*Associate Professor, Department of Aeronautical Engineering, Excel Engineering College (Anna University), Tamilnadu, India*

Abstract: At Present, in Aviation industry there is a strong and rapid growing interest in the development of Urban/Rural Air Mobility (U/RAM) networks, which are aerial transportation systems in, and around major metropolitan areas and rural hilly region where less possibilities of operating big passenger aircraft to cover short distance in challenging geographical location. STOVL capabilities for fixed-wing aircraft is one application of this technology. For rural passenger transport missions in remote area of Nepal, it is risky and difficult during landing in Hilly and Himalayan region due to geographic land structure and slope runway to operate big size passenger or cargo aircraft.
Hence, the sole aim of this paper is to present the practical alternative to these problems in the early days of rural air transportation in aviation industries in Nepal. Here, we discuss about the air accidents that occurred in Nepali sky and along with their reason so we decided to try our level best to come up with solution i.e., our proposed design VAAYU🇳🇵YAAN. This paper clarifies the main motive of deploying VAAYU🇳🇵YAAN over conventional aircrafts.
It is designed in a such a way that it can solve the problem of fatal accidents in aerial transportation in Hilly and Himalayan region faced as result of topographical difficulties, slope and small runway issues along with air traffic problems and helps in enhancing the public transportation all over the country for regional mobility due to short takeoff and vertical landing capacity. As a result of this feature, due to less risk in mobilization of aerial vehicle in Hilly and Himalayan places, people across the country will be connected and benefited.
Keywords: VAAYU🇳🇵YAAN, STOVL, Hilly and Himalayan air mobility, Conceptual Design, Topographical challenges etc.

I. INTRODUCTION

A short take-off and vertical landing aircraft (STOVL) is a fixed wing aircraft that can take-off from a short runway and land vertically. Recent years have seen an increase in interest in the development of Urban/ Rural air mobility (U/RAM) networks, which would provide public access to aerial transportation within metropolitan areas and rural places people living in Hilly and Himalayan region of Nepal where no possibilities of operating large passenger aircraft.
Current and future urban and regional and rural air mobility may be implemented using short take-off and vertical landing (STOVL) vehicles.
STOVL aircraft can take off from very short runways (often made of dirt or grass) and land vertically in any topographical region. Reports show that STOLs aircraft also fails during landing in some cases in hilly region due to land structure and many lives has been lost due to this problem. Thus, we are focusing on rural air mobility, but it is not only connecting people from rural area to city it is about connecting rural agricultural centres, commercial centres and remote mines with the world using the best available commercial technologies which allows agricultural hubs to export their fruit, vegetables, flowers, fresh meat or fish to the major markets and helps in Air cargo services to major metropolitan cities. This technology helps in city aerial mobilization and can be used as best mode of transportation in future.

II. LITERATURE REVIEW

In order to get an answer to our question, Why Nepali Sky is considered as the most risky and unsafe sky in the World? And why it is still in backlist by European Union Aviation safety standard? So, we started a survey regarding Nepali sky, Land Topography, Runway details, Region of Operation, Accidental spots, and Aircraft operating in that fleet. In preliminary conclusion, we came to know due to geographical difficulties and lack of situational awareness Nepal is facing great problems in Rural Air transportation. Due to operation of aircraft with unmatchable topographical design the most of the accident was occurred in many rural places of Nepal. Hence, here we came up with the design of *VAAYU🇳🇵YAAN* to solve the problems faced by Nepali Sky and Aviation sector. Here below we present a list of Air Accidents which we have collected during our survey.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

TABLE 1. List of Air Accident in Nepal

S.NO	NAMEOF AIRLINE& DATE	AIRCRAFT TYPE & REG. NO.	DEPATURE – ARRIVAL/ PLACE OF INCIDENT	P.O. B	N.O. F	REASON
1	BUDDHA AIR (25 SEPT. 2011)	BEECHCRAFT 1900D & 9N-AEK	LUKLA - KTM / Kotdanda, Lalitpur	19	19	Due to poor visibility during landing.
2	AGNI AIR (14 MAY 2012	DORNIER 228-212 & 9N-AIG	POKHARA – JOMSOM/ Near Jomsom Airport	21	15	Due to aircraft's wings impacted a hill during landing.
3	SITA AIR (28 SEPT. 2013)	DORNIER 228 & 9N-AHA	KTM – LUKLA/ Madhyapur Thimi	19	19	Due to technical problem during take-off.
4	NEPAL AIRLINES (16 FEB 2014)	DHC-6 TWIN OTTER & 9N-ABB	POKHARA- JUMLA / DHKHURA, ARGAKHACHI	18	18	Due to geographical troublesome Ness and bad weather.
5	US MARINE CORPS (12 MAY 2015)	BELL UH-1Y VENOM & UH-1Y	KTM – DOLAKHA/ DOLAKHA	13	13	Due to unfamiliar territory and topographical difficulties in landing.
6	TARA AIR (24 FEB 2016)	DHC-6-400 TWIN OTTER & 9N- AHH	POKHARA – JOMSOM / DANA, MYAGDI	23	23	Due to loss of situational awareness and geographical difficulties during flight.
7	SUMMIT AIR (27 MAY 2017)	LET L-410 TURBOLET & 9N-AKY	KTM – LUKLA / LUKLA AIRPORT	3	2	Due to short runway and poor visibility during landing.
8	AIR DYNASTY (27 FEB 2019)	EUROCOPTER AS350 B3e & 9N - AMY	PATHIBHARA TEMPLE - CHUHANDANDA AIRPORT / SISNE KHOLA	7	7	Due to technical problems and bad weather shortly after take-off.

NOTE:
P.O.B = Passenger On-Board
N.O.F = Number Of-Fatalities

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

III. OUR DESIGN PHILOSOPHY

A. Stovl Aircraft — Characteristics Required

The paramount characteristics of STOVL aircraft are as follows:

1) Aircraft must have capability to takeoff from short & rough runway and can land vertically in any place irrespective of its geographical topography
2) Aircraft should offer minimum passenger capacity of 13+2 (crew) and cargo with rectangular cabin for maximum usable space.
3) A high wing configuration with small wing area and high lift coefficient is required to make easy landing and takeoff at very low speed.
4) Pilot visibility is an important element of aircraft design, so there should be proper pilot visibility.

*B. Proposed Design OF **VAAYU YAAN***

Fig. 1 Proposed Design of ***VAAYU YAAN***

C. Design Methodology

The workflow developed for the conceptual design of ***VAAYU YAAN*** is shown in Figure 2. It takes all the main features of the aircraft design (e.g., aerodynamics, propulsion system, mission performance, weight estimation) into account. Accordingly, four main blocks can be identified:

1) *Aircraft's Requirements & Technological Assumptions:* with regards to proposed design here we will discuss specifications of **VAAYU YAAN**.
2) *Aerodynamics:* here we discuss about detail aerodynamic design of **VAAYU YAAN** along with aerofoil selection and wing structure.
3) *Propulsion System:* here we discuss about the ***VAAYU YAAN*** propulsion system and power generation and thrust supplied by aircraft engine.
4) *Mission Performance:* with reference of flight mechanics equation here we judge the ***VAAYU YAAN*** performance
5) *Weight Estimation:* here we carried out the weight estimation of ***VAAYU YAAN*** by breaking down weight configuration of the aircraft into sub-topics i.e., empty weight, payload weight, crew weight, fuel weight etc.

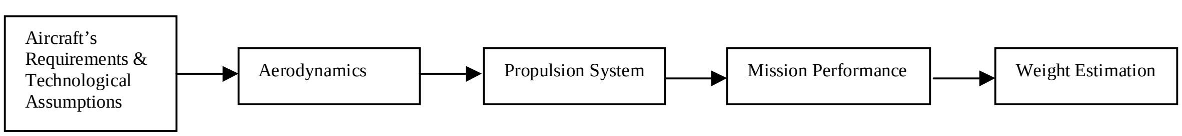


Fig.2 Conceptual design workflow for ***VAAYU YAAN***

a) *Aircraftss Requirements and Technological Assumptions:* The initiative of the aircraft design is the introduction of the aircraft requirements (e.g., range, cruise speed, payload and runway requirements). In the context of the Urban and Rural Air Mobility (U/RAM), the scenario is currently open-ended, as the U/RAM potential market is still under research and development. Hence, at least in the conceptual design phase, Aircraft Requirements are more related to the passenger STOVL configuration and to its potential performance. The base aircraft requirements are listed in Table 2;

Table 2. Parameters for Designed Model ***(VAAYU YAAN)***

S. No.	Specifications	Designed Model *(VAAYU YAAN)*
1	Pay Load	13+2(crew) Passenger or Cargo = 3400 lb. total
2	Length	16 m
3	Breadth	1.4m
4	Height	1.6m
5	Wingspan	17 m
6	Wing area	34 m^2
7	Empty Weight	3300 kg
8	Maximum Take -off weight	6000 kg
9	Runway	2200 ft
10	Cruise Speed	400kmph
11	Cross wind Capacity	25 knots
12	Weather	IFR (Instrument Flight Rules)
13	Service ceiling	25000 ft
14	Fuel Capacity	1850kg
15	Range	900km (Mechi - Mahakali)
16	Fuel Consumption	0.98kg per km

b) *Aerodynamics:* Our Aerodynamic assumption for ***VAAYU YAAN*** is based on wind tunnel data and aerodynamic results obtained from research paper and industrial practiced airfoil selection in aerospace industries which incorporates the flight range condition for proposed STOVL aircraft (i.e., take-off, transition and hover) including ground effects. Here we have proposed to use supercritical wing this is because its structure is atypical, consisting of a box formed from different integrally-milled alloy panels for different components of the wing. The main advantage of deploying this wing over conventional one includes reduction in weight (approximately 14%), elimination of rivets and reducing the workloads of aircraft manufacturers. The Aerodynamics module judges aircraft drag polar, which is necessary to properly evaluate the overall aircraft performance, both in terms of power required and in mission profile performance. Here, we proposed semi-monocoque fuselage since it can withstand considerable damage because of its longerons that absorbs the bending stresses. The total drags induced in ***VAAYU YAAN***, is calculated by using the software ANSYS Fluent.

- *Estimation of $C_{L\ MAX}$ of Airplane:* For ***VAAYU YAAN,*** we are using different airfoil at different position of the wing. The ***VAAY YAAN*** has a geometrically twisted wing in which NACA 23012 airfoil is using at the tip of the wing and NACA23015 is using at the root of the wing. In both of the airfoil the maximum chamber is placed at 15% of the chord length and the thickness are 12% and 15% respectively. Using of these different thicknesses of airfoil produce structural strength to the wing and aerodynamically the NACA 23015 stalls at a small angle of attack than NACA 23012 airfoil. From the numerical analysis of both of these airfoils using ANSYS workbench we get the C_{Lmax} as 1.5 for NACA 23015 and 1.4 for NACA 23012.

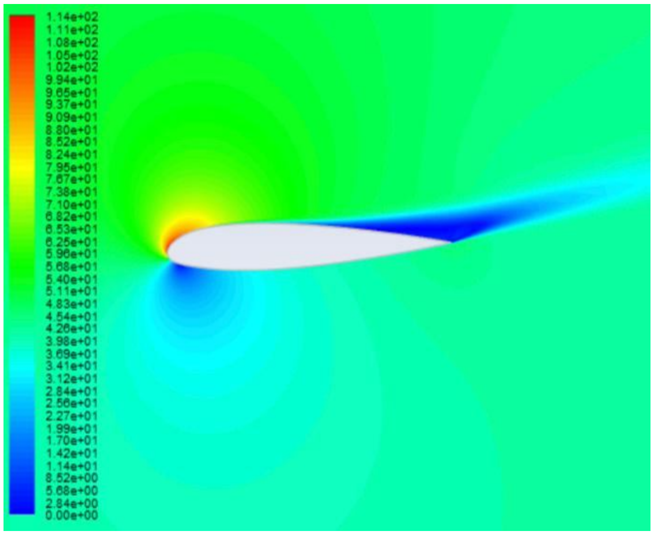


Fig 3. Velocity contour of NACA 23015 at C_{LMAX}

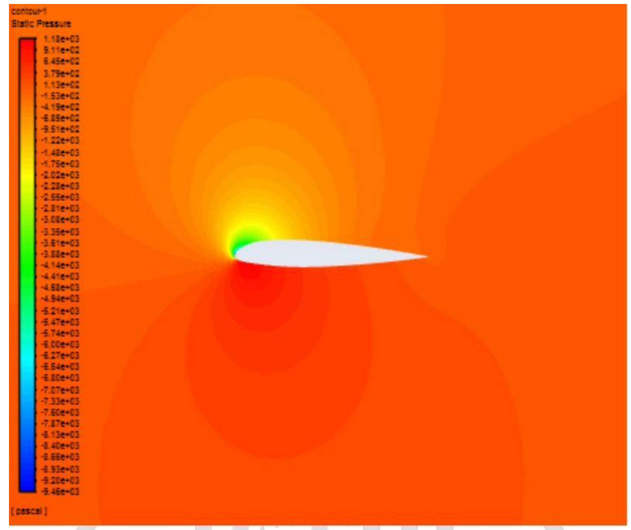


Fig 4. Pressure contour of NACA 23015 at C_{LMAX}

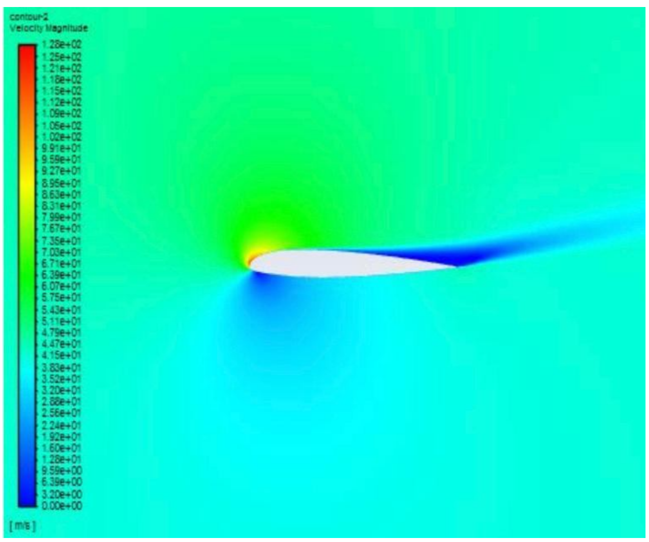


Fig 5. Velocity contour of NACA 23012 at C_{LMAX}

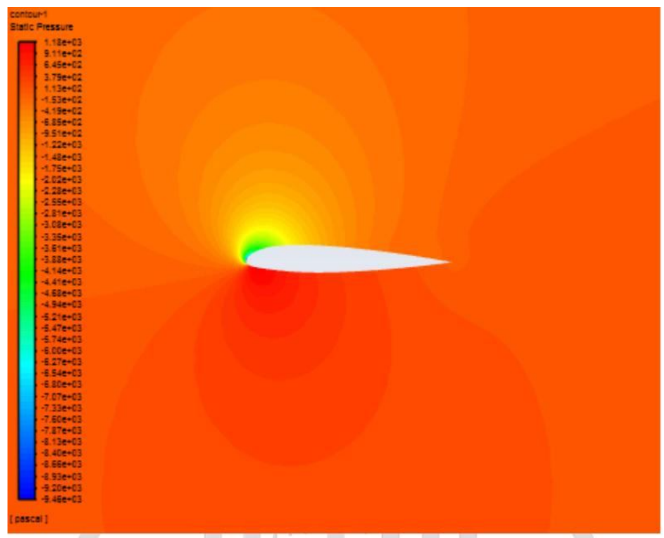


Fig 6. Pressure contour of NACA 23012 at C_{LMAX}

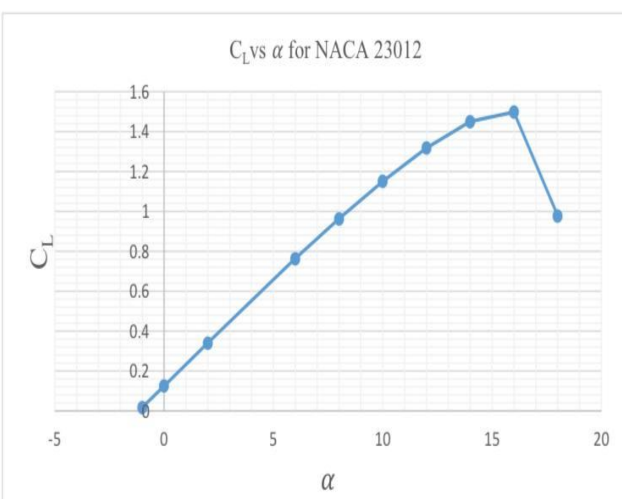


Fig 7. Coefficient of lift Vs Angle of Attack 23012

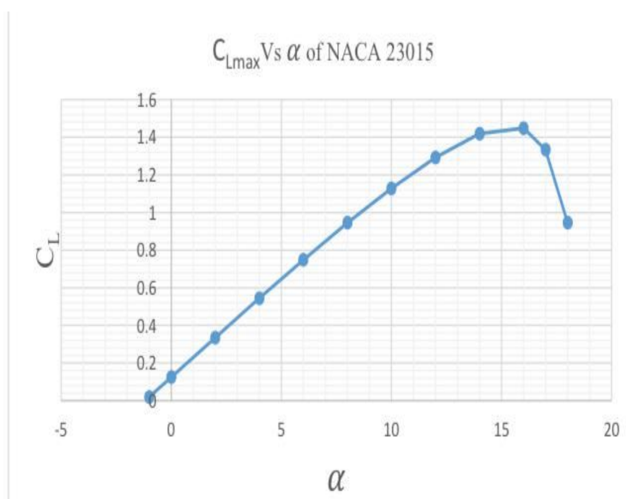


Fig 8. Coefficient of lift Vs Angle of Attack 23015

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue V May 2022- Available at www.ijraset.com

c) *Propulsion System:* Here as per the proposed design, the ***VAAYU YAAN*** is supposed to be powered by two Garrett TPE-331-5-252D engines each driving a four bladed Hartzell HC-B4TN-5ML/LT 10574 constant speed, fully feathering, reversible pitch propellers of dia. 2.69 m & rpm 1591. Nominal engine power is 715 SHP (flat rated at ISA +18 deg C, sea level). The engine is manufactured under license from Honeywell at HAL (Hindustan Aeronautics Limited) Engine Division and is featured by

- ✓ Propeller Control system.
- ✓ Anti-icing and Foreign Object damage resistance.
- ✓ Reverse thrust.
- ✓ Negative torque sensing.
- ✓ Low emission, low noise**.**

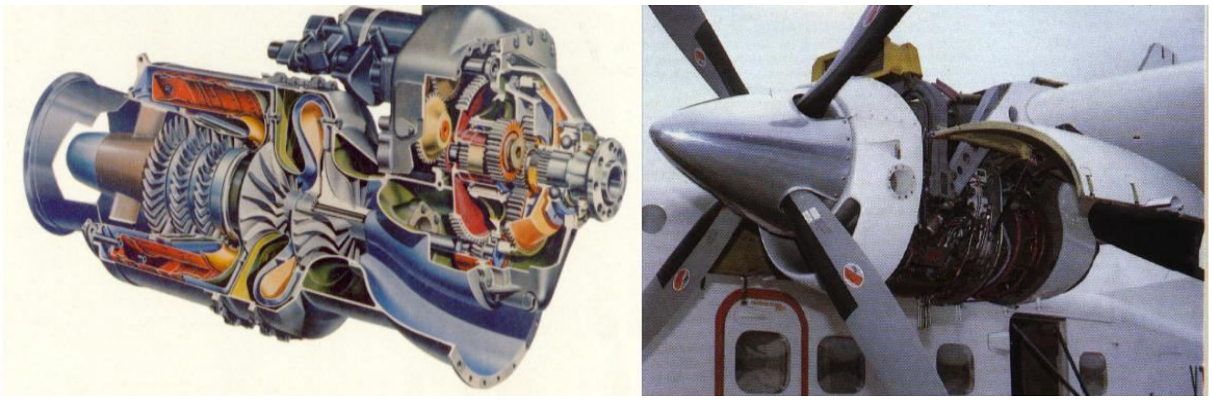
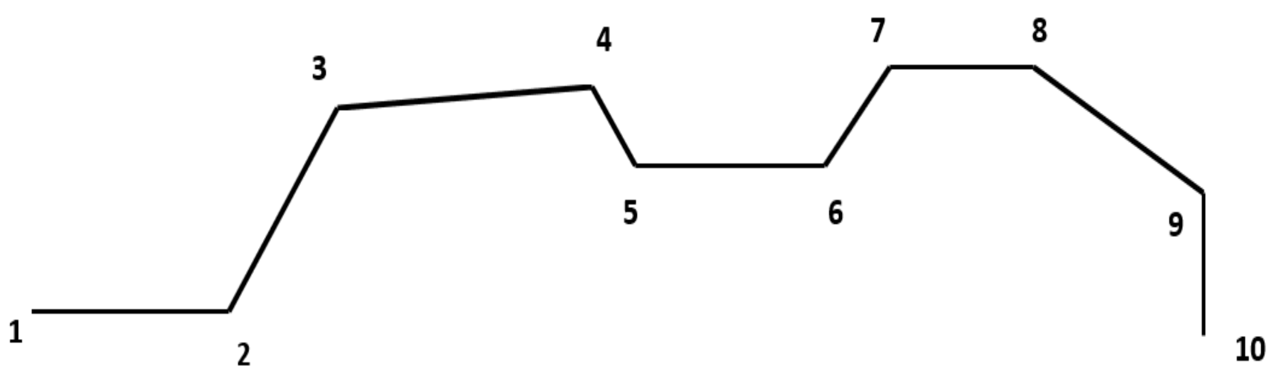


Fig 9. Powerplant (Garrett TPE-331-5-252D)

d) *Mission Performance:* The Mission performance of ***VAAYU YAAN*** describes its performance in each phase of the design mission. All the assumptions about the design mission are shown in figure given below.



1 – 2: Start and Take-off
2- 3: Ascent to Cruise
3-4: Cruise
4-5: Descent
5-6: Cruise
6-7: Ascent to Cruise
7-8: Cruise
8-9: Descent
9-10: Landing
Fig 10. *Mission Profile*

e) Weight Estimation: Weight is the force generated by the gravitational attraction of the earth on the airplane. Each part of the aircraft has a unique weight and mass, and for some problems it is important to know the distribution. But for total aircraft manoeuvring, we only need to be concerned with the total weight and the location of the centre of gravity.

The total weight W of the aircraft is simply the sum of the weight of all of the individual components.

$$\mathbf{W = W_{payload} + W_{fuel} + W_{crew} + W_{power\ plant} + W_{fixed\ equipment}}$$

Payload Weight Validation (W_{PL}):

W_{PL} = No. of passengers*(Weight of passenger + Weight of baggage)

= 15*(75+25)

W_{PL} = 1500 kg

Crew Weight Validation (W_{CREW}):

W_{Crew} = No. of crew members*(Crew weight +Baggage)

= 2*(75+10)

W_{Crew} = 170kg

Approximate Take-off Weight ($W_{TO\ (approx.)}$):

$W_{TO\ (approx.)}$ = 6000 kg [From Parameter data sheet Table 1]

For take-off, segment 0-1 data's shows that,

$\boldsymbol{W_1/W_0 = 0.97}$.

For climb, segment 1-2 data shows that,

$\mathbf{W_2/W_1 = 0.985}$

For loiter, segment 3-4 ignoring the fuel consumption during descent we assume,

$\boldsymbol{W_4/W_3 = 1}$

For landing, segment 4-5 based on historical data we assume that,

$\boldsymbol{W_5/W_4 = 0.995}$

The Brequet's range equation is used to calculate the value of W_3/W_2. As we all know that maximum range is covered during cruise we considering this equation,

$$\mathbf{R = (v_\infty/C_J)\,(L/D)\,\ln(W_2/W_3)}$$

L/D values of similar type of aircrafts we come to know that the approximate the value of L/D for our aircraft to be 15.

So,

$\boldsymbol{L/D = 15}$

From the comparative data sheet,

V_∞ =610 km/hr.

R = 900 km

<u>For Business & Transport Jets</u>

We found the values of C_J as 0.6

So now substituting these values in the Brequet's range equation,

$$R = (V_\infty/C_J)\,(L/D)\,(\ln W_2/W_3)$$

$$= (610/0.6)\,(15)\,ln(W_2/W_3)$$

$$\ln(W_2/W_3) = (900/\ 15250) = 0.059$$

$$\mathbf{W_3/W_2 = 0.94}$$

Mission Fuel Fraction Weight Validation (M_{FF}):

The fuel fraction of each phase is defined as the ratio of the end weight to the begin weight.

$$M_{FF} = (W_1/W_0) \times (W_2/W_1) \times (W_3/W_2) \times (W_4/W_3) \times (W_5/W_4)$$
$$= 0.97 \times 0.985 \times 0.94 \times 1 \times 0.995$$
$$\mathbf{M_{FF} = 0.893}$$

Fuel Weight Validation (W_{FUEL}):

$$W_{FUEL} = (1-M_{ff}) * W_{TO\ approx.}$$
$$= (1-0.893) * 6000$$
$$\mathbf{W_{FUEL} = 642\ Kg}$$

Approximate Operational Weight Validation ($W_{OE\ (approx.)}$):

$$W_{OE\ (approx.)} = W_{OE\ (approx.)} - W_{FUEL} - W_{PL}$$
$$= 6000-642-1500$$
$$\mathbf{W_{OE\ (approx.)} = 3858\ kg}$$

Tentative Empty Weight Validation ($W_{E(tent)}$):

$$W_{E(tent)} = W_{OE\ (approx.)} - W_{TFO} - W_{CREW}$$

where,

$$W_{TFO} = 0.5\%\ \text{of}\ W_{TO\ (approx.)}$$
$$= 3858-0.005*6000-170$$
$$\mathbf{W_{E(tent)} = 3658\ kg}$$

Maximum Take-off Weight Validation (W_{TO}):

$$W_{TO} = W_{E(tent)} + W_{FUEL} + W_{PL} + W_{CREW}$$
$$= 3658+642+1500+170$$
$$\mathbf{W_{TO} = 5997\ kg\ [CORRECTED]}$$

[Note: All the calculations done above are based on Reference from Aircraft Design: A Conceptual Approach by Dr. Daniel P. Raymer.]

IV. CONCLUSION

The objective of this research report was to propose and design an Aircraft (***VAAYUYAAN***) that can meet the needs of Nepali sky at present scenario to avoid the future air accidents. The following are the key conclusions and findings from this study which we have obtained from our survey:

1) The most important conclusion from this project in our opinion (Author's opinion) is that there has been frequent air accident in Nepali Sky and the main reason behind is ramp land structure and small runway. Wind is almost always a cause factor while flying over a mountainous terrain. Dependent upon the direction and speed of the wind, its interaction with the terrain can lead to updrafts, downdrafts and turbulence which may exceeds aircraft limitations or performance capability and leads to horrible accidents as a result of collision with high hills and mountains.
2) Keeping the above conclusions in consideration, we made an approach to put all our efforts and try our level best for solving this matter of Aviation concern of Nepalese Aviation Industry with our impeccable design of ***VAAYU YAAN***. ***VAAYUYAAN*** is not just a conceptual design, it is pie in sky, hope of flame for Nepali people which may drastically change the scope of aerial transportation in Hilly and Himalayan region of Nepal.
3) Although, the ***VAAYUYAAN*** is specially designed for passenger and cargo mode but it is also designed to be used to promote Nepalese Mountain Tourism through Mountain sightseeing of Highest Peaks of the world out of which, majority are situated in Nepal (i.e., 8 out 14 highest peaks having height more than 8000 meters). Along with this, it may be also used for different roles such as Search and Rescue, Aerial Survey, Arms and Ammunitions transport, Casualties Evacuation etc., in upcoming future.

V. ACKNOWLEDGMENT

Project ***VAAYUYAAN*** became a reality with the kind support and help of many individuals, we are deeply grateful to our advisor, Dr. P. Karunakaran for his guidance, patience and support. We are much obliged to our Head of the Department Dr. S.P. Venkatesan and faculty members of Department of Aeronautical Engineering, Excel Engineering College for their enlightening suggestions and encouragements which motivated us throughout our project. We owe many thanks to our classmate and all of our colleagues. They always helped us in exchanging ideas regarding research and gave the enjoyable environment for our project ***VAAYUYAAN***. We are most grateful to our parents; they have always loved us and supported our every choice which helped us in successful execution of project ***VAAYUYAAN***.

REFERENCES

[1] John. D Anderson, Fundamentals of Aerodynamics, Fifth Edition, McGraw Hill Education (India) Private Limited.
[2] John. D Anderson, Aircraft Performance and Design, 2010 Edition, Tata McGraw Hill Education Private Limited.
[3] Daniel P. Raymer, Aircraft Design: A Conceptual Approach, Sixth Edition, AIAA Education Series.
[4] www.airfoiltools.com
[5] https://ijisrt.com/numerical-analysis-of-aerodynamic-performance-characteristics-of-naca-2312-and-naca-2412
[6] Raymer D., AIRCRAFT DESIGN: A Conceptual Approach, Third Edition, American Institute of Aeronautics and Astronautics, Washington, D.C.
[7] https://www.1001crash.com/transport-page-plane_database-lg-2-plane-accident-country-nepal-aircraft-history.html
[8] https://timesofindia.indiatimes.com/world/south-asia/major-plane-crashes-in-nepal-a-timeline/articleshow/10115233.cms
[9] STOVL Aircraft Simulation for Integrated Flight and Propulsion Controls Research, NASA
[10] https://en.wikipedia.org/wiki/Category:Aviation_accidents_and_incidents_in_Nepal
[11] Jackson, Paul. Jane's All the World's Aircraft: 2010-2011. Coulsdon: Jane's, 2010. Print.
[12] McCrea, M., O'Brimski, F., Strickland, P., and Raymer, D., Breaking the Paradigms: Catapulting STOVL, International Powered Lift Conference, Oct. 2000
[13] Large-Scale Instabilities in a STOVL Upwash Fountain, A.J. Saddington,, K. Knowles, in Engineering Turbulence Modelling and Experiments 6, 2005,Science Direct
[14] https://caanepal.gov.np/safety-management-division/Accidents/Incidents-CAAN

AUTHOR'S PROFILE

1) **Mr. Pradeep Kandel**, currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in National level seminars and workshops and, also published research paper on Water scooping mechanism for Fire-fighting Aircraft and Noise Reduction Technology in Turbofans and Airframes of Aircrafts. Research interest includes Aircraft Propulsion, Structural Integration of the Aircraft and Aircraft modelling (RCs and UAVs). Also, into the research of VTOL & STOL.
Contact: pkandel056@gmail.com

2) **Rakesh Kumar Shah,** currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamil Nadu, India. Has presented papers at many National level symposium and seminars, also published research paper on Wing morphing, Water scooping mechanism for Fire- fighting Aircraft and Noise Reduction Technology in Turbofans and Airframes of Aircrafts. Research interest includes Aerodynamics, Aircraft Design, Aircraft Model designing (RCs and UAVs). Also, in the research of Jet Engine optimizations, e-VTOL and STOL.
Contact: rakeshkumarshah70@gmail.com

3) **Dr.P. Karunakaran**, Associate Professor in Department of Aeronautical Engineering. Pursuing research in the field of Industrial Aerodynamics. Having more than 25 years of teaching experience in Aeronautical Engineering. Published more than 30 papers in conferences and journals. Also, into the research in wind tunnel analysis, materials science and manufacturing technology.
Contact: pkarunakaran.eec@excelcolleges.com

4) **Mr. Sumit Pandit**, currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in national level seminars and workshops, also published research paper on Noise Reduction Technology in Turbofans and Airframes of Aircrafts. Core research interest includes aircraft designing and propulsion systems, designing software (Solid works, Catia).
Contact: sumeetpal107@gmail.com

5) **Mr. Ajay Kumar Yadav,** currently pursuing Final year of Aeronautical Engineering at Excel Engineering College, Tamilnadu, India. Has presented many papers in national level seminars and workshops, also published research paper on Water scooping mechanism for Fire-fighting Aircraft. Research interest includes Aircraft Propulsion, Aircraft Structure, and Composite Materials. Also, into the research of UAV, VTOL etc.