# Other Areas of Engineering and Technology

1 paper

# Bird Strikes in Nepal's Civil Aviation, 2020-2025: A Statistical Risk and Damage Cost Analysis

**Roomi Mandal[1]*, Sudip Bhattarai[2]**

[1,2]Department of Mechanical And Aerospace Engineering, Pulchowk Campus, IOE, Tribhuvan University, Lalitpur,Nepal

[1]079msmde016.roomi@pcampus.edu.np, [2]sudip@pcampus.edu.np

## Abstract

This study presents a quantitative risk and financial damage analysis of civil aviation safety occurrences specific to bird strike reported to the Civil Aviation Authority of Nepal (CAAN) between 2020 and 2025. The research examines carefully the operational risk trends, critical aircraft failure modes and the economic impact of avian hazards by utilizing the Mandatory Occurrence Reports(MOR) and a dedicated subset of bird strike events. The findings demonstrate that the growth in reported safety occurrences reflects a maturing Safety Management System(SMS) reporting culture rather than a decline in operational safety. Operational risks and technical failure modes are largely concentrated in low altitude, high workload flight phases i.e mainly takeoff and landing and are restricted to a small cluster of critical aircraft systems and high utilization fleet types.

Bird strike hazards reflect significant seasonal variation, peaking sharply during the monsoon months while survival analysis reveals a short median recurrence interval that indicates a high risk of rapid consecutive strikes. Forward facing components and propulsion systems are predominately affected by the impact causing substantial maintenance costs and operational downtime. Based on these operational patterns, the study affirms the need for targeted airfield wildlife management during monsoon seasons, strict enforcement of aerodrome environmental buffer zone and prioritized safety oversight.

*Keywords: MOR, bird strike, survival analysis, risk analysis*

## Introduction

Air transportation is considered as one of the safest means to travel today. This did not happen by chance. Rather, it is the result of several years of careful analysis such as finding potential hazards, investigating incidents and accidents, and using data and safety recommendation to fix problems before they lead to accidents. One of the main tool of this system is Mandatory Occurrence Reporting (MOR). According to the International Civil Aviation Organization (ICAO) rules of Annex 19 operators, airports, air traffic controllers and aircraft maintenance organizations must report certain safety occurrences to their country's aviation authority. No doubt these reports has become part of safety data. This data helps airlines companies identify spot the risk and hazards and fix problems prior to leading to catastrophic scenarios. Thus, nature of MOR is proactive rather than reacting after an accident happens.

Among the different incident types, bird strikes are a prominent and widely studied hazard across the world. Even so no detailed study has been yet taken place and examined the bird strike specific datasets of Nepal. The gap is filled by this study. It uses CAAN's MOR data from the year 2020 to 2025 in two stages. Firstly, studies how occurrence reporting has transferred over time, how incidents are spread across different flight phases, and which ATA aircraft systems are involved most often. Next, it takes in depth examination specifically at bird strikes using survival

analysis, damage severity patterns, monthly and seasonal trends and repair cost data to build a clear, evidence based picture of this risk.

Bird strikes has become a uniquely Nepalese problem .There are several factors make the hazard especially distinct in Nepal. Due to the country's unique microclimate and the existence of protected biological reserves and travel corridors adjacent to flight routes mean that Nepalese aircraft are more liable to encounter bird strikes. Outdoor slaughterhouses, poor municipal waste management near airports further attracts scavenging birds close to aerodrome boundaries and approach paths. Besides, seasonal biological phenomena such as earthworms surfacing onto runways and taxiways during the monsoon rains stimulates birds toward operational areas during peak morning and evening flight schedules.

In addition to the immediate safety risk, bird strikes also carry a significant and often overlooked economic burden. Impact damage is not distributed evenly across the airframe. It is seen that the engine and propeller, radome and wing surfaces are consistently the most affected components which reflects their exposure during the forward facing, high energy phases of flight. When a strike leads to component damage, the resulting repair or replacement can range from minor to major maintenance work. The maintenance cost can be the full engine replacement with a single such event costing hundreds of thousands of dollars. Nepal's civil aviation airlines companies already contend with challenging terrain, STOL runway constraints and thin margins. Therefore, repeated maintenance costs caused by bird strikes on the top add operational and financial risks to existing safety concerns. This emphasizes the importance of using a systematic, data driven approach to understand the frequency, severity and cost of bird strikes which is useful both in practice and in academic research.

The main objective of this study is to study aviation safety occurrences reported to CAAN between 2020 and 2025 in order to understand overall safety trends and to present a detail overview of bird strike risk. The specific objectives are to: (i) to find and rank the top aircraft systems ATA chapters involved in incidents each year and to check using Pareto analysis; (ii) to study the yearly trend, monthly pattern and seasonal pattern of bird strikes; (iii) to use Kaplan Meier survival analysis on bird strike data; (iv) to identify critical damage zones across flight phases using Pareto analysis and to estimate the repair and maintenance costs linked to damage from major bird strikes.

Notably, no study has yet been showed up on bird strike occurrences in Nepal to examine how bird strike occurrences change with season, the time interval between successive bird strikes using survival analysis techniques and also the maintenance costs incurred to repair aircraft damage caused by these events.

Without answers to these questions, safety decisions at CAAN and among operators tend to be based on guesswork or individual memory rather than solid evidence. Resources for things like wildlife control, inspection schedules or safety directives cannot be well targeted without knowing where the real risk is concentrated. This study addresses that gap by turning six years of raw occurrence reports into a clear, statistically sound risk picture.

## Literature Review / Related Work

As documented by Yadav (2017) in his historical safety synthesis, “Aircraft Collisions and Bird Strikes in Nepal Between 1946 and 2016” the reason for clustering of diverse avian population near the airport area is the countries unique microclimates. Yadav’s seven decade case study also

founded that bird strikes between 1990 and 2013 alone caused the hull loss of at least 66 aircraft and caused 26 fatalities in Nepalese land. Yadav's report determined that engine ingestions 29% and wing strikes 26% comprised for the large proportion of airframe damage. This historical distribution highlights the vulnerability of forward facing cross sections during forward flight.

Aircraft collisions with avian illustrates one of the oldest and most ongoing structural hazards in Aerospace Engineering and Airport Management. This has raised severe risk to human life and Structural integrity. The wide portion of bird strike events globally do not happen in high-altitude en-route airspace as per the International Civil Aviation Organization (ICAO, 2024). Rather they place in low-altitude airport boundary layer. Statistical it has been confirmed that approximately 70% to 75% of bird strikes occur below 500 feet Above Ground Level (AGL), indicating the high workload, high speed and energy flight phases such as takeoff rolling, initial climb, final approach, and landing touchdown.

Regulatory reports from the World Birdstrike Association (Thapaliya, 2016) and technical publication by Thapa (2001) highlights that weak municipal waste management practices, outdoor slaughterhouses and carcass offering practice in nearby neighborhoods contribute to major attractants. A high, prolonged concentration of birds of prey directly inside the aerodrome area and runway approach paths because of these factors.

Recent analytic published by safety networks like AvioSpace (2026) confirm that bird strike hazards in Nepal remain a highly localized operational challenge. Their multi-year review indicates that between 1990 and 2023, mixed aviation accidents accounted for the loss of 92 hulls in Nepal. More importantly, their localized airport data confirmed that 89% of bird incidents occurred directly within or immediately adjacent to the aerodrome environment, with over 60% of those occurrences concentrated specifically during the final approach profile or the physical landing touchdown roll.

From the perspective of financial and operational, bird strikes introduce severe economic asymmetry into airline maintenance management. As mentioned in regional airworthiness studies and safety reviews by the Flight Safety Foundation (2025), maintenance expenditures arising from avian encounters shows an extreme, right-skewed distribution across commercial fleets. Minor strikes involving peripheral, forward facing components such as taxi lights, radomes or pitot probes result in low direct repair costs. In contrast, when foreign object damage occurs within propulsion systems, severe kinetic impacts lead to fan and compressor blade deformation, internal core degradation as well as structural imbalance. These catastrophic powerplant failures frequently force complete engine overhauls or module replacements, causing engine repairs to incur up to 85% of an airlines companies total cumulative wildlife related maintenance expenditure over multi-year operational cycles.

## Materials and Methods

This study adopts a quantitative, retrospective approach, descriptive study design. Retrospective approach is used because it examines past events, data or experiences to understand what happened, why it happened and what can be learned from it. It is based entirely on existing records of MOR collected by CAAN from 2020 to 2025. The study combines descriptive statistics such as trends, frequency counts, pareto analysis, Kaplan-Meier survival analysis.

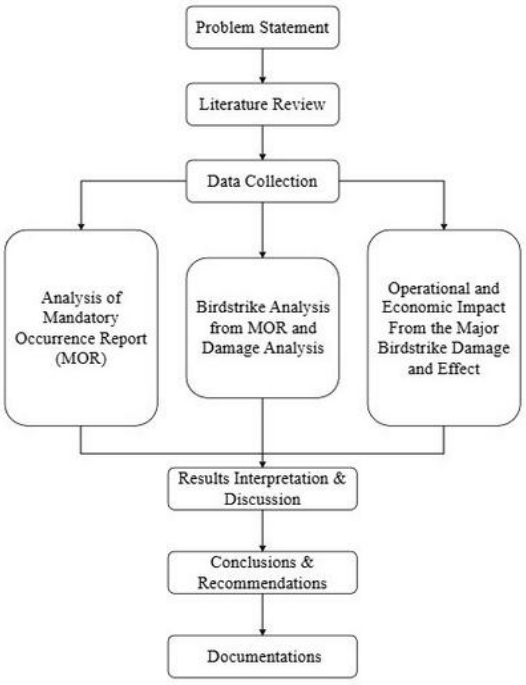



Figure1

Flowchart for Methodology

**Kaplan Meier Survival Analysis**

In order to calculate the survival function for time between successive bird strike events the Kaplan Meier method is used . Here, the survival time is defined as the interval, in days, between the consecutive bird strikes.The Kaplan Meier survival curve equation estimates the cumulative probability of surviving past a specific time t using the formula:

$S(t) = \prod$ , for all $t_i \leq t$ (1)

where,

S(t) is the estimated survival probability at time t.

$\prod$ is the product operator multiplying the survival rates of all time steps up to time.

ti is the specific time point where an event (such as death or failure) happened.

di is the exact number of events that occurred at time ti.

ni is the total number of subjects still at risk right before time ti.

**Pareto Analysis**

A Pareto Analysis which is often called the 80/20 rule can be used in aviation safety to help identify the vital few problems that cause the majority of your safety incidents.This tool was used first to identify the main ATA critical chapters which has been majorly affected and the impact location on the aircraft to see which specific parts of the plane are absorbing the vast majority of bird strikes.

## Economic Analysis

The economic analysis was carried out to find out the financial burden linked with bird strike damage. This analysis primarily focused on bird strike records where actual damage to the aircraft took place.For those events information related to replacement part cost was collected through the operators. The repair costs were grouped and examine by aircraft type, operator and damage severity level. The aim of this was to determine whether certain aircraft types, operators or more severe events were associated with higher repair costs.

## Aircraft downtime and cost correlation

In order to measure the strength and direction of the linear relationship between the two variables(aircraft downtime and cost) pearson correlation was used. The formula is:

r = (2)

Where,

x is the cost of replacement

y is the aircraft downtime

$\bar{x}$ is the mean cost

$\bar{y}$ is the mean AOG

## Results

### Top Twelve ATA Chapter Occurrences by Year

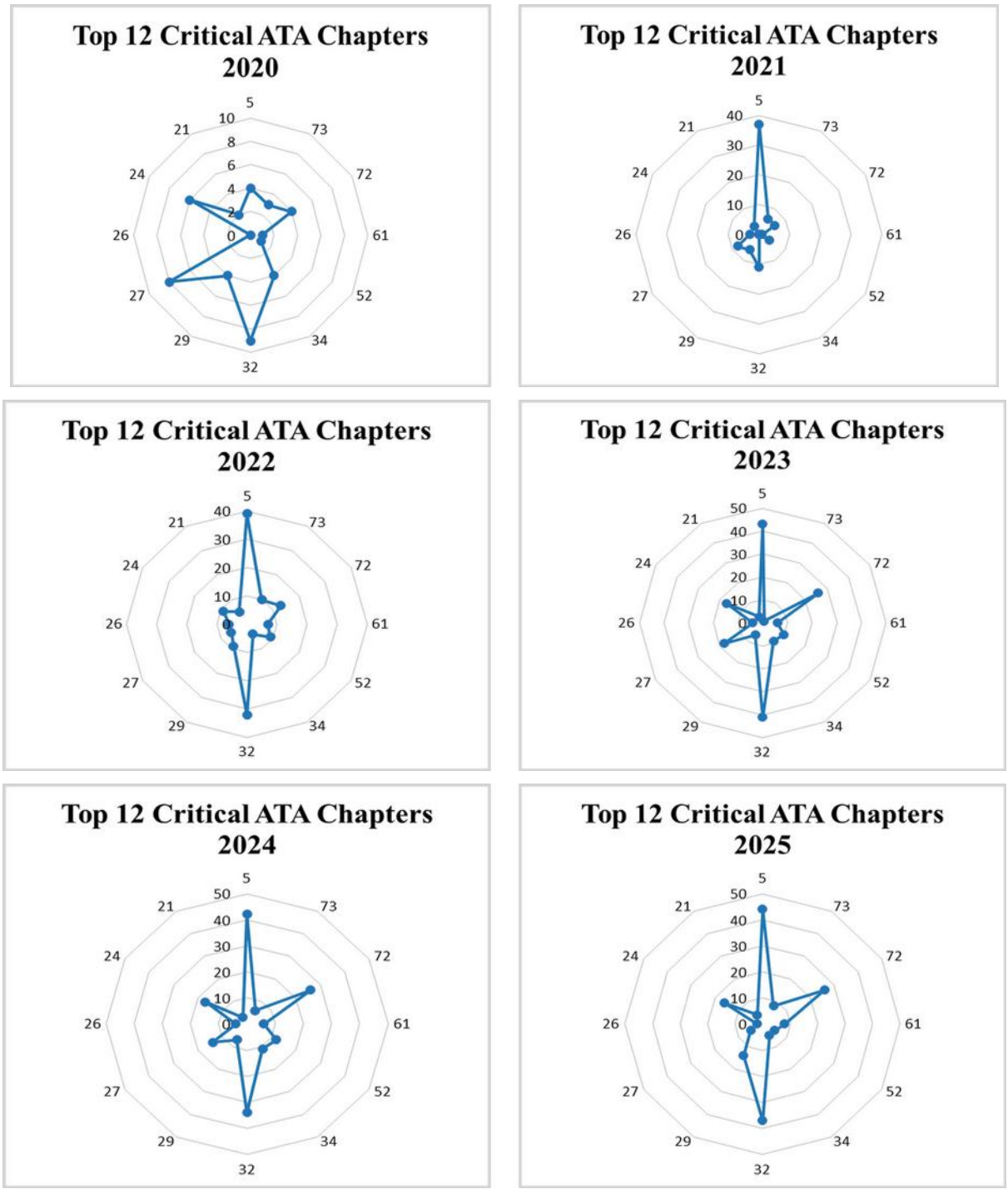



Figure 2

Radar Chart Comparison of Top ATA Chapters

The radar charts of MOR occurrences by major ATA chapter plotted separately for each year against a fixed set of eight reference categories reveal a steady risk profile as well as a clear transformation in shape and magnitude over the study period.

On examination of individual systems, engine/powerplant occurrences tripled i.e from 14 to 43 and landing gear occurrences quadrupled i.e from 9 to 37 between 2020 and 2025. The largest increase was for the time limits which was an eleven fold increase i.e, from 4 to 44. This is more likely explained by strengthened and more consistent reporting practices over time as opposed to an actual eleven fold deterioration of maintenance problems.

From 2022 onward the three systems, time limits/maintenance checks, engine/powerplant and landing gear uniformly stand out as the largest contributors to occurrences. They account for approximately 22-27% each of the top 8 categories every year. For example, in 2025 these three systems comprised for 26.0%, 25.4% and 21.9% of occurrences respectively. This suggests that the main safety risk areas in Nepal's aviation fleet have stayed relatively consistent despite the total number of reports has grown.

***Pareto Analysis of MOR Occurrences***

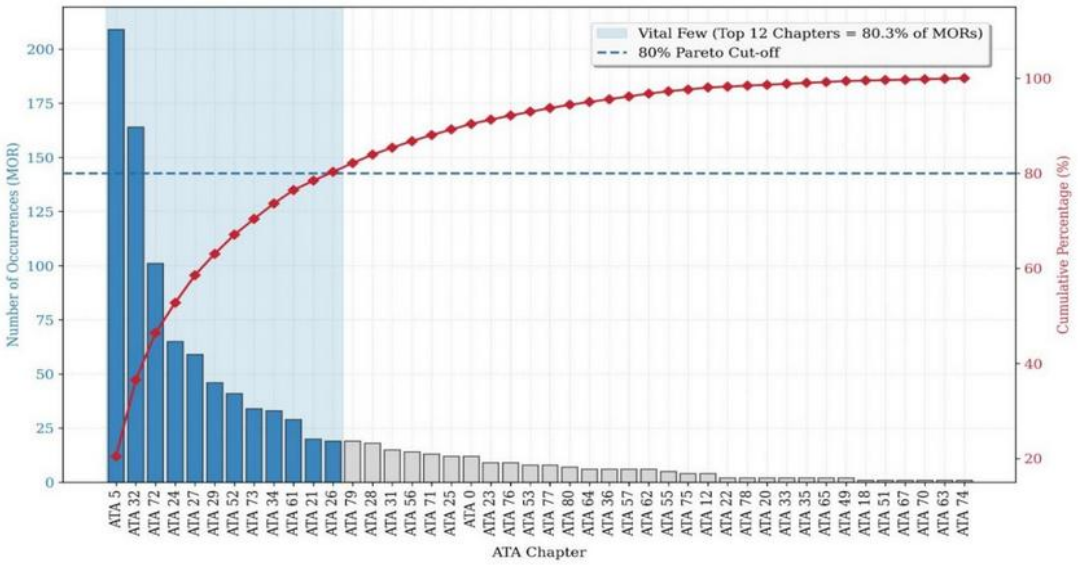



Figure 3

Pareto Analysis of ATA Chapter Occurrences

The top 12 chapters ATA 5, 32, 72, 24, 27, 29, 52, 73, 34, 61, 21, and 26 jointly account for 80.3% of total occurrences, matching with the standard 80% Pareto threshold. While the remaining 32 chapters contribute only minimally, with many ATA chapters lesser than 10 occurrences over the study period. Thus, vital few ATA chapters has been identified and continuous oversight and maintenance program review for these particular chapters should be carried out as it would address the large majority of reported safety events.

**Trend in Bird Strike Occurrences from 2020-2025**

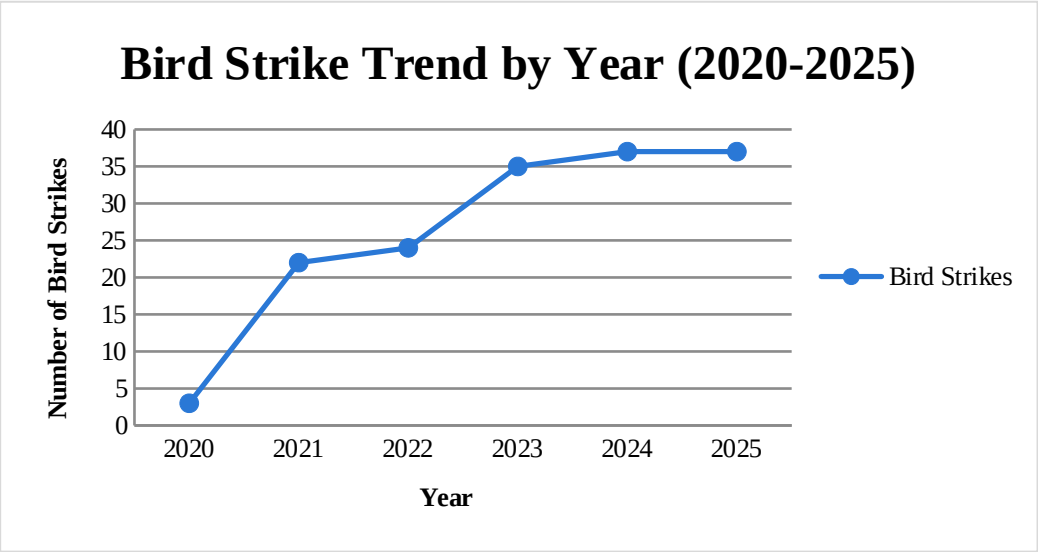



Figure 4

Bird Strikes Reported to CAAN

The trend of bird strike occurrences illustrates that the count grew sharply and then held steady: 3 in 2020, climbing to 22 in 2021, 24 in 2022, then 35 in 2023 and holding constant around 37 in both the year 2024 and 2025.

The trend shows a rapid increase, leveling off at a high number in bird strikes after a very low starting point at 2020. The sudden rise in the early years matches the return of normal flight schedules after the pandemic which simply means more planes in the sky has higher chance of hitting birds.

The numbers flattened out and stayed high in the later years which indicates bird strikes are no longer a rare problem but a continuous risk tied to busy airport operations. The flat line at the end suggests current bird scaring methods are not actually solving the problem. To decrease these numbers, airports need stronger wildlife controls around runways, such as clearing its habitat areas and using effective deterrents to keep birds away from flight paths.

***Monthly Distribution of Bird Strike***

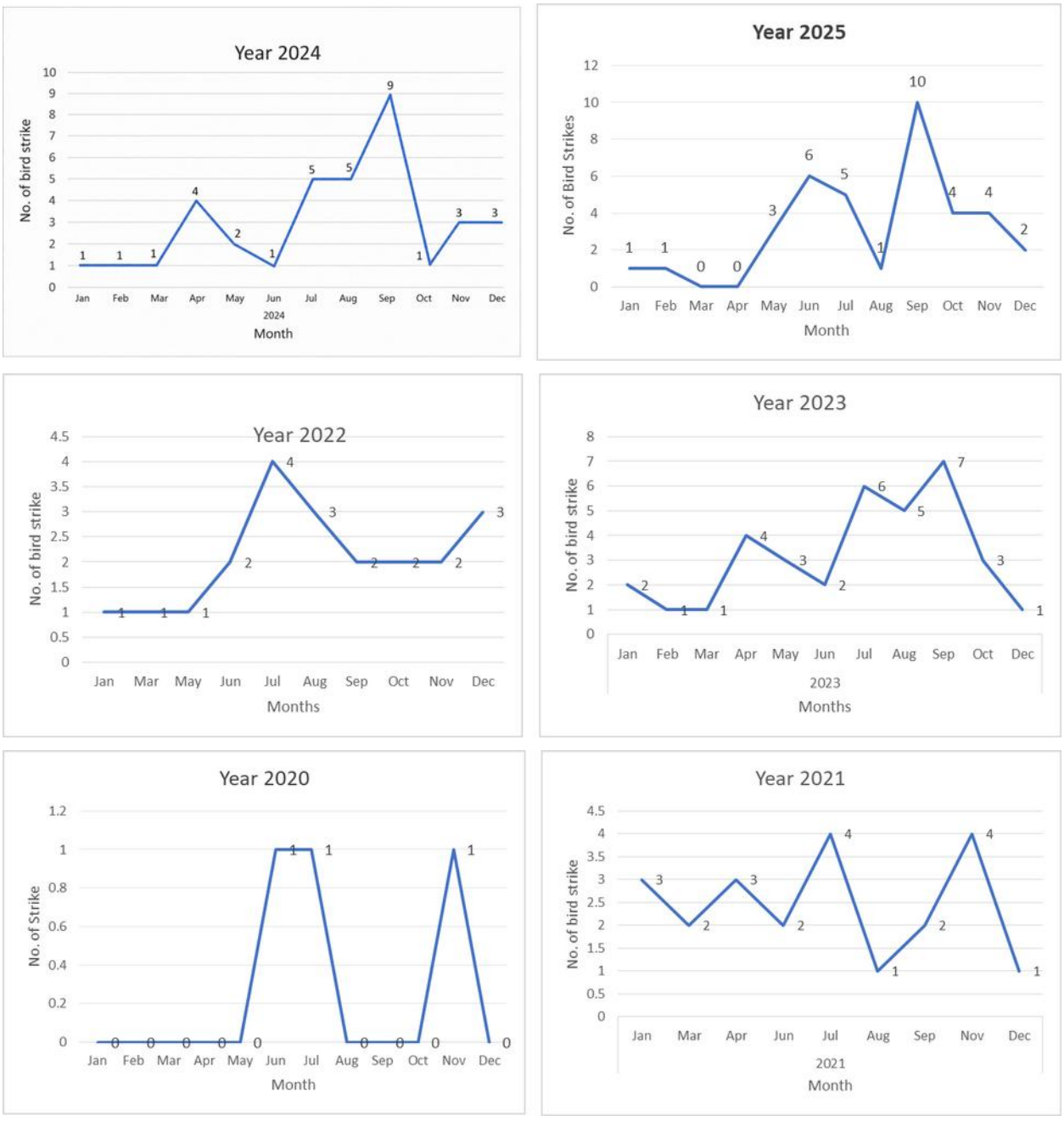



Figure 5

Bird Strikes Reported by Month of Occurrences

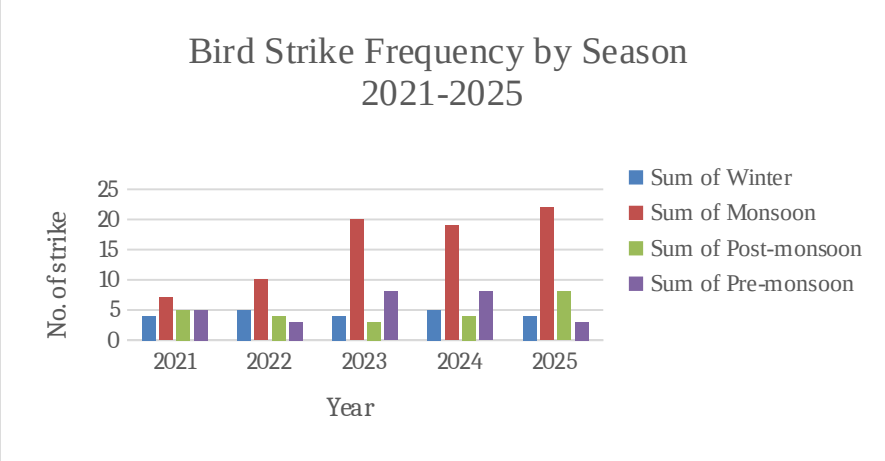



Figure 6

Year wise Seasonal Distribution of Bird Strikes

On studying the seasonal analysis of bird strike events across the four meteorological seasons (Winter, Pre monsoon, Monsoon, Post monsoon) of Nepal from 2021-2025 year showed the monsoon season to be extensively the principle risk period in every year of the study. In the monsoon season strikes increased from 7 in 2021 to 22 in 2025 which is approximately a three-fold increase while in the winter season strike number remained constant i.e 4-5 per year .The graph illustrates that monsoon season strike constituted nearly 54-63% of that year's total occurrences for the year 2023-2025, however for the year 2021-2022 monsoon season strikes showed roughly 30-33%. This indicates that the overall increasing trend in bird strikes driven primarily by the monsoon period as opposed to a consistent increase across all seasons.

***Kaplan Meier Survival Analysis***

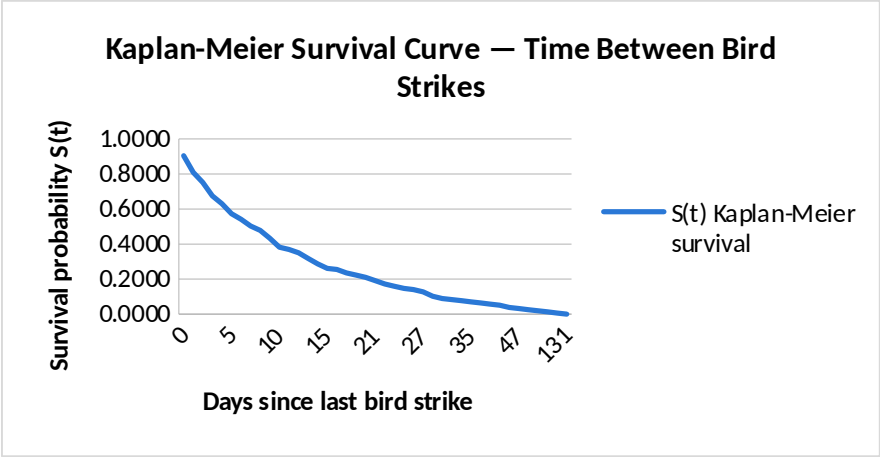



Figure 7

Kaplan Meier Survival Analysis of Time between Bird Strikes

The median survival time is simply the smallest t at which S(t) drops to 0.50 or below. Looking at the survival table S(7) = 0.503 and S(8) = 0.478. This shows the curve crosses the 50% mark between day 7 and day 8 and by convention the median is reported as the first t where S(t) ≤ 0.5

which is day 8. In other terms, half of all the gaps between consecutive bird strikes in the dataset were 8 days or shorter and half were longer.

***Pareto Analysis of Impact Location***

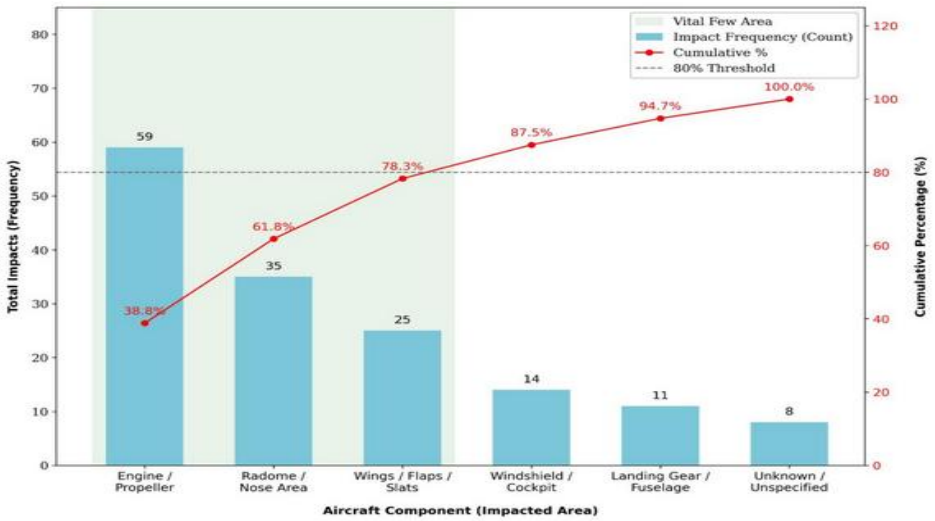



Figure 8

Bird Strikes Reported by Parts of Aircraft (Struck)

Engine and propeller impacts incurs the most severe safety hazards due to the potential for ingestion, thrust loss or internal mechanical failure whereas radome and wing collisions frequently result in structural deformation. This demonstrate that forward facing and propulsion systems are the most affected area due to the bird strike.

**Economic Analysis**

Table 1: Maintenance Cost and Downtime Associated with Bird Strike Incident

| S/No | Aircraft Registration | Operator | Cost | AOG Time |
|---|---|---|---|---|
| 28-Aug-20 | 9N-AHR | Sita Air | 2750$ | 1 Day |
| 22-Jun-21 | 9N-AHR | Sita Air | 2550$ | 16 Days |
| 12-Nov-21 | 9N-AMF | Buddha Air | Nrs 70751 | No AOG |
| 2-Aug-22 | 9N-AHR | Sita Air | 65000$ | 7 Days |
| 7-Dec-22 | 9N-AKL | Tara Air | Nrs16,00,000 | 19 days |
| 8-Mar-24 | 9N-ANA | Air Dynasty | 19077.30 Euro | 7 months |
| 3-Feb-25 | 9N-ALN | Yeti Airlines | $12,995 | 5 Hrs |
| 27-May-25 | 9N-ANZ | Buddha Air | $851,822.78 | 1 Day |
| 31-Jul-25 | 9N-AMY | Buddha Air | $26,108 | 1 Day |
| 8-Nov-25 | 9N-AJS | Buddha Air | Nrs 585859.59 | 1 Day |

The mean cost per event is $99,923 and the median cost is $12,797. The minimum cost is $598 which is the taxi/take-off lamp replacement on a Buddha Air aircraft and the maximum cost is $851,823 incurred for a PW127M engine replacement on a Buddha Air aircraft. The cost for the engine replacement alone account for approximately 85% of the total repair expenditure across the six year period.

### Cost vs. AOG correlation

The correlation coefficient between the cost and AOG value comes out to be r ≈ -0.13. This suggests that there is no meaningful relationship between repair cost and downtime. This suggests that there is no meaningful relationship between repair cost and downtime. Repair cost is primarily influenced by the type of component damaged such as engine or lamp while the AOG duration is more governed by parts availability and logistics, particularly whether the required component is readily in stock or must be specially imported. Buddha Air's $26,108 propeller repair was resolved in just 1 day and the same pattern was for its $851,823 engine repair. The highest cost event i.e the $851,823 engine had only 1 day of AOG whereas the longest AOG event for canopy repair was 210 days whose cost was comparatively cheap ($20,604).

### Limitations

The following are the potential limitations:

a) This study utilized only the records that were reported to CAAN. There are many cases where are under reporting of MOR from the operator side which may not exactly match the true number of incidents that actually happened.
b) The years 2020-2021 was the COVID-19 pandemic time when the flight numbers dropped drastically. Besides, it created a scenario when the airlines companies has difficulty in submitting the physical copy of MOR. As a result only verbal communication was done to convey the hazards.
c) Aircraft system ATA chapter and damage classification relied partly on keyword matching in written incident descriptions. Even though each of the description were carefully read out they were chances that some incidents may have been classified incorrectly, especially where the description was unclear or incomplete.
d) When bird strike records are split by aircraft type, operator, phase, and season all at once some of the groups become quite small. This limits how reliable some of the detailed comparisons can be.
e) For every bird strike record repair cost information was not available. So, as a consequence some records with major damage impact due to the bird strike was not included.

### Conclusion

Firstly, the ATA chapter analysis identified a vital few set of aircraft systems causing the majority of technical occurrences. From 2022 onward, time limits/maintenance checks, engine/powerplant and landing gear continually accounted for 22-27% of top-8 occurrences each year. Also from the pareto analysis confirmed that just 12 of 44 ATA chapters represented over 80% of the total reported occurrences. This suggests that targeted oversight of this small set of systems would resolve the large majority of reported safety events.

Second, the seasonal analysis additionally revealed that the monsoon season is the dominant season for strikes, with monsoon period strikes nearly tripling between 2021 and 2025 and accounting for over half of annual strikes in recent years. This indicates seasonal rather than uniform wildlife hazard growth.

Third, the Kaplan Meier survival analysis described that the risk of a repeat bird strike median recurrence interval is 8 days. This decreasing hazard pattern indicates a clear window during which reinforced wildlife control measures would have the greatest protective effect.

Fourth, the damage impacts were concentrated on the engine/propeller, radome and wing areas, which together accounted for over 78% of all impact locations. This verifies that forward-facing and propulsion critical structures remain the most exposed components to bird strike damage.

Fifth, the economic burden of bird strike damage reveals extreme right-skewed asymmetry. While on the one hand minor component replacements (e.g: lamps, pitot probes, radomes) result in moderate direct costs, on the other hand major powerplant damage triggers catastrophic financial losses. A single PW127M engine replacement comprised for approximately 85% of the total cumulative repair expenditure recorded across the study period.

Finally, correlation analysis demonstrated no direct linear relationship between repair expenditure and aircraft downtime. Extended grounding period is mainly governed by international spare parts procurement, supply chain lead times and customs clearance logistics rather than repair complexity or financial cost.

**Recommendation**

The airport management authority may use natural methods for scaring away birds, such as:

a) Removal of vegetation and mowing grass so that it does not exceed 10–20 cm and also is not a source of food or a place where birds are hidden
b) Drying of water tanks around the airport
c) Discouraging disposing of wanted waste near the airport
d) Drawing on the help of specially trained dogs and birds of prey.

The other prevention equipment can be avian radar. It is an advanced technology used to detect, track and monitor birds in the vicinity of airport airspace. The avian radar can assist in long term wildlife hazard management by identifying recurring bird movements, migration patterns and areas mostly used by birds for feeding and nesting. When significant bird activity is seen near aircraft traffic areas, appropriate measures such as bird dispersal, pyrotechnic devices, acoustic deterrents or other wildlife management techniques can be taken into consideration.

As per the Civil Aviation Regulation,2058 B.S, rule no. 77 there clearly states that no one shall establish an open slaughter house within 3 km form the periphery of the aerodrome area. Also, as per the rule no 78 of the same document, there is rule regarding the pollution. Its states no one is allowed to dispose the solid waste within the 3 km of the periphery of the aerodrome area.The two mentioned rule should be strictly followed in an effort to control the bird strike number. Strict implementation of these provisions should include regular monitoring of the areas surrounding aerodromes, identification of non-compliant slaughterhouses and waste-disposal sites, and appropriate enforcement actions against violations. Coordination among the Civil Aviation Authority, local government authorities, airport management, and other relevant agencies would also be necessary to control activities that attract birds.

## References

Thapa, B. (2001). Management of bird and other wildlife hazards at Tribhuvan International Airport, Kathmandu, Nepal. Bird Strike Committee USA/Bird Strike Canada Proceedings, 13. University of Nebraska - Lincoln Digital Commons.

Yadav, B. K. (2017). Aircraft collisions and bird strikes in Nepal between 1946 and 2016: A case study. Journal of Aeronautics & Aerospace Engineering, 6(3), 193.

AvioSpace Safety Analytics. (2026). Nearly 100 aircraft lost: How common & dangerous are bird strikes in Nepalese aviation? AvioSpace Aviation Insights Network.

Hanine, S. (2025). Innovative bird strike mitigation strategies: Integrating drones and cutting-edge technologies to enhance airport safety. International Journal of Aviation, Aeronautics, and Aerospace, 12(1), Article 4.

Varnousfaderani, E. S., & Shihab, S. A. M. (2024). Bird strikes in aviation: A systematic review for informing future directions. IEEE Transactions on Aerospace and Electronic Systems, 60(4), 4112–4129. https://doi.org/10.1016/j.ast.2025.110303

Civil Aviation Authority of Nepal. (2024). State safety program annual report: Safety data analysis and hazard prioritization. CAAN Corporate Safety Department.

European Union Aviation Safety Agency. (2023). Bird strike damage & windshield integrity vulnerability: Final safety research report (EASA-REP-2023-09). EASA Safety Promotion and Research Domain.

Flight Safety Foundation. (2025). Regional airworthiness needs analysis study (Asia Pacific region): System component failure tracking and power plant reliability updates. Flight Safety Foundation Reports.

International Civil Aviation Organization. (2024). ICAO world wildlife strike statistics: Analysis of the ICAO Bird Strike Information System (IBIS) electronic data (EB-2024/18). ICAO Safety Management Section.

Thapaliya, R. M. (2016, November 23–25). Airport bird/wildlife strike hazard mitigation initiative in Nepal. World Birdstrike Association (WBA) Annual Conference, Amsterdam, Netherlands.

ISBN 978-9905-0-1348-3

