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Uncovering Seasonal Trends in Motor Insurance Claims: A Gender-Based Analysis

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ABSTRACT

The seasonal dynamics of motor insurance claims are shaped by a complex array of factors, including distinct gender-based trends among drivers. This study explores these intricate patterns by analysing insurance claims across various seasons, with a particular focus on the differences between male and female drivers. Utilising a comprehensive dataset and advanced machine learning techniques, the research highlights significant seasonal fluctuations in claim behaviours across genders. Notably, malicious damage claims spike in February for both genders, with additional surges in December and January. Miscellaneous accidents remain stable, pointing to a need for continuous preventive measures. Meteorological events are most frequent in summer, with July marking the peak for both genders, while hydrological events exhibit similar seasonal trends, and climate events show minor peaks. Geophysical events remain steady, emphasising the importance of resilience strategies. These preliminary insights offer valuable implications for improving insurance risk assessments, shaping policy development, and refining pricing strategies. By increasing the precision and equity of insurance models, this study aims to promote safer driving practices, ultimately lowering costs and ensuring more affordable premiums for all policyholders.

Keywords: Gender, Seasonal trends, Catastrophic events, Claims events, Machine learning.

INTRODUCTION

In the intricate landscape of motor insurance, identifying and analysing patterns in claims is essential for optimising risk assessment, pricing models, and customer satisfaction. Among the myriad factors shaping claim frequency and severity, seasonal variations and gender distinctions are particularly significant. Seasonal factors—driven by weather changes, holiday periods, and behavioural shifts in driving—strongly influence the frequency and nature of motor claims. Gender-based differences, too, bring unique complexity to insurance analytics, linked to divergent driving patterns, risk perceptions, and claims behaviour.

Studies such as Lucas et al. (2019) illuminate these distinctions, revealing that women tend to seek support services more frequently and adhere more strictly to speed limits during rainy conditions, motivated by a heightened perception of risk. Men, by contrast, report feeling safer in high-risk scenarios, contributing to behavioural differences in claim trends (Lucas et al., 2019). Despite these insights, the role of gender in insurance pricing remains a subject of debate. Gender-based ratings risk reinforcing stereotypes, potentially disregarding behavioural data that would contribute to fairer, more individualised evaluations (Medders et al., 2021). In response, some regions, notably the European Union, have restricted gender as a factor in setting premiums,

advocating for fairness. Conversely, many support gender-neutral pricing models that incorporate richer behavioural insights, especially as telematics and data-driven models afford more tailored risk assessments (Cather, 2020; Aseervatham et al., 2016).

The insurance industry is increasingly embracing personalised pricing, leveraging advanced technologies to monitor driver behaviour rather than relying solely on demographic factors. Yet understanding the evolution of claim patterns across seasons remains crucial for insurers seeking to refine risk assessments and pricing strategies. Despite the clear importance of seasonal dynamics, limited research has specifically examined gender role in claim behaviour across various incident types and natural events.

This study addresses this gap by analysing the seasonal variation in motor insurance claims for male and female drivers. Using a robust dataset and advanced machine learning techniques, this research uncovers valuable insights into how incident types including malicious damage, meteorological events, and accidents fluctuate over the year. These findings are instrumental in developing more accurate, fair, and cost-effective insurance models that do not enhance risk management and encourage safer driving habits to make premiums more accessible for most customers.

LITERATURE REVIEW

The non-life insurance sector operates in a highly competitive and regulated environment, compelling insurers to design pricing strategies that align with both corporate objectives and dynamic market conditions. Pricing decisions are shaped by various strategic and societal factors, including policyholder gender, age-based premium fairness, and considerations for individuals with serious illnesses or disabilities. To achieve fairness in pricing, insurers must define, measure, and mitigate biases while ensuring consistency and maintaining performance standards. Historical data and statistical models play a crucial role in assessing and addressing fairness bias, particularly in automobile insurance (Isimoya et al., 2022).

Several studies have explored factors influencing motor insurance pricing and claims. Porrine et al. (2020) investigated the impact of the European Court of Justice's Test-Achats ruling on gender-neutral pricing within the motor-vehicle insurance sector. Their research highlighted the legal and economic challenges associated with risk classification, showing that while male and female premiums diverged after the ruling, this shift introduced potential inequalities in the market. Similarly, Gebru et al. (2021) examined seasonal variations in motor insurance claims, finding February to have the highest claim rates and August the lowest, but noted no significant gender-based differences in claim rates. Pernagallo et al. (2024) corroborated the absence of statistical justification for charging women higher premiums, although they observed a narrower distribution of claims among female policyholders.

Advancements in predictive methodologies have further enriched motor insurance research. Alamir et al. (2021) demonstrated that machine learning algorithms could predict motor insurance claim statuses with high accuracy—achieving 98.36% with Random Forest and 98.17% with Support Vector Machines. Xiang et al. (2023) extended the use of machine learning by developing a model that predicts gender based on facial features, with a Gradient Boosting algorithm delivering optimal performance, showing potential applications for biometric verification. Additionally, Poufinas et al. (2023) identified weather conditions and car sales as significant predictors of insurance claims, while Baran et al. (2022) addressed the challenge of imbalanced datasets in claims prediction. Men et al. (2022) introduced a supervised neural network model for driving risk assessment using telematics and insurance claims data. This model improved upon the classical Poisson generalised linear model for predicting claims frequency, enabling insurers to uncover greater portfolio heterogeneity and attract safer drivers through premium discounts.

Despite these advancements, few studies have thoroughly addressed gender-specific patterns in motor insurance claims. This gap highlights the need for integrating gender analysis, seasonal trends, and advanced predictive methodologies to enhance fairness and accuracy in motor insurance pricing and claims forecasting. This review underscores the importance of combining these factors to refine risk assessment models and achieve equitable outcomes in the motor insurance industry.

METHODOLODY

This study uses a dataset of disaster-related claims, segmented by subtype (catastrophic events classified in **Table 1**) and gender-specific metrics, with initial data cleaning performed to ensure consistency and accuracy. The dataset was collected from an insurance company in South Africa, providing a regional perspective on claim trends. Following data preparation, Exploratory Data Analysis (EDA) was conducted to understand the distribution and relationships within the dataset. Descriptive statistics and visualisation techniques, such as histograms and bar

charts, were utilised to identify claim patterns across disaster subtypes and observe gender-based differences in claim probabilities and relative risks. EDA is a statistical method that employs descriptive statistics and graphical tools to enhance data understanding, detect outliers, and test assumptions before applying additional statistical methods (Camizuli and Carranza, 2018).

To assess gender differences in seasonal claim patterns, probability techniques were applied to analyse any statistically significant distinctions. Additionally, four machine learning algorithms—Random Forest, XGBoost, Neural Networks, and Support Vector Classifier—were selected for predicting the likelihood of claims. Each model was trained on a portion of the dataset, with gender and disaster subtype as key predictive features. These algorithms were chosen for their efficacy in classification tasks. This methodological approach integrates data exploration with predictive modelling, offering a robust foundation for analysing disaster-related claims in the insurance sector.

Table 1. Catastrophic events classified into different Subgroups.

Miscellaneous Accidents	**Malicious Damages**	**Meteorological**	**Hydrological**	**Geophysical**	**Climatological**
Explosion	Accidental Damage	Storms	Floods	Landslip	Fire
Send Our Services (SOS)	Theft/Hijack	Hails			Wind Fire
Impact Vehicles or animals or Falling tress	Malicious Damage	Thunders			
	Fire				

RESULTS

Figure 1 shows the distribution of catastrophic events across seasonal patterns is critical for understanding and managing associated risks effectively. Malicious damage claims exhibit a pronounced seasonal variation, with a high incidence in January and February, a decline during the middle months, and a subsequent rise in October, November, and December. In contrast, miscellaneous accidents display a relatively stable distribution, with incidents consistently ranging between 34% and 38%. This stability suggests the influence of persistent risk factors that necessitate year-round preventive measures. Meteorological and hydrological disasters demonstrate distinct seasonal trends, peaking between June and September, with an additional increase observed from March to July. These patterns highlight the importance of seasonal preparedness and the strategic allocation of resources to mitigate the impacts of weather-related disasters. Emphasis must be placed on developing robust infrastructure and implementing early warning systems to enhance disaster resilience during these critical periods. Climatological and geophysical events show a more consistent distribution. Climatological disasters exhibit a slight peak in spring and early summer, while geophysical events remain stable throughout the year. Despite their relative stability, these events demand ongoing monitoring and the implementation of long-term mitigation strategies, including improved building codes and land-use planning. Such measures are essential for reducing vulnerability and enhancing resilience to these types of disasters.

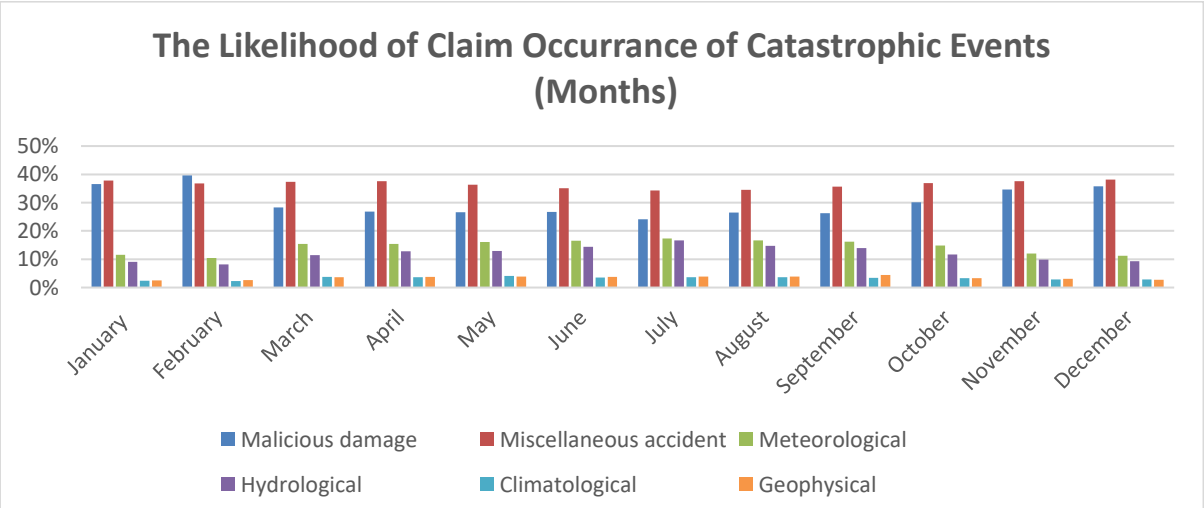

Figure 1. The Likelihood of Claims Occurrence by Months.

Figure 2 depicts distinct seasonal trends in the types of catastrophic events influencing claim frequencies among female clients. Claims related to malicious damage exhibit notable peaks in February (39%) and December (36%), suggesting an increase in incidents during the post-holiday period. This pattern may be shaped by socio-economic factors characteristic of these times of year. Miscellaneous accidents display relative stability throughout the year, with fluctuations confined to a narrow range of 34% to 39%. This consistency indicates the predominance of persistent risk factors and underscores the importance of sustained preventive measures. Meteorological events reach their highest levels during the summer months, particularly between June and August, with a peak of 17%. This trend is likely attributable to seasonal weather conditions typical of this period. Similarly, hydrological events exhibit pronounced peaks in July (17%) and August (16%), correlating with the heavy rainfall commonly experienced during these months. Climatological events show a slight increase during the spring and summer months, from March to August, averaging around 4%. This modest rise may be linked to specific climatic conditions prevailing during this period. Geophysical events, by contrast, remain consistently low throughout the year, accounting for 3% to 4% of claims. Despite their infrequency, these events necessitate ongoing preparedness and resilience-building efforts due to their potential for severe impacts.

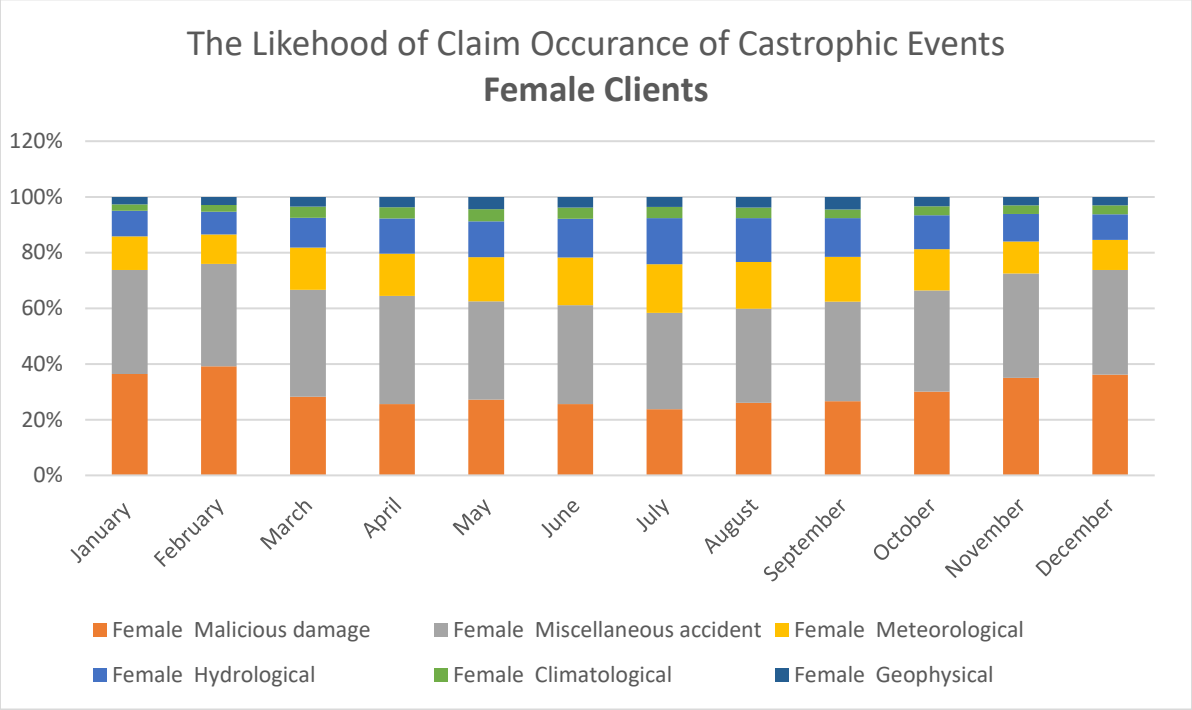

Figure 2. The monthly likelihood of claims arising from various catastrophic events among female client.

Figure 3 presents a monthly analysis of the types of claims filed by male clients as a result of catastrophic events, elucidating key trends within each claim category. Claims related to malicious damage exhibit fluctuations between 24% and 40%, with a notable peak in February and additional increases observed in December and January. These patterns may suggest a potential correlation with particular times of the year, potentially influenced by social and economic factors. Miscellaneous accident claims demonstrate a relatively stable occurrence, with only slight monthly variation, consistently ranging from 34% to 39%. This stability indicates that such incidents are less affected by seasonal factors and are more likely attributable to routine, year-round risks. In contrast, claims arising from meteorological and hydrological events exhibit greater seasonal variability. Meteorological claims range from 10% to 17%, peaking in July, which may reflect the influence of seasonal weather conditions on this claim type. Similarly, hydrological claims fluctuate between 8% and 17%, with a marked peak in July, potentially corresponding to periods of heightened rainfall or related climatic events. Claims associated with climatological and geophysical events remain consistently low, each accounting for 2% to 4%. This consistency suggests that these claim types represent a minimal but steady risk throughout the year.

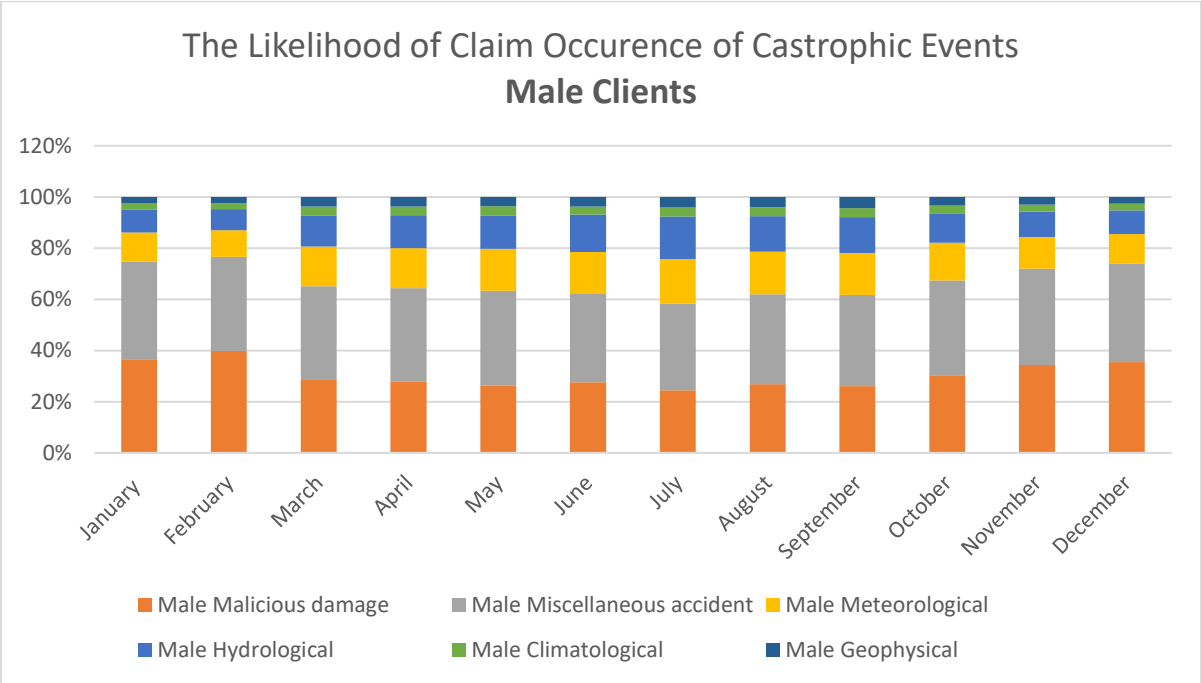

Figure 3. The monthly likelihood of claims arising from various catastrophic events among male client.

GENDER COMPARISON

The comparison analysis provides insights into the seasonal trends of claims filed by male and female clients due to catastrophic events, revealing both similarities and differences in claim patterns between genders.

For both male and female clients, malicious damage claims peak in February, with additional increases in December. This suggests that certain socio-economic factors around these times, potentially related to the post-holiday period, may influence claim frequencies. The fluctuation ranges are similar, with female clients seeing a peak of 39% in February and male clients ranging between 24% and 40%. Miscellaneous accidents remain relatively stable throughout the year, fluctuating between 34% and 39% for both genders. These suggest that the associated claims may be due to consistent, year-round risks rather than seasonal factors.

However, the seasonal trends in weather-related events reveal notable gender differences. For male clients, meteorological claims fluctuate between 10% and 17%, with a peak in July. For female clients, meteorological claims are noted to peak generally in winter and spring months, particularly from June to August. This suggests possible gender differences in exposure or risk during this season. Similarly, hydrological claims for male clients also peak in July (ranging from 8% to 17%), likely linked to seasonal rainfall. For female clients, however, hydrological claims peak in both July (17%) and August (16%), possibly reflecting a similar but slightly extended seasonal impact. Both genders experience consistently low climatological and geophysical claim rates, between 2% and 4% throughout the year, though male and female clients' peak months may slightly differ. This would be showing a general alignment in risk but with minor variations in timing.

In summary, while malicious damage and miscellaneous accidents demonstrate similar patterns for both genders, male and female clients exhibit slight differences in their meteorological and hydrological claim peaks. These variations could indicate distinct risk factors or behavioural patterns influenced by gender. Hence further analysis could explore whether socio-economic, environmental, or behavioural factors contribute to these observed differences.

CLAIMS PATTERN AMONG GENDER SPECIFIC

Table 2 reveals insights into the distribution of claims by disaster subtype and gender, highlighting patterns and implications for risk management. Miscellaneous accidents emerge as the most frequent cause of claims, comprising 37% of the total, followed closely by malicious damage at 31%. Claims attributed to meteorological and hydrological events account for 14% and 12% respectively, while geophysical and climatological events make up a smaller portion, each contributing 3%. When analysing gender distribution, males consistently show a higher likelihood of filing claims across most disaster subtypes, accounting for 57% of total claims compared to 43% for females. This disparity is particularly pronounced in meteorological events (8% for males vs. 6% for females) and hydrological disasters (7% vs. 5%). The relative risk for females is lower across all disaster categories, ranging from

74% to 82%. This indicates a consistent trend of lower claim likelihood among females compared to males' counterparts.

Table 2. The likelihood of claims arising from various catastrophic events Male vs Female client.

Disaster Subtype	Probability of Claim	Probability of Claim is Male	Probability of Claim is Female	Probability of a Claim is Male or Female	Probability of a claims is Disaster Subtype given is Male	Probability of a claims is Disaster Subtype given is Female	Relative Risk Claims (FEMALE VS MALE)
Malicious damage	31%	18%	13%	28.45%	57%	43%	74%
Miscellaneous accident	37%	21%	16%	33.28%	57%	43%	75%
Meteorological	14%	8%	6%	13.71%	57%	43%	75%
Hydrological	12%	7%	5%	11.50%	57%	43%	76%
Climatological	3%	2%	1%	3.20%	55%	45%	82%
Geophysical	3%	2%	1%	3.39%	56%	44%	77%
Total	100%	57%	43%	75.51%	57%	43%	75%

SYSTEM DETECTOR ALGORITHM

Table 3 showcase the algorithm accuracy highlights the predictive strengths of various machine learning models in estimating claim likelihoods across different disaster subtypes. Neural Networks achieved the highest accuracy at 0.76, followed by Random Forest at 0.71, indicating that these models offer the most reliable predictions for disaster-related claims. In contrast, the XGBoost and Support Vector Classifier (SVC) models, with accuracies of 0.64 and 0.58, respectively, are less robust for this classification task.

Integrating these predictive insights with the gender-specific probabilities and relative risks in the initial analysis provides a more targeted understanding of claimant behaviour. Neural Networks and Random Forest models can be effectively employed to refine predictions about which gender is more likely to submit claims across disaster subtypes. Given that males have higher overall claim probabilities across all subtypes, these models can enhance accuracy by focusing on key indicators prevalent among male claimants. However, with the relative risk significantly higher for females in subtypes such as climatological disasters (82%), these algorithms should also be tuned to detect higher susceptibility in females for specific risks. This blended approach, leveraging the strengths of Neural Networks and Random Forests, could enable insurers to make data-driven adjustments, anticipating not only the likelihood of claims but also gender-differentiated risk patterns with a high degree of accuracy.

Table 3. The predictive strengths of various machine learning models in estimating claim likelihoods across different disaster subtypes.

ALGORITHM	ACCURACY
Random Forest	0.71
XGBoost	0.64
Neural Networks	0.76
Support Vector Classifier	0.58

DISCUSSION

The data provided offer a comprehensive view of disaster-related claims and gender-based patterns, complemented by an evaluation of machine learning models' effectiveness in predicting these claims. Beginning with the claim distribution across disaster subtypes, it is evident that "Malicious damage" and "Miscellaneous accidents" are the most frequent claim types, accounting for 31% and 37% of the claims, respectively. Conversely, less frequent claim types such as geophysical and climatological disasters exhibit a substantially lower probability, each contributing about 3% of total claims. This distribution suggests that claims are heavily skewed towards

certain disaster subtypes, reflecting specific risk patterns that are likely influenced by the nature of these events and their frequency.

When considering the gender-based probabilities within these disaster subtypes, male claimants consistently exhibit higher claim probabilities. For example, 18% of "Malicious damage" claims and 21% of "Miscellaneous accident" claims are attributed to males, compared to 13% and 16% for females, respectively. This suggests that males may be more frequently exposed to or impacted by disaster events leading to claims. However, the relative risk (RR) assessment offers a more nuanced interpretation. This shown that females carry a heightened relative risk for claims across several disaster types. Notably, in climatological events, females have an RR of 82% relative to males. This suggests that although males generally have a higher claim probability, females may be more vulnerable or impacted more severely when claims occur within specific subtypes.

To enhance the accuracy of predictions and improve insights into these patterns, a selection of machine learning models has been evaluated. Neural Networks and Random Forests, with accuracies of 0.76 and 0.71 respectively, emerge as the strongest models. These suggests these models' efficacy in identifying nuanced patterns in disaster claims data. On the other hand, XGBoost and Support Vector Classifier (SVC) models demonstrate lower accuracies of 0.64 and 0.58 respectively. These indicate the models' limited effectiveness in this context. These results highlight the value of model selection in predictive tasks. Neural Networks and Random Forest models may be particularly suitable for identifying the overall claim patterns and gender-specific probabilities and risks.

In synthesising these findings, the interplay between claim probability, gender risk, and model accuracy becomes apparent. The higher probability of male claims may inform predictive modelling by prioritising male-specific indicators across the more frequent disaster subtypes. However, given the elevated relative risk observed in females for certain disaster types, predictive models especially Neural Networks and Random Forests should incorporate parameters that capture gender-specific risk factors to enhance accuracy in these areas. This integrated approach, using both high-performing models and a nuanced understanding of gender-specific risks, could inform insurance providers in tailoring their policies more precisely. Insurers could achieve a balanced approach that aligns with actual claim behaviours and gender-differentiated vulnerabilities by adjusting premiums and risk assessments according to these patterns. This may result in fairer, data-driven disaster insurance strategies.

CONCLUSION

The analysis reveals clear trends in disaster-related claim behaviours with Malicious damage and Miscellaneous accidents show to be the most frequent, while less common events like climatological and geophysical disasters show lower claim probabilities. Gender-based insights highlight that males generally have higher claim probabilities across all disaster subtypes, but females carry a greater relative risk, particularly in climatological events. This gender-disparity underscores the importance of considering the frequency the impact severity when assessing risk. The evaluation of predictive models indicates that Neural Networks and Random Forests outperform other methods. They offer enhanced accuracy in identifying these risk patterns across disaster types.

RECOMMENDATION

To optimise disaster insurance strategies, this paper recommends that insurers should leverage high-performing models such as Neural Networks and Random Forests for claim prediction, as these models have demonstrated reliability in identifying complex claim patterns. The insurers should also consider gender-specific risk adjustments, particularly for females in high-risk subtypes such as climatological events. Implementing a risk-adjusted premium structure could ensure fairer pricing aligned with the distinct risk profiles observed. This can enhance both accuracy and equity in premium determination. Finally, periodic reassessment of model accuracy and risk metrics are recommended to account for changing patterns in disaster exposure and claimant demographics, allowing for adaptive and responsive disaster insurance policies.

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