Research Article
Academic Platform Journal of Natural Hazards and Disaster Management
4(1), 34-48, 2023 DOI: 10.52114/apjhad.1212778

What Damages Are the Most Frequent in Airport Infrastructure?

Tarik Lahna[1*], Bernard Foguem-Kamsu[2], F. Henry Abanda[3]

[1]Department of Computer Science, ENIT, France
[2]Department of Computer Science, ENIT-INPT, France
[3]School of the Built Environment, Oxford Brookes University, UK

Received: / Accepted: 21-November-2022 / 27-June-2023

Abstract

Airport is one of the most critical infrastructures that have exhibited substantial growth and profits in recent years. Although airport infrastructure represents an integral part of the economy of cities, researchers have shown that many incidents that have led to flight disruptions have often occurred in airport infrastructure. Also, the maintenance cost of airport buildings has increased significantly, necessitating a call from professionals to investigate efficient methods of curbing the same. Hence, cost reduction is possible by innovating ways thanks to predictive maintenance techniques based on artificial intelligence. However, working on the innovation of processes that modernize maintenance in airport buildings takes much work due to the many causes. Incidents can be caused due to different reasons (Structural, Electrical, Hydraulic, Computing, Unknown, etc.) This paper tackles this challenge by investigating and identifying the most frequent damages and their origins in airport infrastructure based on a statistical study. This paper aims to determine the incidents and their causes in airport infrastructures that should be considered more for future research. The result showed that cracks are the most frequent type of damage, with 22,12% of appearance, and that wear is the most frequent origin of incidents in airport infrastructure, with 29,17% as a frequency of appearance. Also, it shows that 85,51% of cracks are located in runways. These findings help better understand the problem and serve as the point of departure for researchers interested in solving it.

Keywords: Airport infrastructure, Damages, Statistical analysis, Cracking

1. Introduction

Maintenance in airport infrastructure (MAI) is attracting huge interest from both practitioners and academics, knowing the increase of the total number of deteriorations is happening in airport buildings because of different reasons such as climate change, for example [1]. Therefore, maintenance practices are still poor since collecting data to inspect facilities is time-consuming, and the budget and resources allocated for building maintenance are insufficient. These facts explain why the maintenance of facilities and the quality of management are still poor and why incidents frequently occur in aeronautical buildings. In addition, the world knows diverse and severe disasters creating enormous economic and human impacts in many countries worldwide [2]. So, this implies a financial crisis and then limited budgets to repair when there are any failures in airport infrastructure [3]. Therefore, to elaborate innovative methods which may be used as predictive maintenance techniques in airport buildings, a statistical analysis is needed to determine the most frequent types of damages and origins of incidents in airport

* Corresponding author e-mail: lahnatk@ucla.edu

infrastructure. This study will enable to work on efficient methods that may improve the maintenance of airport infrastructure.

By knowing the most frequent incidents in airport infrastructures, future researchers may focus on using artificial intelligence methods to predict these incidents based on their occurrences that were performed in statistical studies. For example, some studies were realized to predict cracks in structures [4].

Generally, industrial plants, including airport buildings, impact various applications. These include maintenance and strategic planning of their operations [4]. Most of these innovative methods are based on machine learning and data science and prevent downtime due to unscheduled maintenance, reducing costs and increasing safety since collaborative intelligent manufacturing will be prioritized after the Covid-19 pandemic crisis [5]. However, the inexistence of innovative methods based on artificial intelligence will result in time lags for these maintenance operations. That is why it is essential to establish the most frequent incidents and their origins to understand where we should prioritize future research on maintenance in airport infrastructures.

The research presented in this paper is exploratory in nature, not causal. It does not seek to solve the problem of detecting damages in airport facilities. It instead aims to improve our understanding of the problem and the extent to which it has been resolved so far and provide a foundation for future researchers interested in solving it. This is why the main objective of this paper is to identify the most critical damage types, given how frequent and what are the origins of these damages. By doing this, future researchers may perform algorithms on these frequent incidents based on artificial intelligence. The authors identified the most frequent objects based on a frequency-based statistical analysis from Google public database showing the incidents that occur in airport infrastructures worldwide. The most critical damage types and the most frequent origins of these damages were ranked based on their frequency of appearance.
More particularly, the purpose of this study, which is based on statistical analysis, is to answer the following research questions:

- First, what steps were used in this study to perform the statistical analysis?
- Second, what are the most frequent incidents in airport infrastructures?
- Third, what are the most frequent origins of these incidents?
- Finally, what is the ultimate goal of identifying these damage types and sources?

To answer these research questions, the paper draws a methodology describing data collection, the hypothesis made for the study, and the statistical analysis. This paper is organized as follows: Section 3 describes the research background. Section 4 describes the research methods that were used in this study. Section 4 presents the statistical results of this study. Section 5 presents the conclusion and discussions. Sections 6 and 7 deal with the conflict of interests and the contributions.

2. Research Background

2.1. Airport infrastructure

Airport facilities are essential for any region in the world [6]. This demonstrates why researchers were solving risk assessments around airport facilities [7]. Moreover, a group of researchers studied airports' impact on Turkey's regional economy. They proved using the two stages least squares method that a 1%-point increase in airline traffic per capita implies an increase in GDP at 0.017% [8]. Therefore, this shows the importance of airport infrastructures for any region worldwide. To avoid problematic incidents and ensure effectiveness in airport facilities, continuous innovation, and new technology are essential to provide a high-quality service offering and complete customer safety. Among the latest technologies, predictive maintenance methods are increasingly present in research, as shown in Frankfurt Airport, where scientists introduced RFID-based maintenance to ameliorate the planning and control of technicians' work [9]. In US airports, researchers were involved in maintenance activities for airport pavements using artificial intelligence methods [10]. Airport infrastructure can be divided into three main categories [11].

a. Essential operational services and facilities
b. Traffic-handling services
c. Commercial activities

These three main categories are detailed in Figure 1:

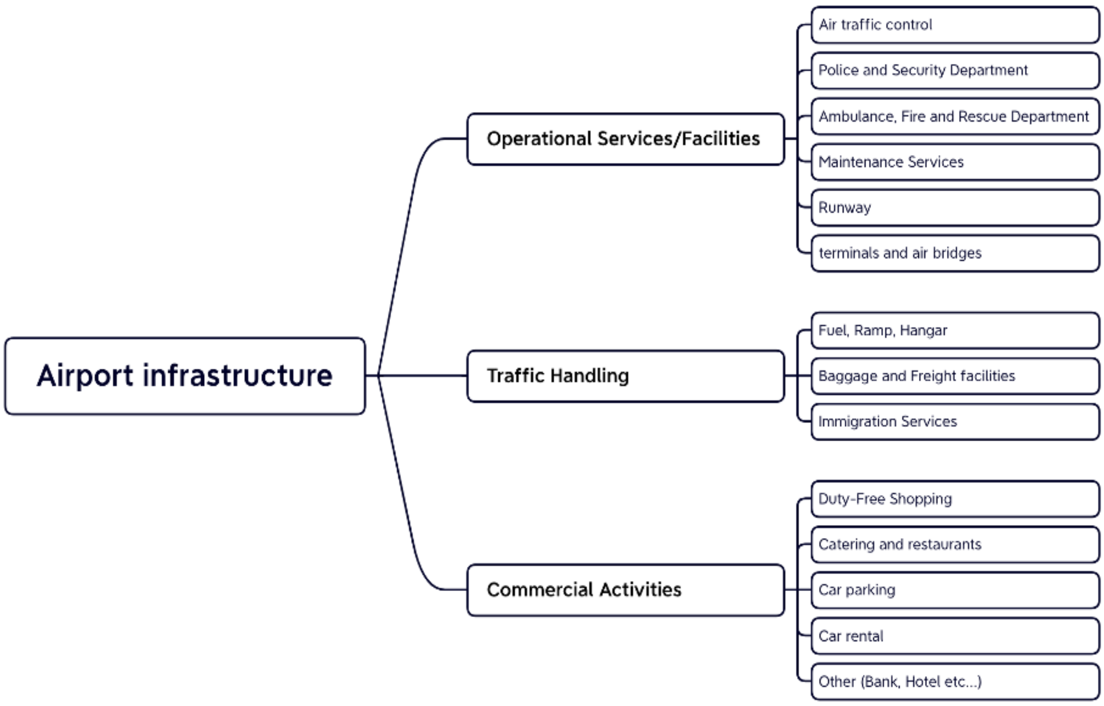

Figure 1. The three main categories of airport infrastructure

2.2. Gap in knowledge and research question

There needs to be a substantive study that prioritizes the types of damages in airport infrastructures based on their frequency of appearance worldwide. However, there are related fields where damages are considered to estimate aircraft accidents, thanks to statistical studies from the academic field [12] and industrial area [13]. Therefore, the statistic of the most frequent types of damages and origins of incidents in airport infrastructure was not determined. On the other hand, some critical damage types in facilities have been identified in the literature [14]. But therefore, it still needs to be determined which damage types are essential in airport infrastructure for automated detection based on their frequency of appearance.

Moreover, if a damage type is critical but not frequent, detecting it automatically in future works is unnecessary. On the other hand, even if a damage type is regular but is not vital, this paper can ignore detecting it. Consequently, this paper aims to establish the frequent critical damages in airport infrastructure so that different algorithms based on artificial intelligence may be performed in priority as part of predictive maintenance methods.

This work aims to bridge the knowledge gaps by answering the following research question: what are the most frequent types of damages and origins of incidents in airport infrastructure in terms of frequency of appearance?

3. Research Methods

The research conducted in this paper is exploratory in nature and follows the methodology framework depicted in Fig. 2.

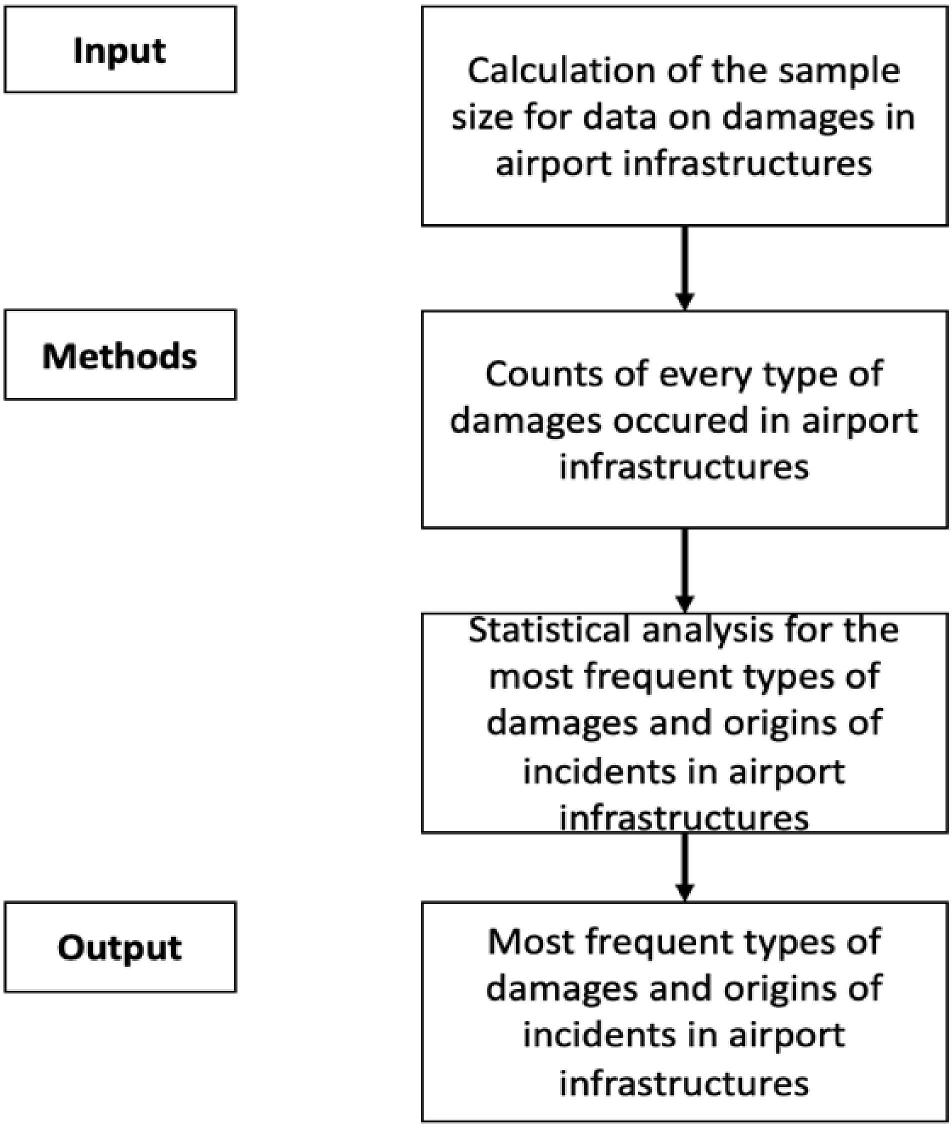

Figure 2. Research methods

The list of damages to airport infrastructure was obtained from the French database of incidents called "Aria" and from Google public database by searching the following keywords in English and French:

1. « Collapse in Airport Infrastructure »
2. « Fissures in Airport Infrastructure »
3. « Leak in Airport Infrastructure »
4. « Electrical failures in Airport infrastructure »
5. « Computing failures in Airport infrastructure »

After searching the following keywords in English and French, and reading all articles from Aria and Google, an Excel file was created to facilitate the statistical analysis by including different information, as illustrated in Figure 3.

Description	Date	Location	type of damages	Origin of damages	Link	Type of Link
A part of ceiling collapsed	07/08/2021	Lyon, France	Collapse of materials	unknown	https://www.lyonmag.com/article/117236/un-morceau-de-plafond-s-effondre-a-l-aeroport-de-lyon-saint-exupery	Press Newspaper
Collapse of airport infrastructure	23/05/2004	Roissy,Paris	Structural collapse	Structure	https://www.aria.developpement-durable.gouv.fr/accident/27228/	French database

Figure 3. Data Collection for incidents in airport infrastructure

Moreover, the list of damages was performed by ordering those elements based on their frequency of appearance. The output is the rank order of the most frequent types of damages and origins of incidents in airport infrastructures. The link to the database is https://github.com/lahnat/airport-infrastructure.git.

3.1. Data collection and assumptions

A list of 312 incidents was examined to find a statistically representative sample of damage types in airport infrastructure. An assumption was made to determine the sample size of the list of incidents needed to do a statistical analysis. This study considered only incidents from 1987 and assumes that there have been 1500 incidents in airport infrastructure in 35 years. Therefore, it means that there are 43 incidents yearly. This value was estimated after computing all incidents in 2019 from all articles worldwide via Google public database. Plus, Yamane established a simplified formula to calculate sample sizes. This formula was used to calculate the sample sizes in Tables 2 and 3 and is shown in Equation 1. A 95% confidence level and a sampling error e = 0.05 are assumed for that formula [15].

$$S = \frac{N}{1 + N\ x\ (e)^2} \tag{1}$$

Where S: Sample size

N: Total number of incidents in all airport infrastructure for 20 years

e: Level of precision or Sampling of error which is ± 5%

Therefore, the number of disasters needed to evaluate a statistical analysis of the most frequent types of damages and origins of incidents in airport infrastructure is 312.

3.2. Statistical methods

The damage types and origin categories that need to be considered are determined by performing a statistical analysis on the frequency of appearance of all damage types and damage origin categories encountered in the typically considered list of incidents. First, the frequency of appearance P is computed by dividing the total counts of each damage or damage origin category (η) by the total number of damages into all case studies (S), which is 312, as described in Equation 2.

$$P = \frac{\eta}{S} \tag{2}$$

3.3. Definition of terminologies used in this study

This paragraph defines the different terminologies that were found during the data collection process and used to compute the frequencies for damage types and damage or damage origin types. Figure 4 illustrates these terminologies for a better understanding and Figure 5 demonstrates the terminologies for the types of damage origins.

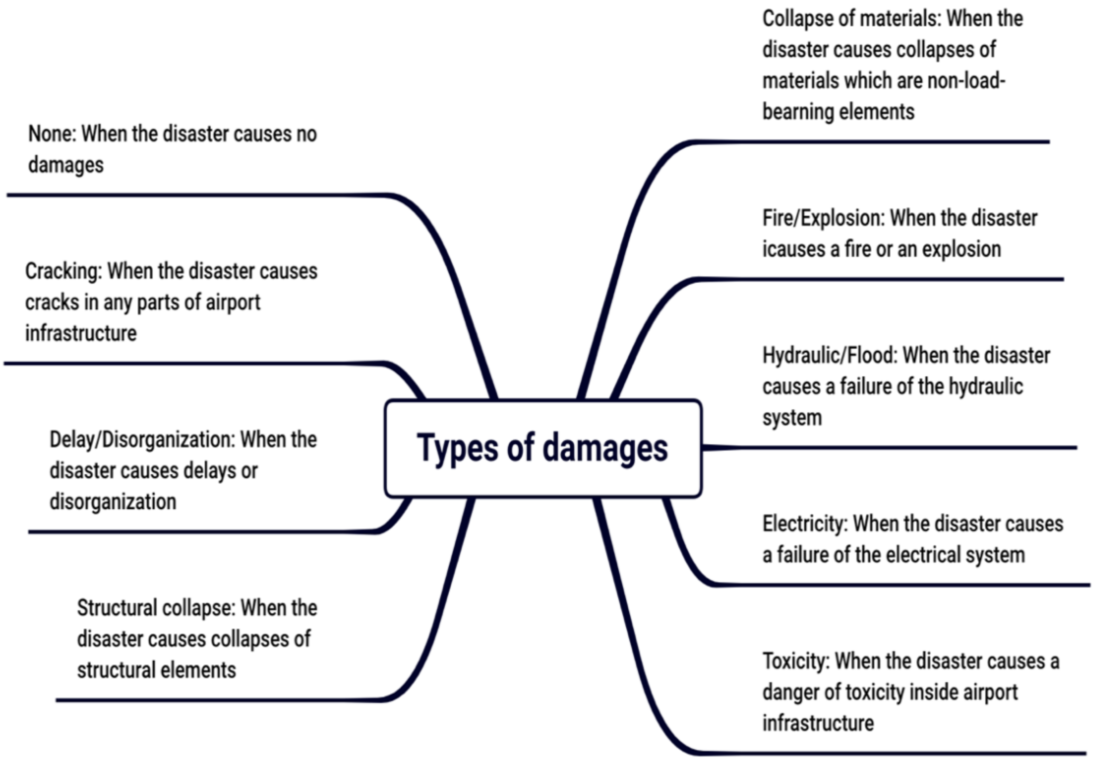

Figure 4. Terminologies for types of damages

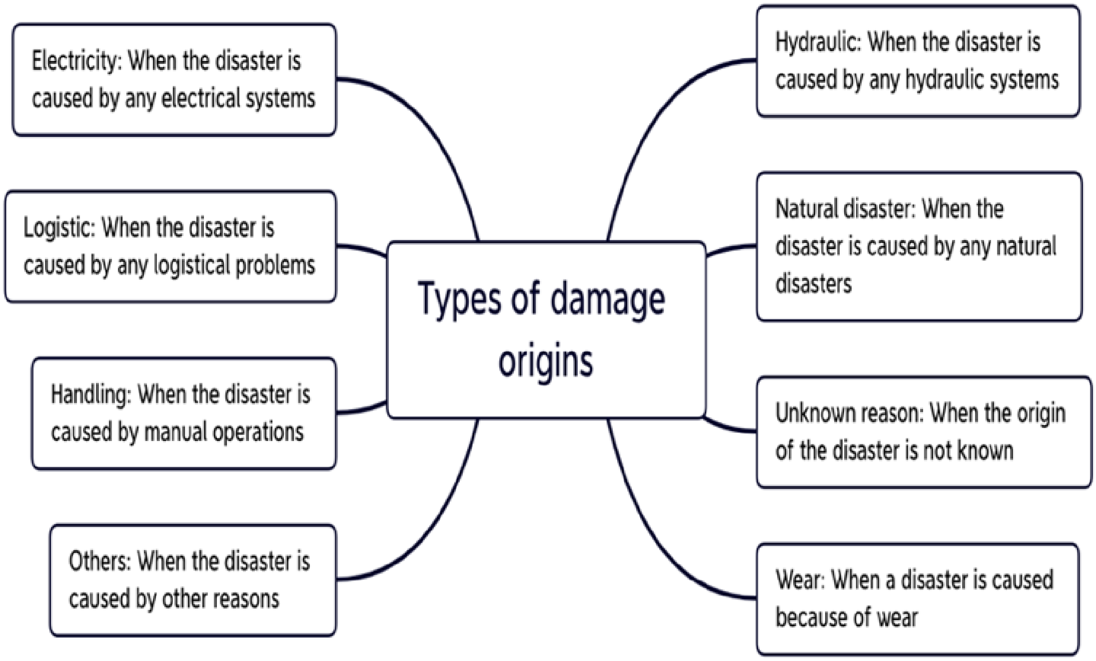

Figure 5. Terminologies for types of damage origins

Therefore, this section allows an understanding of all tools used to perform the statistical studies detailed in the next section.

4. Results and Discussion

4.1. Most frequent types of damages

The damage type rankings are calculated in descending order for all case studies in Figures 6 and 7. Cracking is the most frequent damage in all case studies, with an average frequency of around 22,12 %. Delay/Disorganization and structural collapse follow in percentages being 21,47 % and 14,74 %, respectively. These statistics are essential since most aerospace statistics are performed to evaluate accidents or incidents related only to aircraft.

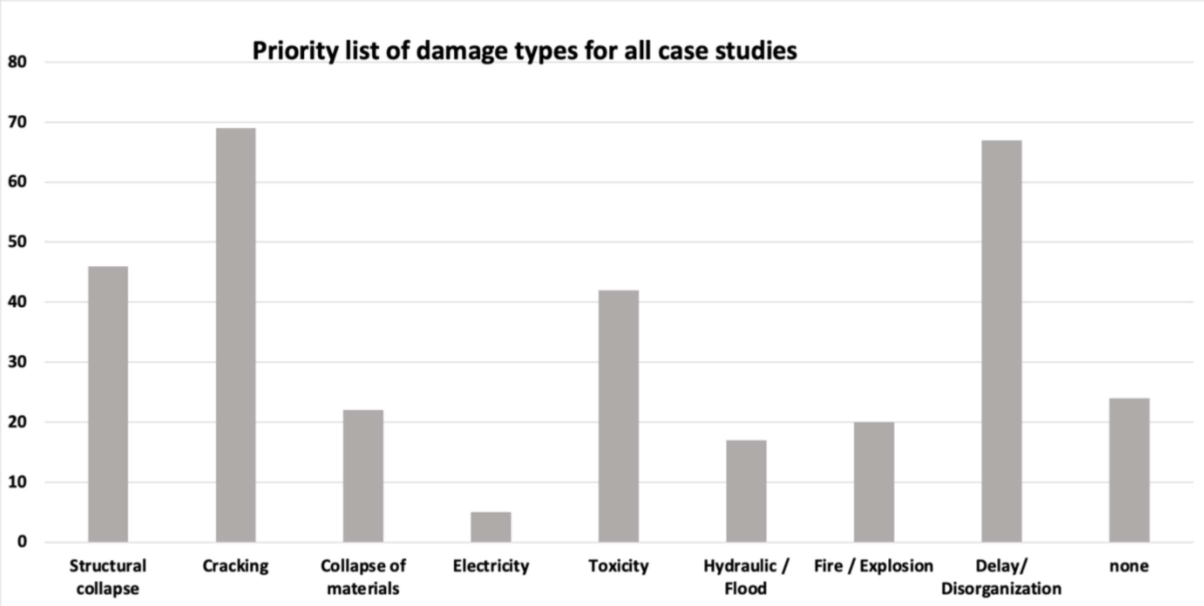

Figure 6. Frequency of damage types for all case studies

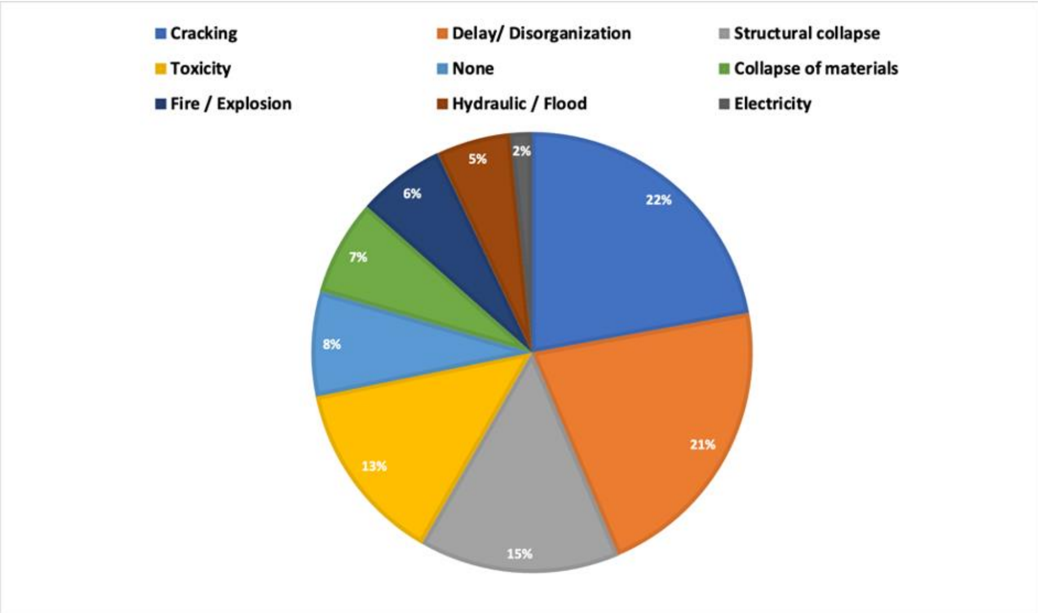

Figure 7. Frequency of appearance in percentage based on the type of damages

As regards structural damages, which are composed of cracking, "structural collapse" and collapse of materials represent 58,33 % of the total number of all case studies. Mainly, cracking represents the damage to the runways of airports, whereas structural collapse is the damage related to the fall of any airport infrastructure. Finally, "collapse of materials" includes all damages related to collapses of materials or non-load-bearing elements inside airports, such as the ceiling. Figure 8 illustrates the part in the percentage for each type of structural damage.

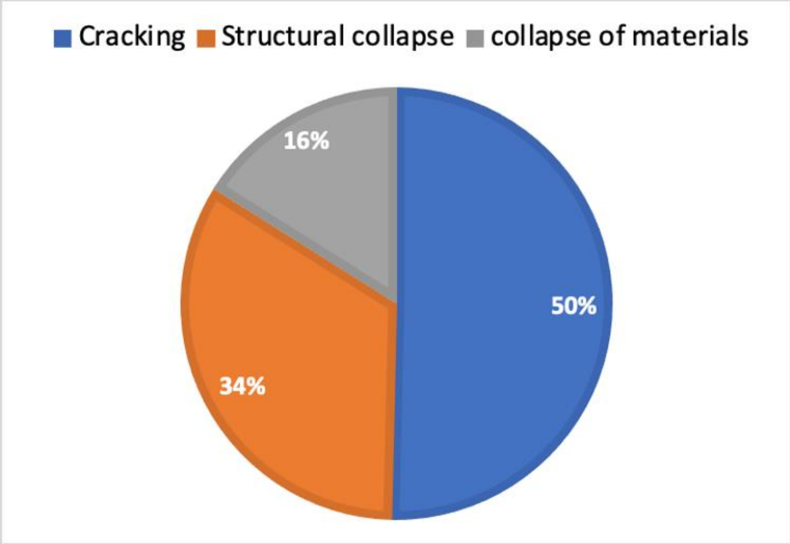

Figure 8. Parts in percentage for each structural damage in airport infrastructures

4.2. Most frequent types of cracks in airport infrastructure

The previous section shows that cracking represents 50% of the total structural damage. However, more than 85% of cracks are located in runways. Therefore, it shows that maintenance needs to be developed to detect this type of cracking which is predominant in airport infrastructure. Table 1 and Figure 9 illustrate the most frequent types of cracks in airport infrastructure.

Table 1. A priority list of cracking types for all case studies

Type Of Cracks	Frequency Of Appearance (%)	Sample Size (S)
Runways	85,51%	59
Walls/Ceilings	8,70%	6
Bridge/Tunnel	2,90%	2
Aircraft Equipment	2,90%	2

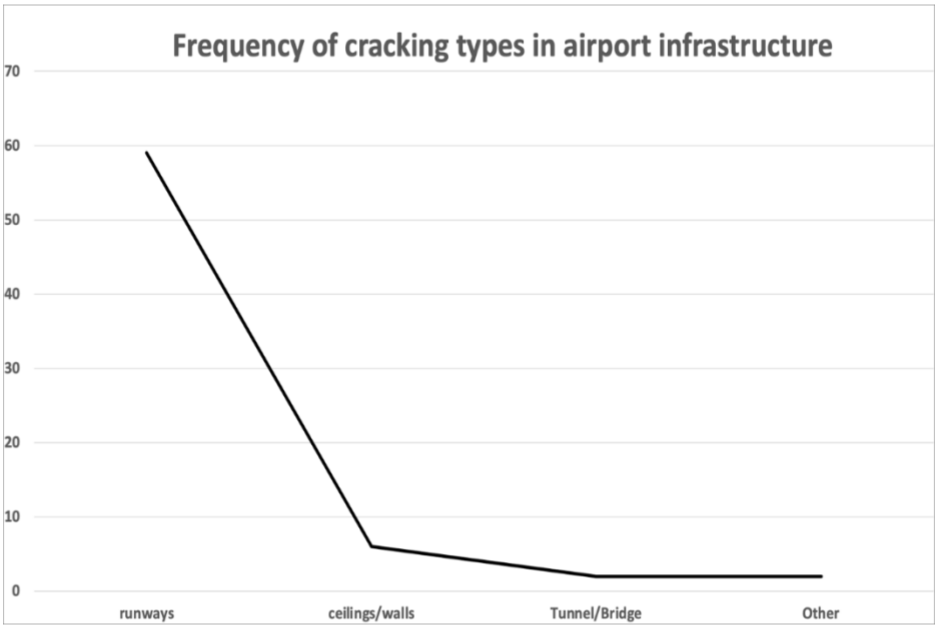

Figure 9. Frequency of cracking types in airport infrastructure

Therefore, runways present a considerable risk of cracks, et a maintenance strategy needs to be improved to avoid delays in airports.

4.3. Most frequent origins of damages

The damage's origin rankings are calculated in descending order for all case studies in Figures 10 and 11. Wear is the most frequent origin of damages in all case studies, with an average frequency of around 29,17 %. Unknown reasons and hydraulic issues follow in percentages, 13,78 % and 13,14 %, respectively. A natural disaster is the fourth origin of damage to airport infrastructure, with 12,18%.

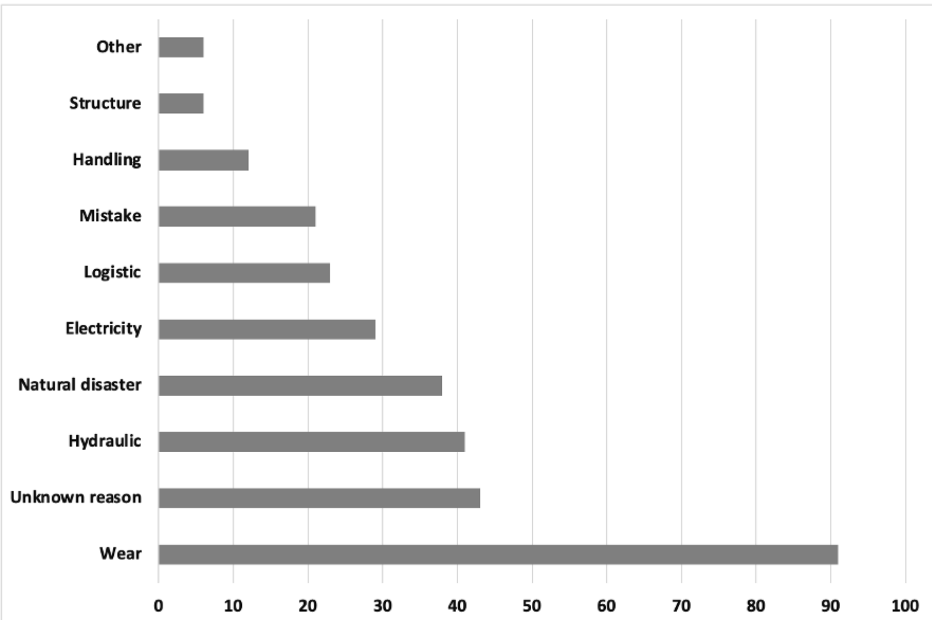

Figure 10. A priority list of damage origins categories for all case studies

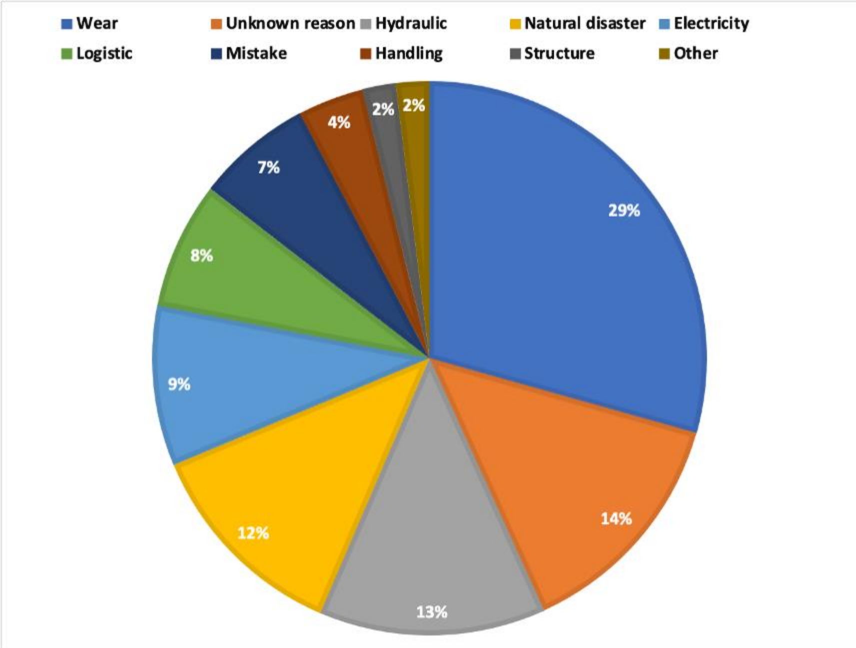

Figure 11. Frequency of appearance in % based on the type of damage origins

Therefore, the results show that better maintenance may improve the efficiency of airport infrastructure and reduce the number of incidents.

4.4. Most evolution of damages in the airport building

This study showed that the number of damages to airport infrastructure is between 15 and 30, except in 2020, as detailed in Figure 12. However, due to Covid-19, the graph shows that damages decreased in 2020 [16]. That is because of the diminution of aerospace activity in the world [17]. Therefore, the number of damages in 2020 is about 10 and dropped by 60% from 2019, as mentioned in other publications [18].

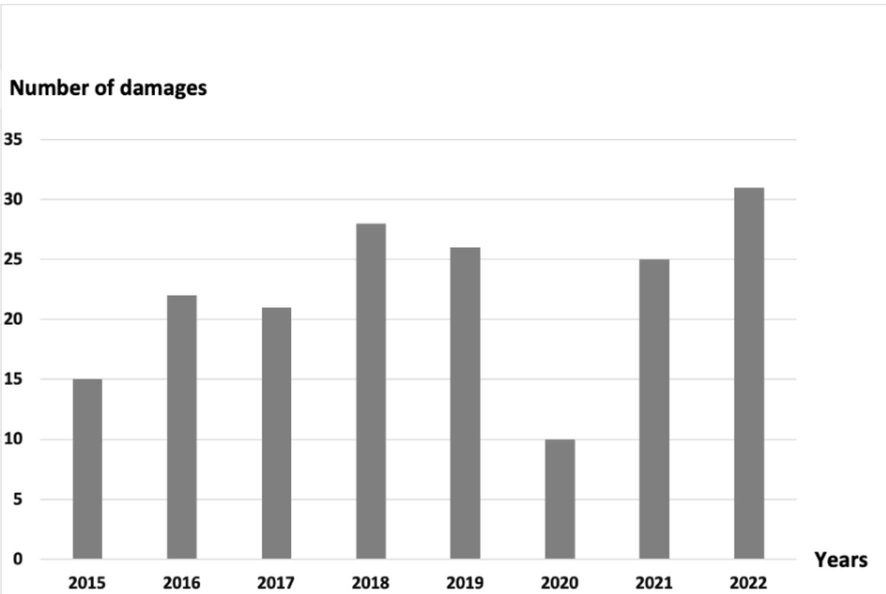

Figure 12. Evolution of the number of damages to airport infrastructure

Furthermore, the graph demonstrates an increase in damages in 2021 compared to 2020. Indeed, the number of damages in 2021 equals that in 2019. That shows the aerospace activity recovered from Covid-19, as mentioned in different publications from different aviation organizations such as McKinsey [19] and ICAO [20].

4.5. Distribution of damages in airport infrastructure around the world

This study illustrates the repartition per continent of damages in airport infrastructure globally, thanks to Figure 13. It shows that Europe has the most significant number of damages to airport infrastructure, with 181 out of 312, the total number of case studies considered in the study. Thus, America and Asia follow in the ranking with 54 and 50, respectively.

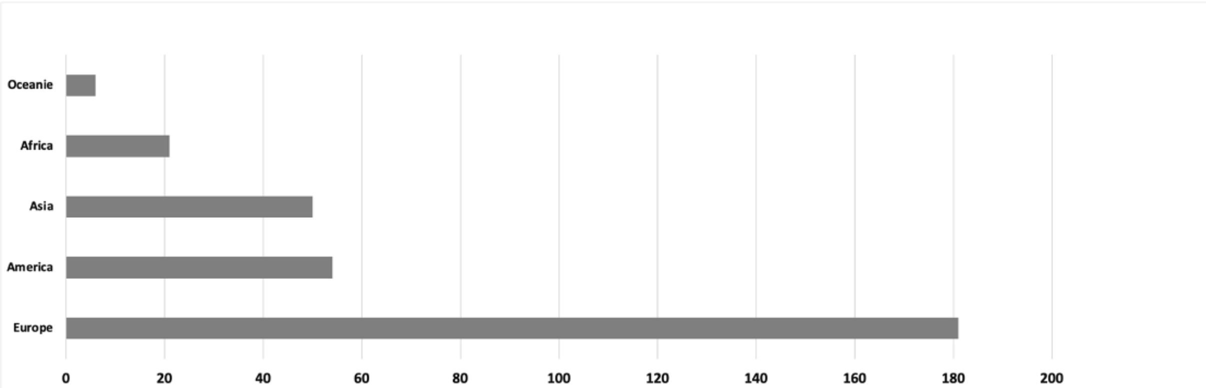

Figure 13. Distribution of damages in airport infrastructure around the world

As expected, Africa has less damage than the lack of information on the continent can explain. Moreover, Table 2 illustrates the distribution of cracks worldwide based on their types. Based on the data, structural damages (Cracking, Structural collapse, and Collapse of materials) is consistently ranked first in each continent.

Table 2. Repartition of the types of damages around the world

Type of damages	Europe	Africa	Asia	America	Oceanie
Cracking	22	16	13	16	2
Delay/Disorganization	39	1	13	13	1
Structural collapse	19	3	10	13	1
Toxicity	40	0	0	2	0
none	24	0	0	0	0
Collapse of materials	4	0	12	5	1
Fire/Explosion	15	1	0	3	1
Hydraulic/Flood	15	0	1	1	0
Electricity	3	0	1	1	0

As regards the origins of damages, wear is consistently ranked first in every continent, as illustrated in Table 3.

Table 3. Repartition of the origins of damages around the world

Origins of damages	Europe	Africa	Asia	America	Oceanie
Wear	44	14	12	16	3
Unknown Reason	21	0	9	11	2
Structural collapse	30	1	2	8	0
Natural disaster	10	2	17	8	1
Electricity	18	2	5	4	0
Computing	24	0	1	4	0
Handling	10	1	1	0	0
Other	24	1	3	3	0

Therefore, the previous research enables us to obtain more detailed results to investigate all sides of this data [21].

5. Conclusion

The most frequent damage types in the three most frequent damage categories (cracking, delay/disorganization, and structural collapse) are ranked based on their frequency of appearance. Also, the results demonstrated that structural disaster (cracking, structural failure, destruction of materials) represents 58,33 % of the total damages in all case studies. Additionally, the article discusses the most important origins of damage categories. The three most frequent origins of damages (wear, Unknown reason, and hydraulic) are also ranked based on their frequency of appearance. The results demonstrate that wear is predominant as the origin of damages with 29,17 %. Furthermore, this article shows that runway crack is the most frequent type, with 85,51% of the total number of cracks. Therefore, investigations are needed to decrease the number of cracks in runways by improving methods using artificial intelligence to prevent them.

Therefore, the creation of data is necessary to develop new innovative technologies. However, the data still need to be improved in this field to ameliorate the predictive maintenance of airport infrastructure. The presented research has room for improvement, and some limitations of this study can direct future research. This study focuses on the damages and their origin, which are essential for future research. Future work involves the implementation of automated classification algorithms (e.g., Convolutional neural networks) for the most critical damage types to detect them as part of predictive maintenance methods. For instance, seeing cracks in structural and non-structural elements may be future work as part of maintenance methods. Therefore, the application of the findings of this paper will enable researchers to investigate methods for automatically detecting these damages as part of predictive maintenance methods.

Conflict of interest

The authors reported no potential conflict of interest.

Author contribution

In this study, the study conception and design, material preparation, data collection, and analysis were performed by Tarik Lahna. All authors contributed to the interpretation of the results. Lahna wrote the first draft of the manuscript, then all authors commented on previous versions and approved the final version.

References

[1] Burbidge, R. (2016). Adapting European Airports to a Changing Climate. *Transportation Research Procedia*, 14, 14–23. https://doi.org/10.1016/j.trpro.2016.05.036

[2] Kovacs, G., Moshtari, M., Kachali, H., & Polsa, P. (2019). Research methods in humanitarian logistics. *Journal of Humanitarian Logistics and Supply Chain Management*, 9(3), 325–331. https://doi.org/10.1108/JHLSCM-12-2019-082

[3] Coibion, O., Gorodnichenko, Y., & Weber, M. (2020). The Cost of the COVID-19 Crisis: Lockdowns, Macroeconomic Expectations, and Consumer Spending. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3593469

[4] K C Laxman, Nishat Tabassum, Li Ai, Casey Cole, Paul Ziehl,Automated crack detection and crack depth prediction for reinforced concrete structures using deep learning, *Construction and Building Materials*,Volume 370,2023,130709,SSN 0950618,https://doi.org/10.1016/j.conbuildmat.2023.130709.

[5] Kawashima, K., Kanai, S., & Date, H. (2014). As-built modeling of the piping system from terrestrial laser-scanned point clouds using normal-based region growing. *Journal of Computational Design and Engineering*, 1(1), 13–26. https://doi.org/https://doi.org/10.7315/JCDE.2014.002

[6] Shen, X., Cai, C., Yang, Q., Anagnostou, E. N., & Li, H. (2021). The US COVID-19 pandemic in the flood season. The Science of the Total Environment, 755(Pt 2), 142634. https://doi.org/10.1016/j.scitotenv.2020.142634

[7] Peneda, M. J. A., Reis, V. D., & Macário, M. do R. M. R. (2011). Critical Factors for Development of Airport Cities. *Transportation Research Record*, 2214(1), 1–9. https://doi.org/10.3141/2214-01

[8] Attaccalite, L., Di Mascio, P., Loprencipe, G., Pandolfi., C. (2012). *Risk Assessment around airport. Procedia* – Social and Bevavioral Sciences. Volume 53, Pages: 851-860

[9] Baltaci, N., Sekmen, O. and Akbulut, G. (2015). The relationship between air transport and economic growth in Turkey: Cross-Regional Panel Data analysis approach. Volume 7; Issue 1; Pages 89-100

[10] Legner, C. and Thiesse, F. (2006). RFID-based maintenance at Frankfurt airport. *IEEE Pervasive Computing*. Volume 5; Issue 1; Pages 34-39.

[11] Barua, L. and Zou, B. (2021). Planning maintenance and rehabilitation activities for airport pavements: A combined supervised machine learning and reinforcement learning approach. *International Journal of Transportation Science and Technology*.

[12] Anil Kapur. (1995). Airport Infrastructure - The Emerging role of the private sector. https://pdfslide.net/documents/airport-infrastructure-the-emerging-role-of-the-private-sector.html?page=47

[13] Iwadare, K., & Oyama, T. (2015). Statistical Data Analyses on Aircraft Accidents in Japan: Occurrences, Causes and Countermeasures. *American Journal of Operations Research*, 5, 222–245.

[14] Airbus. (2020). A Statistical Analysis of Commercial Aviation Accidents 1958-2020.

[15] Flores-Colen, I., de Brito, J., & de Freitas, V. P. (2010). Discussion of Criteria for Prioritization of Predictive Maintenance of Building Façades: Survey of 30 Experts. *Journal of Performance of Constructed Facilities*, 24, 337–344.

[16] Adam, A. (2020). Sample Size Determination in Survey Research. *Journal of Scientific Research and Reports*, 26, 90–97. https://doi.org/10.9734/JSRR/2020/v26i530263

[17] Dai, C. (2020). The Disruptive Effects of COVID-19 on the Aviation Industry, Food Industry, and E-commerce Industry. https://doi.org/10.2991/aebmr.k.201128.012

[18] Xue, D., Liu, Z., Wang, B., & Yang, J. (2021). Impacts of COVID-19 on aircraft usage and fuel consumption: A case study on four Chinese international airports. *Journal of Air Transport Management*, 95, 102106. https://doi.org/10.1016/j.jairtraman.2021.102106

[19] J. Bouwer et al. (2022). Taking stock of the pandemic's impact on global aviation. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/taking-stock-of-the-pandemics-impact-on-global-aviation

[20] Bouwer et al. (2021). Back to the future? Airline sector poised for change post-COVID-19.

[21] ICAO. (2021). Effects of Novel Coronavirus (COVID-19) on Civil Aviation: Economic Impact Analysis.

[22] Lahna, T.,Foguem-Kamsu, B., & Abanda, H.(2022). Causes of damages in airport infrastructure. *6th International Symposium on Natural Hazards and Disaster Management* (ISHAD 2022).