Causes of damages in airport infrastructure

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A B S T R A C T

Airports are major economic hubs that have exhibited substantial growth and profits in recent years. Although airport infrastructure represents an important part in the economy of cities, studies have shown that many incidents that have led to flight disruptions have often occurred in airport buildings. Also, 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 methods thanks to predictive maintenance techniques, which are based on artificial intelligence. However, working on the innovation of techniques that modernize maintenance in airport buildings is very hard due to the many types of cause incidents that exist. In fact, 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. The result showed that cracks are the most frequent type of damages and that wear is the most frequent origin of incidents in airport infrastructure. These findings help in better understanding the problem and serve as the point of departure for researchers who are interested in solving it.

Keywords: Airport infrastructure, Damages, Statistical analysis, Cracking

1. INTRODUCTION

Maintenance in airport infrastructure (MAI) is attracting a huge interest from both practitioners and academics, knowing the increase of the total number of deteriorations which is happening is 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 are time consuming and the budget and resources allocated for building maintenance are insufficient. These facts explain the reason why the maintenance of facilities and the quality of management are still poor and why incidents occur frequently in aeronautical buildings. In addition, the world knows diverse, and severe disasters that are creating enormous economic effects and human impacts in many countries across the world [2]. So, this implies a financial crisis and then limited budgets to repair when there are any failures in airport infrastructure [3]. In order to elaborate innovative methods which may be used as predictive maintenance techniques in airport buildings, a statistical analysis is needed to determinate the most frequent types of damages and origins of incidents in airport infrastructure. In fact, this study will enable to work on efficient methods that may improve and to modernize the maintenance inside airport infrastructure. Generally, industrial plants, including airport buildings, have an impact in various applications. Some of these include maintenance, 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 the costs and increasing safety since collaborative intelligent manufacturing will be prioritized after the Covid-19 pandemic crisis [5]. The inexistence of innovative methods based on artificial intelligence will result in time lags for these maintenance operations.

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 rather seeks 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 important damage types given how frequent and what are the origins of these damages. 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 that are located in all the world. The most important damage types and the most frequent origins of these damages were ranked based on their frequency of appearance.

2. AIRPORT INFRASTRUCTURE

2.1 Damages in airport buildings

Airport infrastructure can be divided into three main categories [6].

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

These three main categories are detailed on Table 1:

Table 1: The three main categories of airport infrastructure

Operational Services/ Facilities	Air Traffic Control
	Police and Security Department
	Ambulance, Fire and Rescue Department
	Maintenance Services
	Runway
	Terminals and Air bridges
Traffic Handing	Fuel, Ramp, Hanger
	Baggage and Freight facilities
	Immigration Services
Commercial Activities	Duty-Free and Shopping
	Catering and restaurants
	Car parking
	Car rental
	Other (Bank, Hotel, etc.)

2.1 Gap in knowledge and research question

There is no substantive study that prioritizes the types of damages in airport infrastructures based on their frequency of appearance in the world. However there are related fields where damages are considered to estimate the aircraft accidents thanks to statistical studies from academic field [7] and industrial field [8]. Therefore, the statistic of the most frequent types of damages and origins of incidents in airport infrastructure were not determined. Some critical damage types in facilities have been identified in the literature [9].But it is therefore still unclear which damage types are important in airport infrastructure for automated detection based on their frequency of appearence. Moreover, if a damage type is critical but not frequent, there is no need to automatically detect it in the future works. On the other hand, even if a damage type is frequent but is

not critical, this paper can ignore detecting it. The Consequently, the aim of this paper is to establish the critical damages in airport infrastructure that are frequent so that different algorithms based on artificial intelligence may be performed in priority as part of predictive maintenance methods.
The aim of this work is to bridge the gaps in knowledge 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. 1.

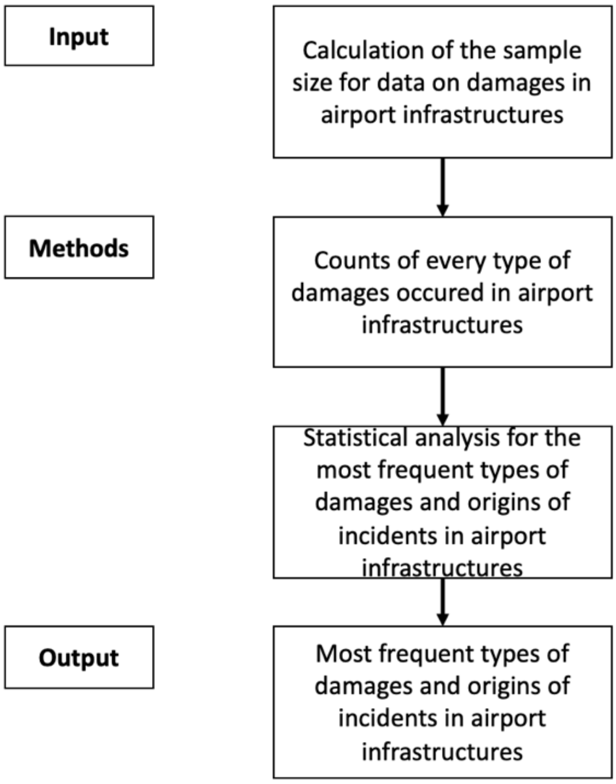

Figure 1: Research methods

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

- Collapse in Airport infrastructure
- Fissures in Airport infrastructure
- Leak in Airport infrastructure
- Electrical failures in Airport infrastructure
- Computing failures in Airport infrastructure

Also, the list of damages was performed by ordering those 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 of 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 determinate the sample size of the list of incidents needed to do a statistical analysis. In fact, this study considered only incidents from 1987 and assume that there are 1500 incidents in airport infrastructure in a period of 35 years. Also, 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 of error e = 0.05 are assumed for that formula [10].

$$\boxed{S = \frac{N}{1 + N \times (e)^2}} \qquad \textit{(eq.1)}$$

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, by using the equation 1, the number of incidents 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 the damage origin categories that need to be considered are determined by implementing a statistical analysis on the frequency of appearance of all damage types and damage origin categories encountered in typical considered list of incidents. The frequency of appearance P is calculated by dividing the total counts of each damage or damage origin category (n) with the total number of damages in all case studies (S) as described on Equation 2.

$$\boxed{P = \frac{n}{S}} \qquad \text{(eq.2)}$$

Moreover, other parameters were computed in the next section for statistical analysis such as the mean and the standard deviation.

3.3 Definition of terminologies used in this study

This paragraph details the different terminologies that were used to compute the frequencies for damage types and damage or damage origin types. Table 2 illustrates these terminologies for a better understanding.

Table 2: Terminologies for types of damages

Types of damages	Definitions
Cracking	When the disaster causes cracks in any parts of airport infrastructure
Delay/ Disorganization	When the disaster causes delays or disorganization
Structural collapse	When the disaster causes collapses of structural elements
Toxicity	when the disaster causes a danger of toxicity inside airport infrastructure
None	When the disaster causes no damages
Collapse of materials	When the disaster causes collapses of materials which are non-load-bearning elements
Fire / Explosion	When the disaster causes a fire or an explosion
Hydraulic / Flood	when the disaster causes a failure of the hydraulic system
Electricity	When the disaster causes a failure of the electrical system

Table 3 defines the terminologies for the types of damage origins.

Table 3: Terminologies for types of damage origins

Types of damage origin	Definitions
Wear	When the disaster is caused because of wear
Unknown reason	When the origin of the disaster is not known
Hydraulic	When the disaster is caused by any hydraulic systems
Natural disaster	When the disaster is caused by any natural disaster
Electricity	When the disaster is caused by any electrical systems
Logistic	When the disaster is caused by any logistical problems
Handling	When the disaster is caused by manual operations
Others	When the disaster is caused by other reasons

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

4. RESULTS

4.1 Most frequent types of damages

The damage type rankings are calculated in descending order for all case studies in Table 4. 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 important since most aerospace statistics are performed to evaluate accidents or incidents related only to aircraft.

Table 4: Priority list of damage types for all case studies

Type of damages	Frequency of Appearance (%)	Sample Size (S)
Cracking	**22,12%**	**69**
Delay/Disorganization	**21,47%**	**67**
Structural collapse	**14,74%**	**46**
Toxicity	**13,46%**	**42**
none	**7,69%**	**24**
Collapse of materials	**7,05%**	**22**
Fire/Explosion	**6,41%**	**20**
Hydraulic/Flood	**5,45%**	**17**
Electricity	**1,60%**	**5**

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. Mostly, cracking represents the damages on runways of airports whereas structural collapse are the damages that are related to the fall of any airport infrastructure. Finally, "collapse of materials" includes all damages that related to collapses of any materials or non-load-bearing elements inside airports such as the ceiling for instance. Figure 2 illustrates the part in the percentage for each type of structural damage.

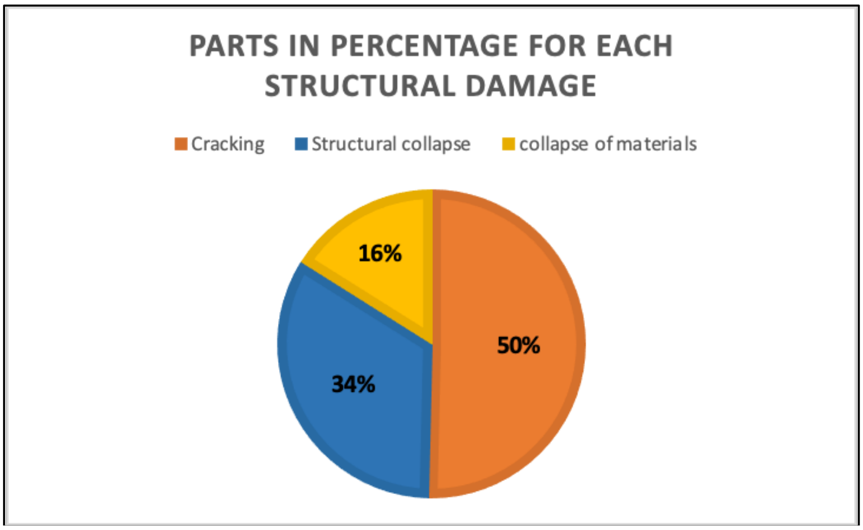

Figure 2: Parts in percentage for each structural damage in airport infrastructures

4.2 Most frequent origins of damages

The damage's origin rankings are calculated in descending order for all case studies in Table 5. 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 being 13,78 % and 13,14 % respectively. Natural disaster is the fourth origin of damages in airport infrastructure with 12,18%.

Table 5: Priority list of damage origins categories for all case studies

Origin of damages	Frequency of Appearance (%)	Sample Size (S)
Wear	29,17%	91
Unknown reason	13,78%	43
Hydraulic	13,14%	41
Natural disaster	12,18%	38
Electricity	9,29%	29
Computing	9,29%	29
Handling	3,85%	12
Other	1,60%	6

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

4.3 Most Evolution of damages in airport building

This study showed that the number of damages in airport infrastructure is between 15 and 30 damages except in 2020 as detailed in Figure 3. Due to Covid-19, the graph also shows that the number of damages decreased in 2020 [11]. That is because of the diminution of aerospace activity in the world [12]. In fact, the number of damages in 2020 is about 10 and dropped by 60% from 2019 as mentioned in other publications [13].

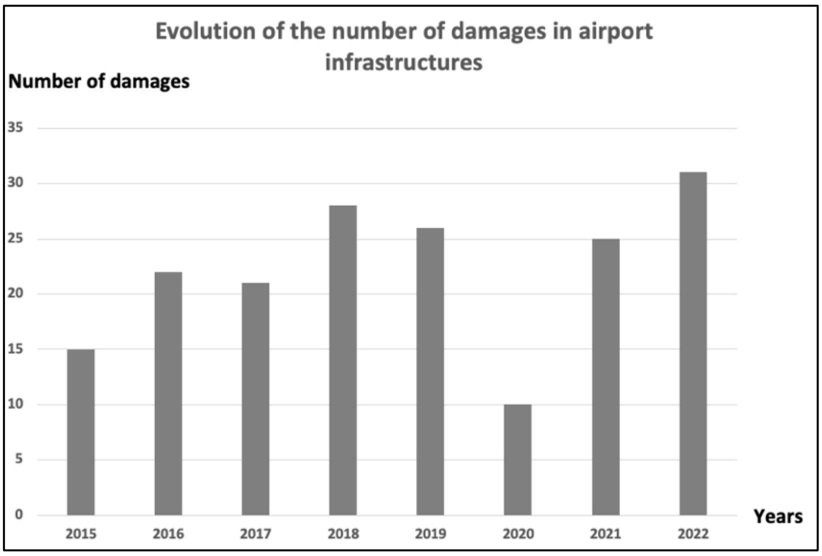

Figure 3: Evolution of the number of damages in airport infrastructure

Furthermore, the graph demonstrates an increase of damages in 2021 compared to 2020. Indeed, the number of damages in 2021 is equal as in 2019. That shows the aerospace activity recovered from Covid-19 as mentioned in different publications from different aviation organizations such as MacKinsey [14] and ICAO [15].

4.4 Distribution of Damages in Airport Infrastructure Around the World

This study illustrates the repartition per continent of damages in airport infrastructure in the world thanks to Figure 4. It shows that Europe has the greatest number of damages in airport infrastructure with 181 out of 312 which is the total number of case studies that were considered in the study. Thus, America and Asia follow in the ranking with 54 and 50 respectively.

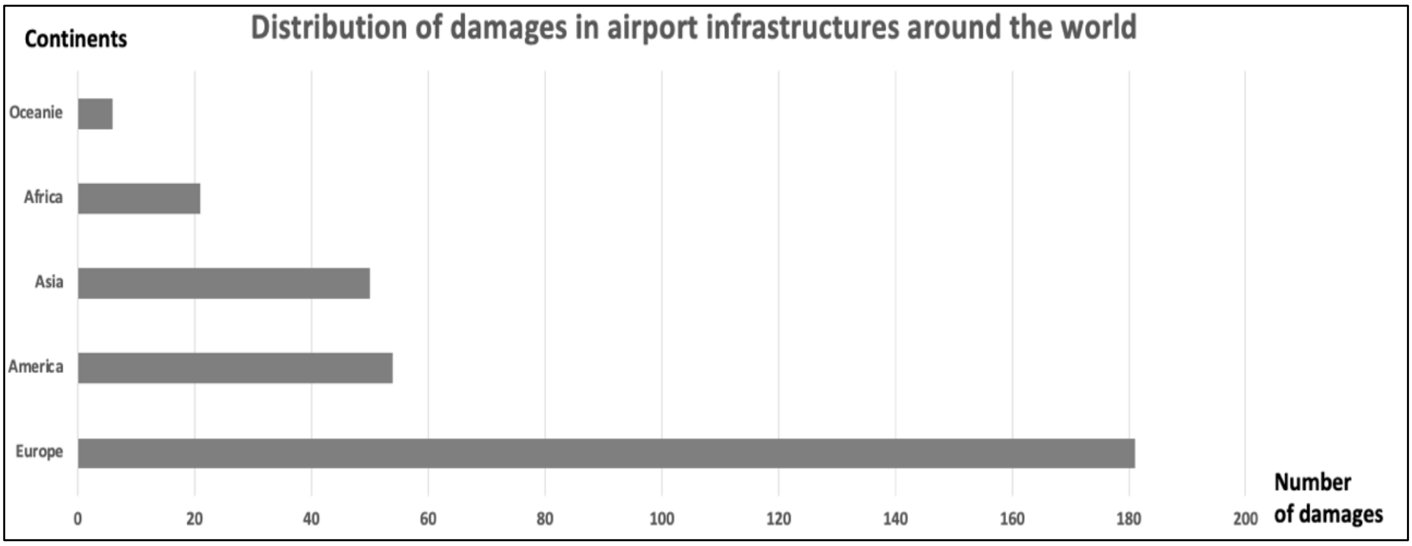

Figure 4: Distribution of damages in airport infrastructure around the world

As expected, Africa has a fewer number of damages that can be explained by the fact of the lack of information on the continent.

4. CONCLUSION

The nine most important damage types in the three most frequent damage categories (cracking, delay/disorganization and structural collapse) are ranked based on their frequency of appearance. The results also showed that structural disaster (cracking, structural collapse, collapse of materials) represents 58,33 % of the total number of damages in all case studies that were considered in this study.

The paper discusses the eight most important origin of damage categories. The three most frequent origin of damages (wear, Unknown reason and hydraulic) are also ranked based on their frequency of appearance. The results demonstrate that lack of maintenance is predominant as the origin of damages with 29,17 %.

This paper marks the first study specifically aimed at identifying the most damage types and the most frequent origin of damage categories in airport infrastructure. The contribution is therefore the discovery of the most frequent damage types and the most origin of damage categories in 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 that are important to consider for future research. Future work involves implementation of automated classification algorithms (e.g., Convolutional neural networks) for the most important damage types to detect them as part of predictive maintenance methods. For instance, detection of crackings in structural and non-structural elements may be one of the future works as part of maintenance methods. Therefore, application of the findings of this paper will guide researchers on investigating methods for automatically detecting these damages as part of predictive maintenance methods.

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