EAI Endorsed Transactions
on Smart Cities
Research Article EAI.EU

Intelligent Dashboards to Monitor the Occurrences in Smart Cities – A Portuguese Case Study

R. Silva, M. Silva, G. Caldas, F. Portela* and H. Santos

Algoritmi Center, University of Minho, Azurem Campus, Guimarães, Braga, Portugal

Abstract

This article concerns the needed response by the Professional Fire Brigade Regiment (FBR) in the city of Lisbon. To solve and answer the question "How to improve FBR intervention requests when an emergency is detected?" the project aims to create a functional prototype containing interactive dashboards allowing the analysis of indicators that improve decision capacity. As results attest, 58% of false alarms are cancelled even after the emergency and rescue means have been activated to the location. About 97% of the suspended requests are not cancelled before the means are sent. The number of records of occurrences tends to increase over the 8 years of study. Sunday is the weekday with the highest number of associated records, with 23.33%, specifically at 9 am and 8 pm. Autumn is the season with more occurrences, with 26.51%. More than 50% of the occurrences are in the administrative services closing time and more than 50% of the registrations send only one vehicle to the place. These indicators aim to understand if these variables are probabilistically associated with requests for interventions to be able to anticipate these scenarios and help in decision-making whenever necessary.

Keywords: Smart Cities, Business Intelligent, Intervention Requests, Data Science, Big Data..

Received on 25 October 2022, accepted on 17 December 2022, published on 27 December 2022

doi: 10.4108/eetsc.v6i4.2796

1. Introduction

The United Nations (UN) analysed the growth for the next 30 years. The world population is expected to grow by 2 billion people, from 7.7 billion to 9.7 billion [1].
It is possible to perceive a high population growth with a transition to an increasingly urbanised population which paves the way for different challenges in different areas, especially in the sustainable development of a Smart City [2]. One of these challenges is developed in this article, which is, the assurance of response to emergency requests by the emergency and rescue services. Based on this scenario, technology emerges as a predominant factor to assist the management of cities today.

Today's smart cities have certain patterns in common, such as:

- According to Weiss et al. [3] Smart Cities are cities that focus on a particular model, with a modern vision of urban development and that recognize the growing importance of information and communication technologies in directing economic competitiveness, environmental sustainability, and quality of life in general;
- With the increasing development of technologies associated with cities, a high amount of data to be generated daily was observed. As previously understood, there are certain challenges that a Smart City must overcome and the amount of data to be created by the technological infrastructures inserted in cities is one of them;
- The search for solutions through technology stands out and there are more and more solutions to fight these challenges to ensure the sustainable growth of cities;

*Corresponding author. Email: cfp@dsi.uminho.pt

- However, beyond the huge amount of data to be generated, it is important to understand that these have different formats, making the analysis process much more complex and intensive for those who use these data. Furthermore, all cities have their mode of operation, i.e., no city is similar and therefore the needs tend to be specific and objective when making decisions;

The Portuguese capital city, Lisbon, is the case study of this article. It has about 500,000 inhabitants, which explains why requests for help during an emergency tend to be rather critical. The Lisbon Professional Fire Brigade Regiment (FBR) is the focus entity of this article. It is responsible for the safety of people and goods in the city through rescue actions, prevention, and civil protection support.

The article's objective is to help solve a challenge suggested by LxDataLab, a Management and Urban Intelligence Centre of Lisbon. This challenge focus on:

- Historical homologous periods of the occurrences of the FBR and other entities, characteristics, state and causes of the occurrences and degree of risk, among others;
- Three main focuses: a temporal analysis, an understanding of the occurrences' characteristics and finally the mode of intervention and the current state of the occurrences;
- A Big Data problem, in the sense of transforming this high amount of data into a highly effective and efficient process for the FBR when decision-making is necessary, specifically in an emergency intervention request;
- Solve the problem and answer the question "How to improve FBR intervention requests when an emergency is detected?";
- Developing a functional prototype containing interactive dashboards allowing the analysis of city-state indicators and the identification of variables that may be associated with intervention requests ~~to~~ anticipate these scenarios;

The data were analysed in the "Talend Data Quality" tool to understand the data provided, and their quality and get some conclusions. After that, the data provided in 3 spreadsheets (.xls) was properly organised in a data warehouse to reach a result. The data warehouse structure consisted of a table of facts and eleven dimensions, which were placed in a SQL database using the workbench management tool. The transformations that some attributes had to undergo were performed through MYSQL commands. The result was illustrated with dashboards using the data visualization tool, Tableau.

The article is structured into seven chapters. The first chapter addresses the objective of the case study and its relevance. The second chapter refers to the background, explaining the basic concepts present in the practical development of the article and the kind of work already done regarding the subject. Three previous works were studied. The third chapter presents the materials and methods used for the execution of the article as well as the data model and tools used. The fourth chapter shows the results of the case study. The fifth chapter presents the discussions, an analysis of the main results obtained, as well as measures to act on these events. In the sixth chapter, one can read the conclusions of the development of the prototype and in the seventh chapter the bibliographical references used for the development of the article.

2. Background

Today, there is a variety of new challenges in our cities, created by technological advances and urban development. These challenges lead to the Smart City concept. For Anthopoulos [4] a Smart City is defined as an innovative city that uses information and communication technologies and other means to improve the quality of life, the efficiency of operations and urban services. However, managing a Smart City is not an easy process. Making a good decision at a critical moment can lead to a more efficient operation, a more profitable city, or perhaps more satisfied citizens. This is how the concept of Business Intelligence (BI) emerges. At the moment, BI is understood as a set of data that has been collected from the past and the present to make better decisions about the future. This data is selected through certain criteria to draw conclusions. Business Intelligence makes the whole process of decision-making more intelligent, clearer, and as likely to be the future [5].

Equally important, the concept of Data Science emerges, and this concept came from the accelerated growth in government and trade data creation [6]. According to Cady [7] the concept is explained through complex algorithms and analysis that organise the data, being possible to obtain forecasts, to help in decision-making with greater accuracy, speed and efficiency, concrete hypotheses are obtained, being also possible the anticipation of future scenarios.

However, managing and analysing data always offer great benefits to organisations as it is understood. However, as a result, they also imply other challenges. In this way, the concept of Big Data has expanded to explain a situation in which the logistics of storage, processing or data analysis have surpassed the traditional operational skills of organizations [8].

2.1. Smart-Cities (and type of occurrences)

The "Smart-City" concept has become extremely popular and consists of the use of a plethora of IT innovations to make cities smarter for the citizens. This concept first appeared in the 1990s and the main focus was on the impact of new Information and Communication Technologies on modern infrastructures within cities.

A dense environment, like that of cities and capitals, requires its subsystems to work as one system with intelligence being infused into each subsystem. According to [9,10], they indicated that the smart city has six possible characteristics: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living.

With Smart-City it is easier to acknowledge the occurrences happening, and the prevention of them, so the response to requests for intervention in an incident by the emergency and rescue services would be more effective. ANEPC (Portuguese National Emergency and Civil Protection Authority) identified 143 types of occurrences, for example, fires, road accidents, harsh weather, and hazards [11].

Several works with positive impacts have been done combining data science and IOT and using actual occurrences, disasters or socio-economic data to create smart and sustainable cities. [12–14].

2.2. Related Works

The purpose of this subchapter is to analyse works related to the inherent paper.

A Portuguese Decision Support System

The first work analysed refers to a dissertation under the theme "Cidades Inteligentes: Um novo paradigma urbano - Estudo de caso da cidade do Porto". The objective of this work was to understand and demonstrate what is the situation in the city of Porto, as a future potential intelligent city [15]. This dissertation studied several projects, one in particular to create a centre that would support decision-making in the city. The creation of this centre includes elements from the areas of mobility, police, firefighters, civil protection and environment, among others. However, it is an experimental pilot work, unique in Portugal. This centre has tried to respond to the city's problems, for example, when someone needs to break a door down it takes an average of 2h30 to do it.

Given the objectives presented in this work, it provides knowledge and explains the characteristics of the city of Porto, intending to create a project to support the decision-making for the different problems of the city later on. However, it is only experimental, whilst the present article elaborates a functional prototype of interactive dashboards with real data from the city of Lisbon, which found patterns and variations to help decision-making.

A project that investigates mobility in cities

The second work analysed concerns a dissertation named: "Centro de Operações Integrado: Câmara Municipal do Barreiro Cidades Inteligentes - Análise de um estudo de caso". The goal of this dissertation was to analyse and prepare an integrated solution between existing domains at Barreiro Municipality, creating all the essential conditions, both in terms of infrastructure, communications and the response provided by the Municipality to the needs and expectations of its citizens [16]. This dissertation focused on the challenge of mobility in cities. However, this challenge was not only solved by the increase of existing public transport fleets, but also with their modernisation and use of technologies enabling their control and management. Even though the goal has been achieved, there was no real implementation of the project as the data sources were not provided, as well as some essential application resources.

The work elaborated in the article has an added value, as the Lisbon Municipality provided the actual data for the project, and in addition to traffic data, climate data and historical data of FBR occurrences were also provided.

App: Building Intelligence System

The third work analysed no longer concerns Portugal, but Boston. Firefighters when responding to an emergency call of an occurrence like a fire in a building, have a very short time to evaluate the situation and plan a response. Although governments collect a wide variety of information about each building in cities, most fire departments do not have access to this data, leading to unnecessary risk exposure and the inability to make informed firefighting decisions [17]. Thus, Building Intelligence System emerged as a web application that integrates seven sources of city data to provide an optimised view of individual buildings in Boston.

This technological solution, although well implemented, only responds to requests for help in the type of occurrences such as fires. The other objective of this article is to find variables that might be associated with any type of emergency request.

3. Materials and Methods

For the development of the project, it was necessary to use different tools for different purposes as well as different methodologies. Firstly, Case Study was used with the objective of understanding in detail the case under study to help formulate the problem that the article intends to answer [18].

Then, in a second moment, Lab Experiments was used, which consisted in performing a set of tests and configurations on the chosen variables to analyse the data under study, which in the practical part was developed and tested [19]. With these experiments, one was able to comprehend and identify the trends of the variables under study to understand how they evolve and respond to the paradigm of this article.

The first phase did not fully use the case study methodology because only a case was created, but it was essential to understand the topic. The data science team did not have any expertise in managing occurrences at the beginning, and this phase was crucial to understanding the issues and getting sensitive to this area. This phase involved studying the environment and selecting the case from the several datasets received before proceeding with the Lab Experiment work. The experimental work was developed to answer the main questions (KPIs formulated), so an Extract Transforming and Loading (ETL) process was conducted. Then, a set of intelligent dashboards was prepared using the selected data.

The research process followed the lab experiments steps combined with a case study:

1. Examine the need for the experiment (case study);
2. Define the objective for the experiment (case study);
3. Define measures;
4. Identify the important variables;
5. Perform experiments;
6. Analyse results;
7. Act on results;
8. Create reports.

Figure 1 explains and illustrates what kind of technologies and tools were used as well as their designation.

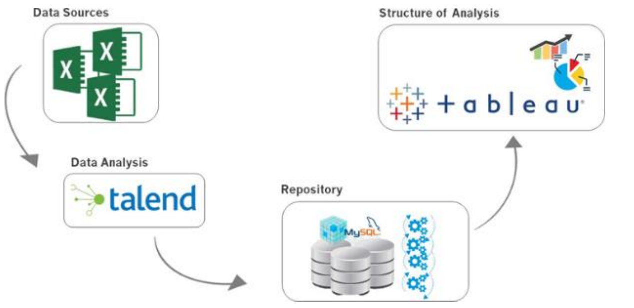

Figure 1. Structure of the procedure to be performed

As illustrated in **Figure 1**, the initial focus for the project development was to have data sources to feed the analytical system intended to be built. These data sources were provided by LxDataLab in spreadsheet (.xls) format. These data divide into 3 spreadsheets, and each has 65,000 occurrences, which makes a total of 195,000 occurrences. Once this stage was concluded, an analysis of the data provided in the "Talend Data Quality" tool was undergone to understand what data were provided, their quality and conclusions about the attributes that feed the data sources. After understanding the characteristics of the data, that is, analysing the type of data delivered and what format they were in, it was intended to store them in a structured database. Therefore, it was necessary to build a central structure in which the data were optimised and integrated. The data chosen to respond to the case under study and after being properly organised were placed in a SQL database using a workbench management tool. The transformations that some attributes had to undergo were performed through MYSQL commands. In the last stage of the process, after the database was operational and properly loaded, the Tableau tool was used for the analysis of the data obtained. In this stage, interactive dashboards were created to find patterns and facts that help decision-making when needed by the emergency and rescue services. In Table *1* it is possible to visualise which tasks were performed in each tool.

Table 1. Tool used for the development of the tasks inherent to this paper

Tool	Tasks
Talend	ETL (Extract Transform Load)
MySql	Data Base
Tableau	Data Visualization

Equally important was to understand how the data were organized and to do this Kimball's approach was used. A Data Warehouse was built, through data collection, subject-oriented, integrated, non-volatile and time-varying to support management decisions [20]. For this, an entity and relationship diagram (ERD) was developed.

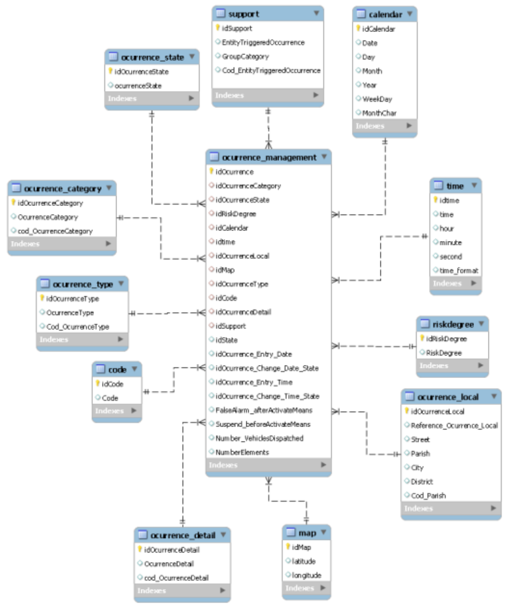

Figure 2. Entity and Relationship Diagram (ERD)

Figure 2 shows the ERD with the respective table designations, the relationship between them and the respective attributes such as metrics, primary keys, and foreign keys. The model is conceived in a star model containing a fact table, and eleven-dimension tables. The fact table, called “occurrences_management” is made up of sixteen foreign keys and four facts that result from the connection to the dimension tables and four facts.

4. Experimental Case Study

After receiving the datasets, the team identified the occurrences data as the most relevant to use in this work. Then the team needed to study the Lisbon reality and understand the type of occurrences, their needs, and features, among other details. After finishing the understanding phase, indicators were defined to answer the main questions. Then was time to work with the data and do the ETL process. During the preparation process (ETP) a data quality analysis was performed, and a set of classes was created to help classify the data. Finally, the data were analysed, the KPIs were implemented, and the dashboards were produced. This chapter explains the main results of the last stage of the project, a Business Intelligence analysis, after using the Kimball methodology and following Lab Experiment steps.

4.1. Data Preparation

The analysis through a graphic visualisation makes the analysis much more intuitive and immediate. This way dashboards were elaborated with the help of the statistical data visualisation tool Tableau.

For the development of the project, the data were provided by the LxDataLab entity. Real data from the city of Lisbon were sent, thus, it is important to notice that these data are written in Portuguese. However, before presenting the analysis, it is also important to understand which data were selected. The data used refer essentially to occurrences such as:

- History in homologous periods of the occurrences of the FBR and other entities;
- Distribution of occurrences among the different Civil Parishes of the Municipality of Lisbon;
- Number of elements and vehicles sent to the location of the occurrence;
- Type of occurrences and most registered categories;
- Closing status of the occurrences;
- Entities which trigger more occurrences;
- Management of false alarms and suspension of intervention requests;
- Degree of risk of the occurrences.

Having understood what kind of data was chosen, an analysis is then carried out with the assemblage of these variables to find patterns and facts that help the decision-making, when necessary, by the emergency and rescue services.

4.2. Data Analysis

The carried-out analysis aimed to answer some important questions as well as enter standards to help and facilitate decision-making. The analysis carried out is divided into three major focuses:

- Time analysis of occurrences;
- Analysis of the characteristics of the occurrences;
- Analysis of the mode of intervention and status of occurrences.

Time analysis of occurrences

Before analysing patterns in the city of Lisbon, it is important to understand in a temporal way how occurrences are being conducted and how they tend to evolve. This temporal analysis refers to the homologous period from 2011 to 2018 and intends to answer five main questions:

1. How do occurrences tend to evolve?
2. Which season of the year tends to have more occurrences? And how are these occurrences?
3. Which categories of occurrences exist more regularly in the different seasons of the year?
4. On which day of the week and month are there more occurrences?
5. Depending on the day of the week, what is the time of most occurrences?

The answers obtained to these five questions and after the analysis of the dashboards resulted in the following:

- Over the years the number of recorded occurrences tends to evolve;
- The season with the highest percentage of records, 26.51%, is Autumn;
- In Autumn, the type of occurrence with 69.93% that stands out is Infrastructures and Roads;
- The category of occurrence that stands out in Summer is related to buildings. In Winter it is water supply, road cleaning and flooding. In Spring, occurrences that need support to the population and in Autumn the occurrences related to transportation and equipment;
- Sunday is the day of the week with the highest tendency to register occurrences, with 14.81%;
- On Monday, the hour with more associated records is 10 pm, with 21.67%;
- On Tuesday, the hour with more associated registers is 1 pm, with 25.42%;
- On Wednesday, the hour with more associated registers is 4 pm, with 23.33%;
- On Thursday, the hour with more associated registers is 4 pm, with 20%;
- On Friday, the hour with more associated registers is 6 pm, with 30%;
- On Saturday, the hour with more associated registers is 10 am, with 21.67%;
- On Sunday, the hour with more associated registers is 9h and 8 pm, with 23.33%.

After completing the temporal analysis, an analysis of the characteristics of the occurrences was also elaborated to understand in detail what was happening.

Analysis of the characteristics of the occurrences

Once the temporal analysis is concluded and understood as the occurrences happen and tend to evolve in time, the main characteristics of the occurrences under study are addressed. After looking at the characteristics of the occurrences, the aim is to answer eight questions:

1. How are the occurrences geographically arranged in the Civil Parishes of the Municipality of Lisbon?
2. Which Civil Parish in the Municipality of Lisbon has the highest number of registered occurrences?
3. What happens in more detail in the 5 Civil Parishes of the Municipality of Lisbon with the highest number of registered occurrences?
4. How does the degree of risk differ in the Civil Parishes of the Municipality of Lisbon?
5. Depending on the type of occurrence, which entities mainly trigger the emergency call?
6. Which type of occurrence is registered more often? Does the month have any influence?
7. Depending on the type of occurrence, how many elements of the emergency and rescue services on average are sent to the location?
8. Depending on the type of occurrence, how many vehicles are sent to the location?

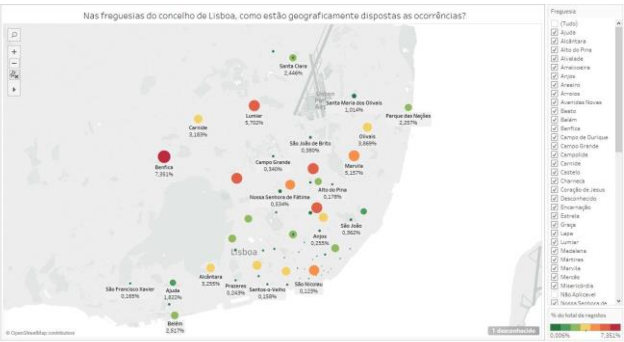

Figure 3. Geographical Analysis of the Civil Parshes of the Municipality of Lisbon

Figure 3 shows that the highest number of occurrences recorded is in the Civil Parish of Benfica with 7,351%. To understand this fact, separate research was carried out on the number of inhabitants in these Civil Parishes of the Municipality of Lisbon and one can see that, in ascending order, there are more inhabitants in the Civil Parishes of Lumiar, Benfica and Olivais. It is, therefore, possible to conclude that although the Civil Parish of Benfica is one with the highest number of inhabitants, it does not interconnect to the highest number of occurrences.

In short, it is possible to conclude from this analysis that:

- 100% of the occurrences recorded in the Civil Parish of Lumiar are at the level of Services, particularly in the collection and rescue of animals;
- The Civil Parish of Parque das Nações shows 50% of occurrences with chemicals and 50% of eventual river dumpings:
- The Civil Parishes of Misericórdia, Beato, Marvila and Ajuda (100%) have in their history occurrences of moderate risk only;
- The Civil Parish of São Vicente (6.90%) is the one with the highest percentage of records of high-degree occurrences;
- 43.48% of the Fire occurrences are triggered by Security Forces;
- 50% of the Pre-hospital occurrences are triggered by Medical Emergency;
- The types of occurrences more often recorded are "Activities", "Services" and "Fires";
- The number of vehicles sent to an occurrence, regardless of its type, is one vehicle only;
- An average of 6 elements are sent to the place of occurrences such as Legal Conflicts, Civil Protection, Infrastructure and Roads or Technological and Industrial incidents;
- When the type of occurrence is fire, 4 vehicles (4.35%) are sent to the location.

Once all the main characteristics inherent to the occurrences under study have been concluded and assimilated, it is also important to analyse the mode of intervention and their state. Thus, the following analysis tends to highlight some evidence of the state of the occurrences to help decision-making and, additionally, assist in the execution of the whole procedure when an occurrence happens.

Analysis of the mode of intervention and the state of the occurrences

It was intended in an intuitive way to address the existence of false alarms of occurrences, the suspension of means of intervention related to the number of vehicles/elements sent and the final status of the occurrences. This way, it is possible to answer six questions:

1. When there is a false alarm, even after activating the emergency and rescue services, in what state is the occurrence?
2. Is there a suspension of the request for support before activating the emergency and rescue services?
3. Being a false alarm or suspension of occurrence, how many vehicles of the emergency and rescue services are sent to the location?
4. Does the state of the occurrence influence its degree of risk?
5. Does the entity that triggers the occurrence influence the state of the occurrence?
6. Does the entity that triggers the occurrence influence its degree of risk?

Below are the answers to the above questions, intending to find standards for effective improvement in the management of occurrences. In short:

- 58.82% of the false alarms are cancelled even after the emergency and rescue means of intervention for the location have been activated;

- 97.10% of the requests for suspension are not cancelled before the means are sent to the location;
- Be it a false alarm or a distressed call suspension, an average of 1 vehicle is sent;
- The higher the degree of risk associated with the occurrence, the state of the occurrence is "Administrative Closure"; the state associated with a zero risk occurrence is "Operational Closure";
- Regardless of the entity that triggers the occurrence, the state of the occurrence is mostly "Administrative Closure" and its degree of risk is moderate;
- The Management of occurrences and intervention requests (GOPI) and the volunteer fire department (CBV) entities have 100% of records with a moderate degree of risk;
- The Lisbon Municipal Council (CML) entity has 100% of records with a high degree of risk;
- The Municipal Civil Protection Service (SMPC) entity has 77.78% of records with zero risk degree.

5. Discussion

Once the development stage is over, an analysis of the main results obtained is made, as well as the measures adopted. Table 2 is a summary of the relevant results achieved and the respective measure

Table 2. Analysis of the main results with the respective measure of action

Event	Measures
Autumn is the season that registers more occurrences, with 26.51%	There is a similarity between all seasons.
The category of occurrence that stands out in the different seasons of the year: • Summer is related to buildings; • Winter relates to water supply, road cleaning and flooding; • Spring occurrences relate with support to the population; • Autumn occurrences relate to transportation and equipment.	Special attention to the occurrences most often recorded in a different season of the year is needed as well as an increase in the number of elements sent to the location.
Sunday, with 23.33%, is the weekday with the highest number of associated records, specifically at 9 am and 8 pm.	Special attention to this day and time to prevent the registration of occurrences needed.
The Civil Parish of Benfica registers more occurrences (7,351%).	The intervention of emergency and rescue services must be increased in the Civil Parish of Benfica.
The Civil Parish of Lumiar registers 100% of occurrences at the level of Services, particularly in the collection of animals.	The population of Lumiar must be informed that the recorded occurrences happen with animals.
50% of the occurrences in the Civil Parish of Parque das Nações happen with chemicals and the other 50% are river dumpings.	The population of the Civil Parish of Parque das Nações should be alerted to this type of occurrence.
The Civil Parish of São Vicente (6.90%) has the highest percentage of records of occurrences with a high degree.	Special attention to the Civil Parish of São Vicente should be paid and notice that most of them are high-risk occurrences.
The number of vehicles sent to an event, regardless of their type is one vehicle.	At least one vehicle should be always available for an occurrence.
58.82% of the false alarms are cancelled even after the emergency and rescue means of intervention for the site have been activated.	The emergency and rescue services should activate their means only when it is confirmed that it is not a false alarm.
97.10% of the suspension requests are not cancelled before the means are sent to the location.	The emergency and rescue services must be able to cancel the means before being sent to the location.
100% of records of The GOPI and CBV entities are of moderate risk; 100% of records of the CML entity are of high risk; The SMPC entity has 77.78% of records with zero risk.	When the emergency and rescue services know which entity triggers the occurrence, they should be able to perceive the type of risk of the occurrence.

To sum up, in each event, the main measure is about the attention needed to prevent the events. In other situations, the measures involve maintaining emergency and rescue services vehicles always available and aware.

6. Conclusion

There was an essential question to answer: "How can we improve the requests for the intervention of the Professional Fire Brigade Regiment (FBR) when an emergency is detected in a Smart City? To answer this challenge was developed a prototype with interactive dashboards and it was successfully achieved. These dashboards are the result of actual data provided by the Municipality of Lisbon. This prototype aimed to assist decision-making and understand data patterns to identify variables that may be probabilistically associated with intervention requests.

As a result, 24 dashboards were obtained to meet the expectational goals. In short, this analysis highlights:

- The understanding of the level of false alarms and suspension of media before and after they are sent to a location, and the need to improve because there are more than 50% of false alarms and requests for suspension which is a rather high percentage;
- The highest number of occurrences is recorded on Sundays, with 23.33%;
- In terms of geographical distribution, it was understood that the Civil Parishes of Benfica, Lumiar, Alvalade and São Domingos de Benfica are the most critical;
- The registered occurrences tend to increase over the 8 years of study and the state after the conclusion of the occurrence is mostly "Administrative Closure";
- Regardless of the entity that triggers the occurrence, the state of the occurrence is mostly "Administrative Closure" and its degree of risk is moderate;
- The number of vehicles sent was also analysed depending on the type of occurrence, and on average only one is sent.

In future work, it is necessary to increase the variety of data present in the data warehouse which would consequently increase the analysis of Business Intelligence in the practical part of the article. In addition to this analysis of Business Intelligence, it would also be necessary to use the OLAP tool to make the analysis more enriching and intuitive so that at the time of an occurrence decision-making might be more direct and clearer.

7. References

[1] The United Nations. World Population Prospects 2022. https://doi.org/978-92-1-148373-4.

[2] Bibri S. Big Data Science and Analytics for Smart Sustainable Urbanism. Springer Cham; 2019.

[3] Weiss M, Bernardes R, Consoni F. Cidades inteligentes como nova prática para o gerenciamento dos serviços e infraestruturas urbanos: a experiência da cidade de Porto Alegre. Urbe Revista Brasileira de Gestão Urbana 2015;7. https://doi.org/10.1590/2175-3369.007.003.AO01.

[4] Anthopoulos LG. Understanding Smart Cities: A Tool for Smart Government or an Industrial Trick? vol. 22. Springer Cham; 2017.

[5] Scheps S. Business Intelligence For Dummies. John Wiley & Sons, Inc.; 2008.

[6] Steele B, Chandler J, Reddy S. Algorithms for Data Science. Cham: Springer International Publishing; 2016. https://doi.org/10.1007/978-3- 319-45797-0.

[7] Cady F. The Data Science Handbook. John Wiley & Sons, Inc; 2017.

[8] Hurwitz J, Nugent A, Halper F, Kaufman M. Big Data For Dummies. 2013.

[9] Giffinger R, Fertner C, Kramar H, Kalasek R, Milanović N, Meijers E. Smart cities - Ranking of European medium-sized cities. 2007.

[10] Perera C, Zaslavsky A, Christen P, Georgakopoulos D. Context Aware Computing for The Internet of Things: A Survey. IEEE Communications Surveys & Tutorials 2014;16:414–54. https://doi.org/10.1109/SURV.2013.042313.0019 7.

[11] ANEPC. PLANO NACIONAL DE EMERGÊNCIA DE PROTEÇÃO CIVIL. n.d.

[12] Ahsaan S, Mourya A. Prognostic Modelling for Smart cities using Smart Agents and IoT: A Proposed Solution for Sustainable Development. EAI Endorsed Transactions on Smart Cities 2018:169916. https://doi.org/10.4108/eai.13-5- 2021.169916.

[13] Luís B. Elvas, Sandra P. Gonçalves, João C. Ferreira, Ana Madureira. Data Fusion and Visualization towards City Disaster Management: Lisbon Case Study. EAI Endorsed Transactions on Smart Cities 2022;6:e3. https://doi.org/10.4108/eetsc.v6i18.1374.

[14] Nesmachnow S, Baña S, Massobrio R. A distributed platform for big data analysis in smart cities: combining Intelligent Transportation Systems and socioeconomic data for Montevideo, Uruguay. EAI Endorsed Transactions on Smart Cities 2017;2:153478. https://doi.org/10.4108/eai.19-12-2017.153478.

[15] Fernandes M. Cidades Inteligentes: Um novo paradigma urbano - Estudo de caso da cidade do Porto. Católica Porto Business School, 2016.

[16] Durand A. Cidades Inteligentes - Análise de um estudo de caso, 82. Instituto Politécnico de Setúbal, 2013.

[17] Hillenbrand K. Boston Equips Firefighters with Hazard Data 2016.

[18] Patton E, Appelbaum S. The Case for Case Studies in Management Research. Management Research News 2003;26:60–71. https://doi.org/10.1108/01409170310783484.

[19] Webster M, Sell J. Laboratory Experiments in the Social Sciences. 1st ed. Academic Press; 2007.

[20] Kimball R, Ross M. The Data Warehouse Toolkit: The Definitive Guide to Dimensional Modeling, Third Edition. 3rd ed. John Wiley & Sons, Inc.; 2002.