Fire Mitigation Analysis in Aviation, Commercial, and Industrial Sectors in Morocco

December 14. 2017

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Submitted to:

FIREPRO
Engineers/Consultants/Experts
ENGINEERING

WPI

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Chapter 1. Introduction

Natural disasters and catastrophic events, such as hurricanes, earthquakes, and fires, are the greatest catalysts for the revision of protocols and laws to increase safety. For instance, Hurricane Andrew hit South Miami, Florida with Category 5 storm winds and rain in August of 1992 destroying 63,000 homes and damaging 100,000 (Jacobo, 2017). After witnessing the extent of damage caused by the hurricane, the state and local government officials reflected on the building codes in place. The South Florida Building Code was one of the best building codes in the country at the time, so the extent of damage from the storm indicated an issue with the then-current code. Upon reflection, the main issue was the lack of enforcement and implementation of the South Florida Building Code. Bryan Koon, director of the Florida Division of Emergency Management, told ABC News, "Florida took Andrew as a lesson learned" (Jacobo, 2017). Florida's government officials acknowledged the likelihood of another natural disaster of similar magnitude when addressing the enforcement of building codes. Construction companies and building specialists prioritized the implementation and practice of building codes in anticipation of another powerful natural disaster similar to Hurricane Andrew. The state and local government officials, construction companies, and building specialists promoted effective risk mitigation techniques. They analyzed the effects of Hurricane Andrew, reflected on faults within the building codes, and carried out new practices to employ risk readiness, and to prevent financial and property loss in the future.

The example above indicates that risk mitigation is not effective when practiced by only one party. The government enacting the South Florida Building Code did not save Miami from catastrophic damage. Those responsible for practicing the building codes were a main cause of the extent of Miami's devastation. Therefore, risk mitigation is the responsibility of all stakeholders who can be affected by natural disasters and catastrophic events.

Our team plans to employ effective risk interpretation and mitigation processes to target fire safety risk management in Moroccan public and workplace environments. There are many fire protection companies, such as FirePRO Engineering, that work as a liaison between clients and government-mandated and recommended fire and safety codes to ensure optimal safety within the clients' establishments.

FirePRO Engineering is an engineering group headquartered in Casablanca, Morocco. The company specializes in four sectors of fire protection including engineering design, system installation, training, and integrated solutions. FirePRO is concerned about the need for up-to-date fire safety applications for their clients, who are primarily from the aviation, commercial, and industrial sectors. These three sectors are valuable to FirePRO, because they target public and workplace safety all throughout the country. Fire safety within the aviation sector is important because of the influx of aviation passengers year to year; aviation passenger traffic experienced a "sharp increase of 13.34%" from 2016 to 2017 (ONDA, 2017). Thus, the increase of people traveling by air in Morocco presents a need to determine if current fire safety is adequate. Commercial spaces welcome large volumes of people, making fire protection techniques crucial to public safety. Fire safety is also essential for industrial establishments, due to the high fire risk produced by materials and processes in industrial occupancies.

Our team will collaborate with FirePRO to conduct fire safety application assessments within the aviation, commercial, and industrial sectors through on-site observations and systematic consultations with fire safety specialists. From our observations and consults with experts, our team will collect data on fire safety in the three environments. Our goal is to evaluate current implementation of fire safety codes in public and workplace environments in Morocco and identify gaps between current fire safety applications and the corresponding fire codes. Our objectives to meet our goal include the following:

1. Investigate fire safety applications and systems present in aviation, commercial, and industrial environments
2. Compare Moroccan and international fire safety practices to determine best practices in all environments
3. Document social dimensions concerning fire safety awareness within all environments.

These three objectives will frame our research and methodological strategies for this proposal.

Chapter 2. Literature Review

FirePRO presented our team tasks to address both the need and/or effectiveness of FirePRO's fire mitigation services as well as the improvements that can enforce fire mitigation practices in Morocco's aviation, commercial, and industrial environments. The Literature Review chapter provides the background information necessary to fulfill our project's goals and objectives. To begin, the chapter discusses important background information about our sponsor FirePRO, Morocco's growing economy, the overall importance of fire safety and fire risk mitigation, and current Moroccan fire safety practices; these topics outline the significance of our project task. Next, the chapter introduces our project's stakeholders to outline who fire safety mitigation processes affect in the three sectors. Finally, we reflect on Moroccan fire-safety data and international fire safety case studies to provide perspective on Morocco's utilization of fire risk mitigation.

2.1 FirePRO Engineering

FirePRO is a multifaceted company located in Casablanca that offers a variety of fire protection and safety services. The company conducts trainings, supports international and national fire codes through fire system installations and fire engineering practices, and focuses on research for innovative fire prevention solutions. Training services include first-aid training, confined space training, hazardous environment training, and fire drill training. FirePRO supports industries' fire code requirements by informing clients on necessary and recommended fire systems, on workplace fire safety strategies, and on evacuation plans. The company provides professional installation of fire protection systems such as smoke alarms, sprinkler systems, heat detection systems, and more. In addition, FirePRO prioritizes the advancement of fire mitigation technologies, and conducts research on potential improvements in fire protection. The company refers to required and recommended national and international fire codes, insurance company safety regulations, and clients' needs to ensure effective risk mitigation for all clients in Morocco (FirePRO Engineering, personal communication, November 2017).

2.2 Economic Development of Industrial and Commercial Companies in Morocco

FirePRO's efforts to enforce fire risk mitigation are under increasing strain as commercial and industrial fire risk mitigation sectors of Morocco grow. The country has seen successful economic growth and development in past years. According to the *Royaume du Maroc Ministere de I'lndustrie, de I'lnvestissement, du Commerce et de I'Economie Numerique*, new and traditional industries in Morocco both contribute greatly to the national economy. Among the more traditional industries is the textile industry. Morocco's textile industry includes over 1,200 textile producers, which offer 27% of the kingdom's industrial jobs. In 2016, the industry contributed 34.2 billion dirham to export turnover (amount of exported goods). Thus, the textile industry is a strong contributor to the Moroccan economy.

New industries have also greatly contributed to Morocco's economy. In recent years, Morocco has attracted the attention of international automobile companies. The development in the automobile industry was notable in Morocco from 2014 to 2016, which corroborates the 50% increase in export turnovers. This industry contributed 40 billion dirham in 2014, and 60 billion dirham in 2016 (Ministry of Industry, 2017). Thus, even though traditional industries are performing well, new industries are contributing more to the economy every year. Morocco saw a 4.8% growth in GDP in 2015. GDP development in Morocco is outstanding compared to countries of similar size and terrain, such as Algeria and Tunisia, who stand at 3.7% and 1.1%, respectively (International Monetary Fund, 2016). Hence, the introduction of new industries and ongoing successes of traditional industries prove that growth is working in Morocco's favor.

2.3 Fire Risk Mitigation

Rapid growth means more risk for technology and enforcement failure. Risk mitigation is one of the most important aspects of fire protection, although in order to save money, many commercial entities do not prioritize the practices of risk mitigation. For many years, the model for fire protection specialists favored cooperation from management "based on the loss suffered by the industry" (Davletshina, 1998). Now, commercial management is beginning to understand that by using risk mitigation to eliminate the causes of most fires, such as unsafe acts and conditions, they can prevent the majority of fires. While companies do not tend to invest in risk mitigation, in the long run, fire risk mitigation has proven to save millions of dollars.

Fire mitigation practices can fall into the following categories: existence and maintenance of fire safety systems, fire safety education, and fire code enforcement (Davletshina, 1998).The model for fire risk mitigation can be seen below in Figure 1:f

Figure 1: Diagram to demonstrate the codependent relationship of fire mitigation practices (Daveltshina, 1998).

Fire code enforcement attributes to the use and regulation of fire safety systems and applications. Inspections and system maintenance supports the third category of fire mitigation. Existence and maintenance of fire safety systems refers to the establishment of a fire-safe environment. Engineers and fire safety specialists contribute the most to establishing a fire-safe environment, as they interpret fire codes, control implementation of fire codes, and service fire systems. Fire safety awareness and education promotes fire safety consciousness among groups of people in different environments; educating stakeholders on the various ways to reduce fire hazards can help to prevent fires.

Fire mitigation is not possible or effective when one or more of the fire mitigation segments are absent (see Figure 1 above). Fire safety awareness and enforcement programs will not prevent fires without the existence of fire safety systems and a strong foundation of fire engineering principles (Davletshina, 1998). The existence and maintenance of fire safety applications will be ineffective if people are not trained on how to react and use fire prevention devices, such as a fire extinguisher, during a fire emergency.

Fire code enforcement is inadequate if people exposed to fire risk do not have the proper training. There are numerous organizations whose goals are to educate and promote the practices of fire risk mitigation. Two fire protection engineering associations that influence global fire regulations include the National Fire Protection Association, NFPA, and the Occupational Safety and Health Administration, OSHA. The NFPA "is a global nonprofit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards" (NFPA, N.d.). The NFPA mainly creates fire codes and standards that establish criterion for ever-changing environments; the NFPA also participates in research, public education, advocacy and training. Secondly, the OSHA is an association that "assures safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance." (United States Department of Labor, N.d.). The NFPA and OSHA are American organizations that promote social dimensions and technical applications of fire safety. The United States is a leading country in fire protection, and many countries including Morocco base their national fire standards on American fire code practices.

2.4 Current Moroccan Fire Safety

International fire codes that have proven to minimize fire risk and loss highly influence Moroccan fire code. Moroccan fire code implementation depends on several factors. The main factors in choosing which fire codes to follow in aviation, commercial, and industrial environments include budget allowances, insurance company requirements, and company regulations. The following sections further explain the international influence on Moroccan fire codes and fire safety within each of the three sectors.

2.4.1 International Fire Codes Adopted by Morocco

American fire codes and French labor laws have heavily influenced Moroccan fire mitigation practices (FirePRO Engineering, personal communication, November 2017). For example, Moroccan fire code includes the following: NFPA 30, NFPA 70, NFPA 72, and NFPA 101. NFPA 30 is the Flammable and Combustible Liquid Code, and addresses the storing and handling of flammable and combustible liquids. NFPA 70 is the Standard for Electrical Safety in the Workplace, and encompasses safe installation and inspection of electrical systems. NFPA 72 is the National Fire Alarm and Signaling Code, and covers fire detection, signaling, and emergency communications demands. Lastly, NFPA 101 is the Life Safety Code, which covers

the life safety for new and existing buildings (NFPA, N.d.). The above NFPA fire codes are a few of the many United States fire codes adopted by Morocco.

Morocco has also adopted and modified the French Labor Law. The French Labor Law enforces fire prevention and protection practices for employers to impose on their employees through necessary trainings. The labor laws' descriptions of required industry trainings can be found in articles *R. 4227-1 to R. 4227-41, R. 4227-55 to R. 4227-57* on the *Règlement Sécurité* website (INRS, 2015). By adopting and revising the United States NFPA codes and the French Labor Law, Morocco has been able to construct stronger fire codes for all industries.

Mr. Zouheir M. Yakine, a fire protection engineer at FirePRO, stated the following about the Moroccan Labor Law:

> All new employees of a company must undergo safety training as a part of employee orientation. Returning employees must undergo routine safety training; in most industries, trainings are conducted yearly or bi-yearly. If a person were to transfer from one industry to another, he would need to participate in the safety trainings appropriate to the new industry (FirePRO Engineering, personal communication, November 2017).

Upon reflection, our team believes fire safety education through the Moroccan Labor Law strongly supports one of the three pillars of effective risk mitigation. Moroccan fire code encompasses some of the best aspects of fire codes and labor laws around the world.

2.4.2 Aviation Fire Safety

Morocco is a part of the United Nations, and therefore must follow global aviation fire code standards written and monitored by the International Civil Aviation Organization. The ICAO creates policies to ensure airports are safe, efficient, secure, economically sustainable and environmentally responsible (ICAO, N.d.). It is important to maintain the safety of all aviation facilities within the United Nations in order to continue the positive impact that the air transport industry plays on national and international economies (ICAO, 2016). Additionally, maintaining the safety in aviation facilities is vital to mitigate fire damage in the case of a fire emergency.

United Nations airports all have Rescue and Firefighting Services, or RFF services, which are in charge of maintaining the airport's fire safety. The RFF is in charge of any fire risk regarding:

1. Aircraft parking, landings and taking offs
2. Aircraft emergencies
3. Car and taxi incidents within the airport
4. Rescue operations

Rescue and Firefighting Services are also in charge of fire safety throughout airport facilities. All airports have a category number based off of dimensions (length and fuselage width) of the airplanes that pass through the airport (ICAO, 2014). This category number determines the fire safety systems required for the facility.

Although there are no recent documented fire incidents in Moroccan aviation facilities, airport fire safety is very important. According to the ICAO,

> ...an outstanding characteristic of aircraft fires is their tendency to reach lethal intensity within a very short time. This presents a severe hazard to the lives of those directly involved and can hamper rescue or evacuation efforts (ICAO, 2014).

Fire risk exposure in airports contributes to the need for strong fire mitigation. In order to consider all fire safety risks, our team will take into account fire safety on the tarmac as well. A typical civil airplane, such as an A320 aircraft, can hold approximately 6,300 gallons of fuel in its wings (Airbus, N.d.). Jet fuel, or kerosene, is highly flammable and consequently, contributes to large fire risks.

2.4.3 Commercial Fire Safety

There are many examples of commercial industry fire accidents that reflect on the industry's poor fire risk mitigation practices. For example, in 2016, a sponge mattress furniture store caught fire in Sale, eventually including a three-story building and two cars (HuffPost Morocco, 2016). The Huffington Post article acknowledged the sponge mattresses' flammability and the material's contribution to the size of the fire. In 2015, Zara, a commercial retail store located in Casablanca, caught fire, but fortunately damage was minimal and there were no casualties (Morocco World News, 2015).

The Moroccan Ministry of the Interior and the General Director of Civil Protection addressed commercial fire risk issues in *Reglement de Securite contre les Risques D'Incendie et de Panique dans les Constructions*. Book 2 of *Les établissements recevant du public (ERP)* discussed fire safety requirements for buildings with large volumes of people. The Moroccan fire code classifies shopping malls into the first category of public spaces requiring special attention to fire mitigation. Moroccan fire codes provide guidelines on building specifications such as exit widths and customer capacity per square meter (Ministere de L'Interieur et al, N.d.). Although the Moroccan government does not enforce fire codes in commercial environments, the

recommended government fire codes are strong and consider the risk factors of commercial spaces.

2.4.4 Industrial Fire Safety

Fire safety is important for the industrial sector due to the exposure of flammable materials. Out team found many instances of fire catastrophes in Morocco. In 2008, a fire occurred at another mattress factory in Casablanca (See Figure 2). Fifty-five lives were lost. Short circuits in the facility caused the fire and the emergency exits were not accessible to those inside the factory (USA Today, 2008). Moreover, the chemicals stored in the building helped the fire to spread much faster throughout the factory (Abdennebi, 2008).

Figure 2: Fire at Mattress Factory in Casablanca (Reuters, 2008)

Additionally, our team researched the fire that occurred in 2002 in the Sidi Moussa prison, killing 49 and injuring 90. The incident brought question to high population densities and the associated safety risks (New York Times, 2002).

In Book 5 of the *Reglement de Securite contre les Risques D'Incendie et de Panique dans les Constructions*, the Ministry and Director General discussed fire safety requirements for industrial workplaces. The document included exits widths for companies with different number of employees. Book 5 also specified accessible exits within thirty meters for anyone inside the

building is suggested (Ministere de L'Interieur et al, n.d.). For the factory fire incident mentioned above, the factory did not follow the exit door requirement closely and consequently, lives were lost in the fire.

Important research topics for our team to consider in industrial settings are the products present in the facility (such as flammable liquids or materials), accessible fire exits throughout the facility, and the control of population density in highly populated facilities.

2.5 Stakeholders

For the aviation industry, our main stakeholders will be airport managers, airport employees, and travelers. In the commercial sector, our stakeholders will be mall managers, store owners, and shoppers. Lastly, our stakeholders in the industrial sector will be industrial managers and workers. We will consider all of the stakeholders mentioned in order to have the strongest impact on each environment.

2.5.1 Managers

In the aviation, commercial, and industrial sectors, managers are a major stakeholder; managers' jobs prioritize the safety and functionality of the facility. Managers in the aviation sector include airport managers as well as Office National des Aéroports' fire personnel. In the commercial sector, the manager role includes the mall manager as well as any mall fire safety personnel. Lastly, in the industrial sector the role of manager is solely made up of the facility manager.

2.5.2 Airport and Industrial Employees

Employees are important stakeholders in the aviation and industrial sectors. The number of fire safety systems present in the workplace have a great impact on the workers in the event of a fire. In addition, day-to-day actions performed by employees have a large impact on the general safety of the workplace.

2.5.3 Travelers and Shoppers

Travelers in airports and shoppers in malls are also important stakeholders to consider for our project. This demographic is the least knowledgeable about fire safety systems present in the airport or mall, respectively. If evacuation routes or fire exits are not easily accessible or visible, the large number of travelers or shoppers can complicate fire emergencies due to confusion.

2.6 International Studies on Fire Safety

2.6.1 Studies in the Aviation Sector

Airport terminals around the world handle large volumes of passengers every day. A fire in an airport terminal building could impair efficient operation of the airport for an extended amount of time, and could very likely cause casualties and fatalities. In 1996, a fire in the Dusseldorf airport caused toxic smoke to enter the airport's ventilation system. This fire killed sixteen people and injured more than fifty others (The New York Times, 1996). In 2009, a discarded cigarette butt caused a fire and filled the Perth Airport terminal building with thick smoke. The airport had to evacuate 1,500 people and delay flights for up to four hours (The Courier Mail, 2009). Researchers have put efforts into studies to improve fire safety in airport terminals. Researchers have presented various technical findings as well as recommendations to make airports safer.

One fire safety study discussed the idea of compartmentation. Paula Beever, a fire protection researcher from the United Kingdom, presented fire safety strategies in airport terminals. Airport buildings hold large amounts of passengers, so high-ceiling designs will aid the movement of people and provide a better sense of space in the terminal. However, design without compartmentation lacks the ability to control the spread of fire and smoke (Beever, 1991). Beever used the Kansai Airport in Osaka, Japan as an example. She discussed the usage of separate "cabins" in the retail areas. Retail spaces in airports have high fire load and require independent fire protection systems. Beever suggested each cabin has low ceilings and independent sprinkler systems to contain fire within the cabin in the event of an emergency. Then, each cabin can control the rate of fire spread. If a cabin configuration was not feasible, sufficient distance between combustible materials could also restrict fire spread from the area of origin. She called this concept the "islands" strategies. Beever commended the positive effects that the cabins and islands strategies would have in airports (Beever, 1991).

However, another study opposed Beever's cabins suggestion. Professor Wan-ki Chow, Chair Professor of Architectural Science and Fire Engineering at Hong Kong Polytechnic Institute, evaluated the cabins fire safety design in the Hong Kong Airport retail shop area. Chow focused on the potential of flashover in Beever's cabins model. In his computational fluid dynamics simulation, the low ceiling of the cabins reduced the time between ignitions to flashover. Thus, the cabins do not promote slower rates of fire spread as Beever suggested.

Additionally, cabins must have an available open door for people to exit in the event of a fire; an open door enables the smoke to still spread outside of the cabin. Professor Chow suggested that solely utilizing the cabins design is not sufficient enough to ensure fire safety in airport terminals for workers and travelers (Chow, 1997). Chow constructed a full-scale experiment with other fire protection researchers to demonstrate flashover in cabins. The experiment demonstrated the need for an effective smoke extraction system in all cabins in order for Beever's model to consider all risk factors (Shi et al, 2007).

Researchers have studied airport terminal cabins in Morocco. Although Moroccan airports' passenger capacity doesn't compare to that of the Osaka Airport and Hong Kong Airport, Morocco saw a total commercial passenger volume of 1,768,458 in October of 2017. This measurement indicates a 13.34% increase from October of 2016 (ONDA, 2017). The increase in passenger flow in the aviation sector address the need to assess airport fire safety in Morocco.

2.6.2 Studies in the Commercial Sector

Large commercial establishments attract substantial volumes of customers. Since the population density in commercial environments is high, a fire incident will greatly affect public safety. In 1996, a fire in the Garley Building in Hong Kong's major shopping district killed 32 people and injured 79 (The New York Times, Nov 21 1996). In 2000, a fire broke out in a commercial building in Luoyang, China and took 309 lives (Smith, 2000). Evidence shows that these fires are mainly due to insufficient building maintenance (Zhao et al, 2004). Zhao and his research team concluded that fire safety systems needed updates. However, the commercial companies faced heavy financial burdens that limited routine fire safety system maintenance.

Our team reviewed two commercial fire safety studies that developed mathematical models and used these models to analyze fire safety in commercial buildings and to make recommendations. Professor Wan-ki Chow proposed a ranking system for fire safety in high-rise non-residential buildings in Hong Kong. The ranking system first considered invariable factors, such as building height and staircase width. Then, the ranking system checked for the presence of fire service installations, such as fire hydrants and fire alarm systems. Professor Chow used his 15-point ranking system to make detailed recommendations for old non-residential high-rise buildings in Hong Kong (Chow, 2002).

In a more recent study, Nan Zhang and Sihui Dong proposed methods to evaluate fire safety in large shopping malls. Zhang and Dong's evaluation method utilized the Gustav method, a semi-quantitative analysis to convert qualitative data to a quantitative scale. Zhang and Dong wanted to emphasize the protection of lives in the event of a fire emergency, so they revised the weighted scale in Gustav's method. The authors also took into account the equipment level and firefighting experience of the nearby fire brigade. Zhang and Dong then applied their semi-quantitative analysis method to analyze fire risk levels in a shopping mall in Dalian, China. The 84,000-square-meter mall sits in a central commercial district and welcomes 200,000 to 300,000 customers every day. With their analysis, they were able to make recommendations for needed fire risk mitigation in the Dalian mall, including increasing smoke extraction capability and adding fire evacuation maps in the mall. (Zhang et al, 2016).

Commercial buildings are the focus points of these two studies. Researchers adopted semi-quantitative methods to analyze fire risk mitigation within commercial spaces. Zhang and Dong explained that in fire safety studies, pure qualitative analysis does not accurately identify levels of fire risk, while pure quantitative analysis, encompassing big data, provides reliable evaluations of fire risks. The semi-quantitative method takes qualitative information and uses mathematical models to yield numerical values; researchers can then use the numerical values to describe fire safety conditions in a building, or to compare conditions among different buildings (Zhang et al, 2016). Because semi-quantitative analysis is effective in analyzing fire risk, our group will consider this practice for assessment of fire risk in aviation, commercial, and industrial environments.

2.6.3 Studies in the Industrial Sector

There have been a large number of fatal fire accidents in factories around the world. In 1993, 87 workers died in a toy factory fire accident in Shenzhen, China. In 2000, 36 people died in a shoe factory fire accident in Guangdong, China (BBC, 2000). Over the years, fatal factory fires still show up in the news. A review of case studies offers some approaches to fire safety in factories.

Researchers inspected 73 factories in Vietnam and found that although factories had made encouraging progress in the development of fire safety, rates of non-compliance remained persistent. They found non-compliance in areas such as the absence of readable or visible exit signs, of adequate fire-fighting equipment, and of maintenance of electrical wires (Woodard,

2013). Another inspection of 58 garment factories in Vietnam showed that 50% of the factories had emergency exits that were difficult to reach. A factory manager interviewed and stated, "Fixing this problem is relatively simple and straightforward once found, but many factories lack a systematic approach to prevent it from reoccurring in the future" (Aroq Limited, 2014). The problem of missing fire safety systems and inadequate emergency exits is a problem in many facilities, such as the mattress factory our team discussed in section 2.4.4.

Aminu Umar and his research team from *Universiti Teknologi Malaysia*, attempted to use a systematic approach to evaluate factories in Nigeria, specifically for plastic production factories. The framework had a checklist and a numerical weighting scheme to obtain a score on risk mitigation applications. The numerical weighting scheme was based on experts' opinions on risk mitigation (Umar et al, 2014). In another study conducted by Umar, the researchers looked into the experts' influence on the weighting scheme. They admitted the unavoidable influence from the experts but also emphasize the need to use Analytical Hierarchy Process (AHP) to obtain a reasonable weighting scheme (Umar et al, 2015). Developing a weighting scheme for developing a score on risk mitigation applications is a good technique for numerically representing a facility's rating of risk mitigation.

2.7 Background Information on FirePRO Clients in the Three Environments

FirePRO has designated specific companies for us to visit in order to understand the types of clients the company serves in the aviation, commercial, and industrial sectors. We will visit the Office National des Aéroports, the Morocco Mall, and TAQA Morocco. Descriptions of the FirePRO clients are below. We recognize that exclusively visiting FirePRO clients introduces a bias to our project. However, we do not have the resources and contacts to visit a non-FirePRO client's site while in Morocco.

2.7.1 Aviation Sector Client: Office National des Aéroports

The Office National des Aéroports (ONDA) is one of FirePRO's main clients in the Moroccan aviation industry. ONDA employees in Morocco work for the International Aviation Community. ONDA oversees the operations of civil airports in Morocco. The organization also focuses on development projects to modernize infrastructures and to upgrade safety equipment in the aviation industry (ONDA, 2017).

2.7.2 Commercial Sector Client: Morocco Mall

FirePRO is the fire protection company responsible for installation and maintenance of fire safety systems in the Morocco Mall and safety training for the Morocco Mall employees. The mall contains more than 350 retail shops, offers more than 600 international fashion and design brands, and extends over 10 hectares of land. The Morocco Mall expects to receive more than fifteen million visitors a year, and provides 26,000 Moroccans with jobs (Morocco World News). A map of the Morocco Mall is shown below in Figure 3. This map illustrates the large scale of the Morocco Mall.

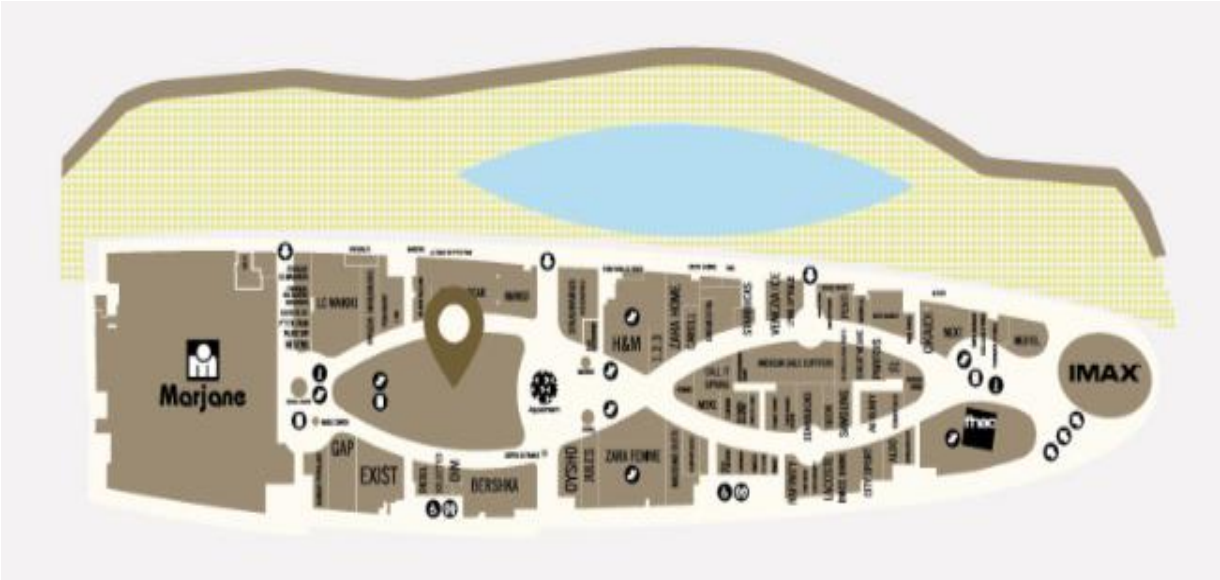

Figure 3: The Morocco Mall layout map. The superstructure is 250,000 m^2 large, which is equivalent to about 46 football fields (Morocco Mall, N.d.).

Fire risk mitigation is crucial for superstructures like the Morocco Mall, due to the large social capital. FirePRO's goal is to maximize safety for all visitors and employees of the mall.

2.7.3 Industrial Sector Client: TAQA Morocco

TAQA Morocco is one of FirePRO's main clients in the industrial sector. TAQA is the leading private electricity producer in Morocco. Its thermal energy plant provides 2,056 megawatts of energy to Morocco annually. TAQA's facility has a one-million-ton coal storage park and two fifty-thousands-cubic-meter oil tank. This plant is in El Jadida region (TAQA

Morocco, 2016). One can recognize the many fire safety risks in these environments. FirePRO helps this company mitigate their fire risks.

2.8 Summary

The Literature Review highlights the complexity of fire safety in aviation, commercial, and industrial environments throughout the country of Morocco. The case studies reviewed in this chapter have indicated the motivations to further investigate fire safety in the aviation, commercial, and industrial sectors. Research papers have also provided our team with effective methods to utilize in our project such as semi-quantitative techniques. In our Methodology Chapter, we will discuss our methods to accomplish our three objectives: investigation of fire safety systems and applications present, comparisons between Moroccan and international fire safety practices, and documentation of social dimensions of fire safety awareness.

Chapter 3. Methodology

Aviation, commercial, and industrial site assessments will address the following objectives to determine the implementation of fire safety codes and to establish differences between current fire safety applications and recommended fire codes. We will address the following objectives:

1. Investigate safety applications and systems present in aviation, commercial, and industrial environments
2. Compare Moroccan and international fire safety practices to determine best practices in all environments
3. Document social dimensions concerning fire safety awareness within all environments.

Our team will visit three different sites in Morocco: Office National des Aéroports (ONDA, aviation sector), Morocco Mall (commercial sector), and TAQA Morocco (industrial sector). The details of our data collection strategies are outlined below.

3.1 Map Fire Safety Applications and Systems

Our team will visit a sample of representative sites in the aviation, commercial, and industrial sectors to investigate fire safety applications and systems. These site visits will include visual and written documentation. One team member will be responsible for taking photos of fire safety systems. We will designate one team member to take observational notes during the visits. Every group member will be present for the interviews with site managers.

Our open-ended interviews with staff will help to build a profile of safety systems in each location. We prefer open-ended interviews because we would like to gather data on the questions we ask, and on any additional information mentioned. In the book *Researching the City*, Kevin Ward speaks of different types of interviews. "...to talk to important (or knowledgeable) people and elicit information from them (about what they do, about their relationship to others, about their ways of working, their position in networks of power, about what they know as a result of their particular expertise or area of responsibility)" (Ward, 2014). Our interviews with security staff, site managers, and factory supervisors will mainly gather information about the site and their responsibility to keep the facility fire safe.

In the event that the interviewee speaks English, one team member will conduct the interview. In the event that the interviewee speaks only French and/or Arabic, the FirePRO engineer accompanying us on our site visit will ask our team’s interview questions on our behalf.

Every team member will be present for each interview. One of us will record all interviews and the other two of us will take notes. The FirePRO engineer will then translate the conversations to our team at a later time.

3.1.1 Aviation Sector

Our team will visit the Office National des Aéroports, which is headquartered in the Mohammed V International Airport in Casablanca. Prior to our site visit to Mohammed V International Airport, we will analyze any sitemaps provided by FirePRO. Our team will also document the variety and distribution of all fire safety systems through photographs and a checklist of fire safety systems in high-risk areas of the airport.

We will conduct face-to-face interviews with airport managers at the Office National des Aéroports during our site visits. The purpose of these interviews is to further understand the fire safety systems present in the aviation facility as well as how often the systems are updated. We hope to interview at least five airport managers in different departments of the facility. In the interview templates, we will keep track of the interviewee name (with permission), facility name, department name, and time. Appendix A includes interview questions. We will accomplish our first objective once we investigate current fire safety systems and applications present in the Aviation sector, as shown in Figure 4 below.

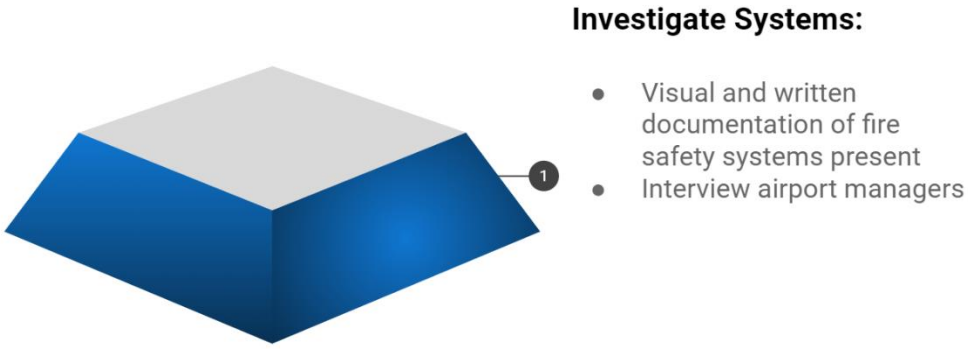

Figure 4: Methodology Strategy One for aviation sector

3.1.2 Commercial Sector

Our team will visit the Morocco Mall, which is located in the outskirts of Casablanca, Morocco. Prior to our site visit to the Morocco Mall, we will analyze any sitemaps provided by FirePRO. Our study will also document the variety and distribution of all fire safety systems

through photographs and a checklist of fire safety systems in high-risk areas of the commercial establishment.

Interviews with building managers and fire safety personnel will address the Morocco Mall's safety equipment inspection routines and emergency evacuation drills. We hope to interview at least five building managers, and five fire safety personnel. In these interviews, we will be keeping track of the interviewee name (with permission), and facility location name. Interview questions can be found in Appendix B. We will accomplish our first objective once we investigate current fire safety systems and applications present in the Commercial sector, as shown in Figure 5 below.

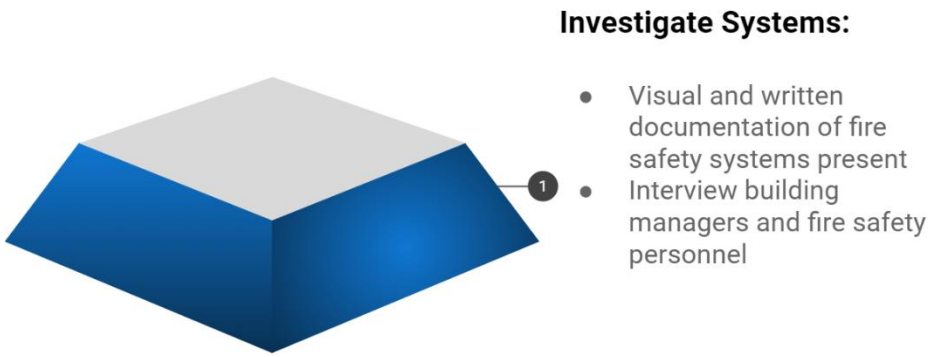

Figure 5: Methodology Strategy One for Commercial Sector

3.1.3 Industrial Sector

Our team will visit TAQA Morocco, which is located in El Jadida, Morocco. Prior to our site visit to TAQA Morocco, we will analyze any sitemaps provided by FirePRO. Our team will also document the variety and distribution of all fire safety systems through photographs and a checklist of fire safety systems in high-risk areas of the commercial establishment.

Interviews with facility supervisors will address the energy plant's safety equipment inspection routines, emergency evacuation drills, and fire application updates. In these interviews, we will be keeping track of the facility name, and interviewee name (with permission). Interview questions can be found in Appendix C. We will accomplish our first objective once we investigate current fire safety systems and applications present in the Industrial sector, as shown in Figure 6 below.

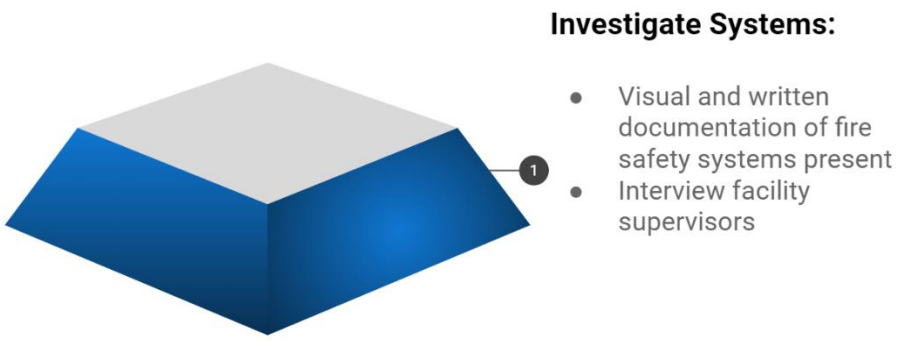

Figure 6: Methodology Strategy One for Industrial Sector

3.2 Compile Best Practices for International Fire Safety Implementations

Our team will compare Moroccan and international case studies in order to establish best practices for Moroccan fire safety systems in aviation, commercial, and industrial settings. We will learn from past projects FirePRO has completed, and conduct content analysis to compare and contrast case studies.

We will record data through our first objective, tabulate data, and then analyze the data to compare fire safety practices throughout Moroccan and international airports, commercial spaces, and industrial settings. We will compare best practices within each of the three sectors by using qualitative and semi-quantitative analysis. Our interviews will determine our qualitative data. We will gather quantitative data through on-site observations. Our semi-quantitative method applies mathematical scales to convert qualitative data to quantitative data; this method can compare qualitative data more effectively. Nan Zhang and Sihui Dong conducted a fire safety evaluation project on a shopping mall in Dalian, China. The researchers successfully assessed the fire safety conditions by designing a numerical scale scheme to quantitatively compare fire risks (Zhang et al, 2016). Since their project targeted fire safety evaluation in different environments, we will be adopting the same method. We will determine our semi-quantitative analysis by scaling on-site qualitative data.

3.2.1 Aviation Sector

The investigation of fire safety applications and systems in the aviation sector (refer to Chapter 3.1.1) determines our qualitative data to accomplish our second objective. Our team will then work with FirePRO to compare our qualitative data to international qualitative data to

determine the best feasible practices in Moroccan aviation environments. Refer to Figure 7 below to visualize the progression of our objectives at this stage.

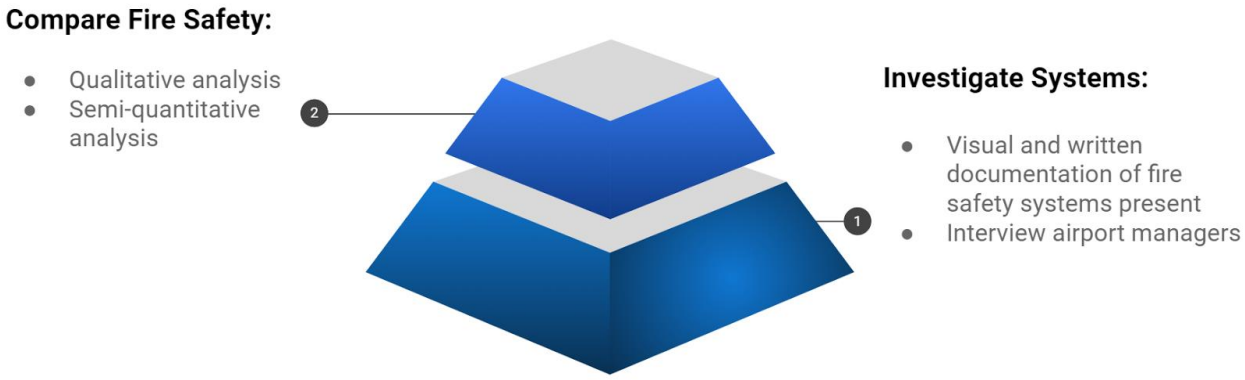

Figure 7: Methodology Strategy Two for Aviation Sector

3.2.2 Commercial Sector

The investigation of fire safety applications and systems in the commercial sector (refer to Chapter 3.1.2) determines our qualitative data to accomplish our second objective. Our team will then work with FirePRO to compare our qualitative data to international qualitative data to determine the best feasible practices in Moroccan commercial environments. Refer to Figure 8 below to visualize the progression of our objectives at this stage.

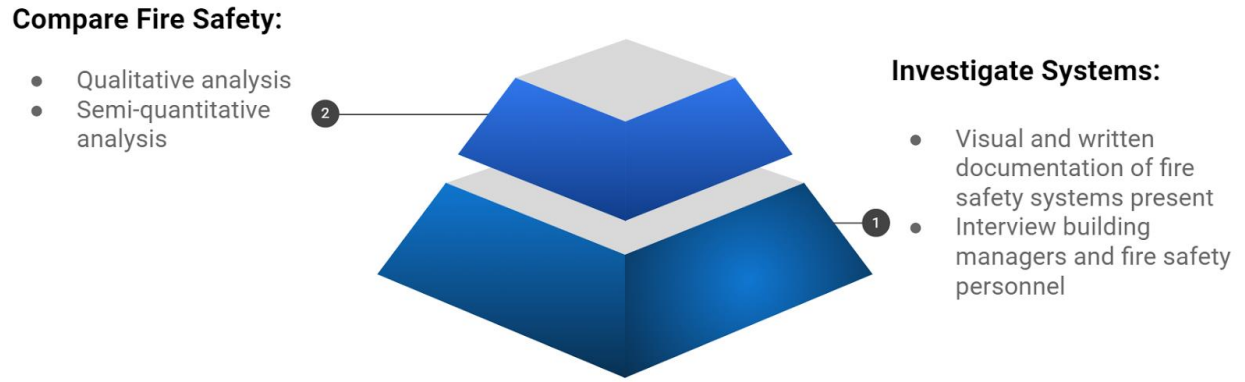

Figure 8: Methodology Strategy Two for Commercial Sector

3.2.3 Industrial Sector

The investigation of fire safety applications and systems in the industrial sector (refer to Chapter 3.1.3) determines our qualitative data to accomplish our second objective. Our team will

then work with FirePRO to compare our qualitative data to international qualitative data to determine the best feasible practices in Moroccan industrial environments. Refer to Figure 9 below to visualize the progression of our objectives at this stage.

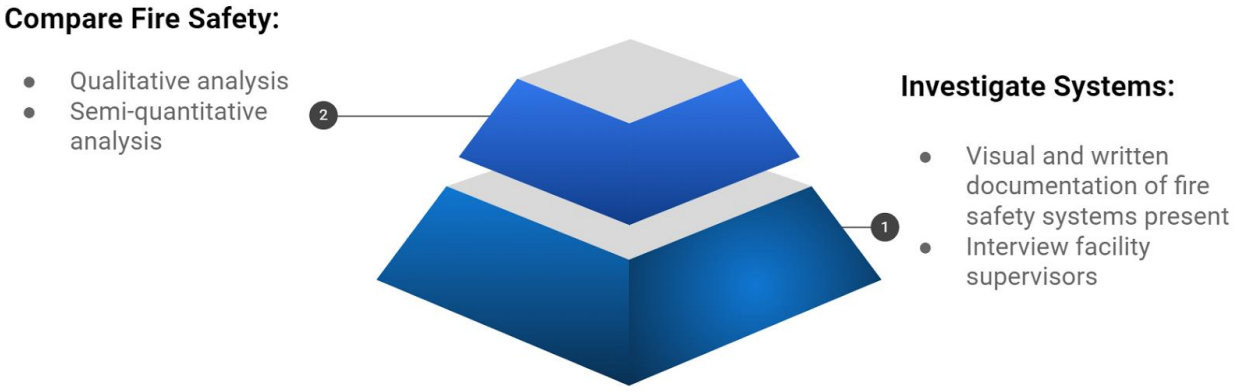

Figure 9: Methodology Strategy Two for Industrial Sector

3.3 Document the Social Dimensions of Fire Safety Awareness

To document the social dimensions of fire safety awareness in aviation, commercial, and industrial environments, our team will collect data through surveys. We will select the samples for our surveys using sample of convenience. Compared to interviews, surveys can indicate broader trends; interviews, on the other hand, explore deeper into the reasons behind trends (Ward, 2014). In this case, we will be using surveys to collect as many straightforward responses as possible regarding fire safety awareness in the three public and workplace environments.

3.3.1 Aviation Sector

Our team will survey airport employees and travelers at the Office National des Aéroports. We will survey airport employees to understand the facility's work environment, emergency fire exit accessibility, and fire extinguisher knowledge. By surveying travelers, our group will grasp the visiting frequency of travelers, and fire safety awareness. Our surveys with travelers in the airport will be brief, as they may have limited time to spare. We hope to survey at least 10 airport employees and 10 airport travelers during our site visit with FirePRO. Our third objective and associated methods can be seen below in Figure 10. Our survey questions can be found in Appendices D and E.

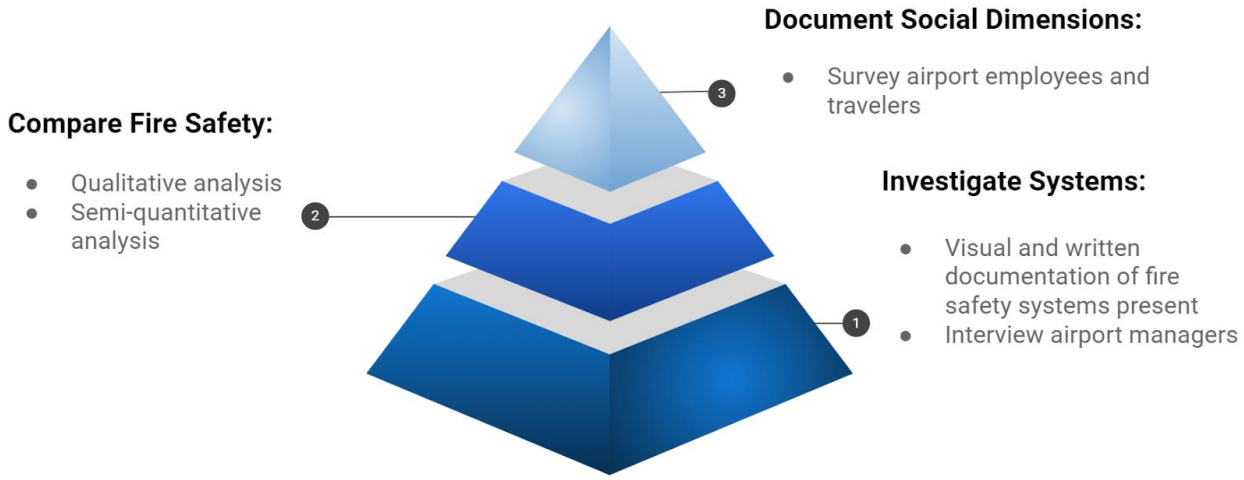

Figure 10: Methodology Strategy Three for Aviation Sector

3.3.2 Commercial Sector

In order to accomplish our third objective for the commercial sector, we will survey mall customers in the Morocco Mall. Our survey will inform our team on the customers' average time spent in the mall, the level of population density in the mall, and the possible fire exits throughout the mall. We hope to survey at least 20 mall customers for statistically significant data. These surveys will be anonymous to protect the identities of our mall customer survey subjects. Our third objective and associated methods can be seen below in Figure 11. Our survey questions can be found in Appendix F.

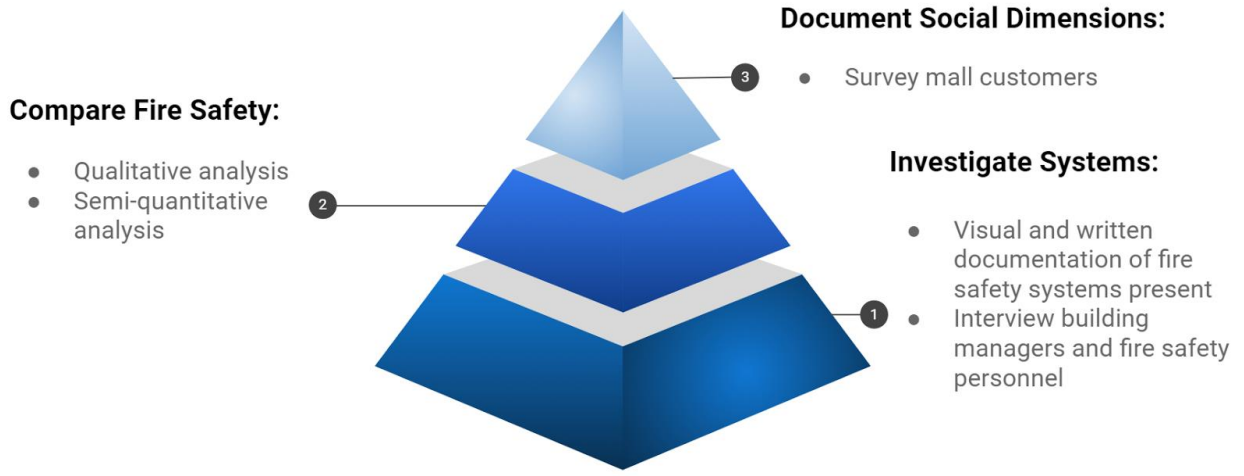

Figure 11: Methodology Strategy Three for Commercial Sector

3.3.3 Industrial Sector

Our team will survey industrial employees at the TAQA Morocco site. We will survey the industrial employees to better understand employment safety trainings, workplace fire safety applications, and experience with fire incidents. We hope to survey at least 10 industrial employees during our site visit with FirePRO. These surveys will be conducted anonymously to prevent any issues between supervisors and employees. Our third objective and associated methods can be seen below in Figure 12. Our survey questions can be found in Appendices F.

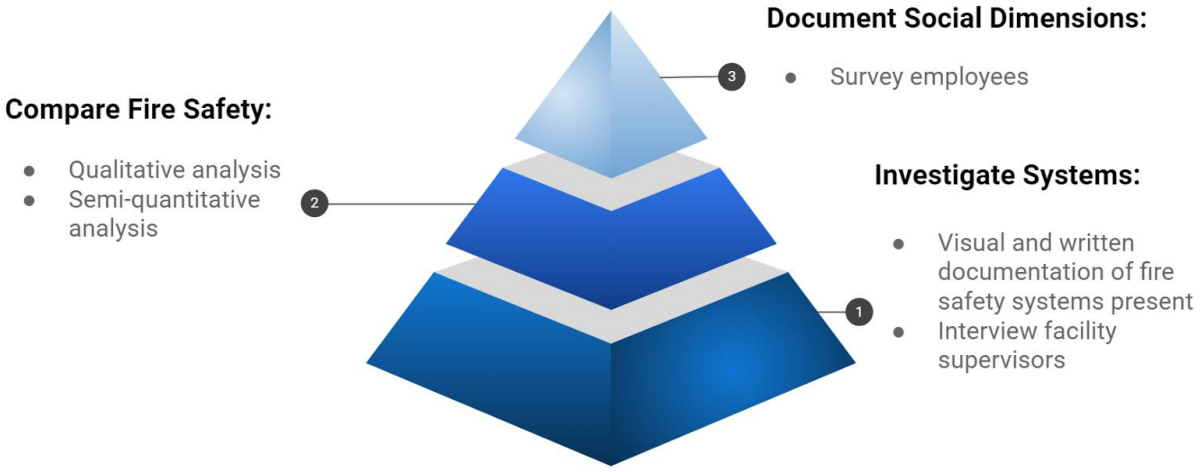

Figure 12: Methodology Strategy Three for Industrial Sector

3.4 Data Management, Translators, and Site Visit Logistics

In all of our interviews, we will ask permission to use names. All of our surveys will be anonymous to prevent workplace conflict between employers and employees.

Our team needs two translators, one to translate between English and Darija, and the other between English and French, to assist our individual interviews. We need the translators between week three and seven. We will determine the best translations of technical terminology with our translator. Our team will practice with the translators to calibrate nuances in technicality as well as to determine how often we should expect the translator to relay information to us. We will be recording all of our interviews in writing and audio for data analysis and review.

The aviation, commercial, and industrial sites we visit may be difficult to travel to in one day and may require more than one day of data collection. We will arrange our travel and any necessary overnight stays for site visits with our sponsor, FirePRO.

3.6 Estimated Timeline

Below is our team's estimated timeline for our IQP project in Morocco:

Timeline	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
	1/8 to 1/12	1/15 to 1/19	1/22 to 1/26	1/29 to 2/2	2/5 to 2/9	2/12 to 2/16	2/19 to 2/23	2/26 to 3/2
Orientation								
Assess any maps provided								
Semi-quantitative analysis								
TAQA Morocco								
Office National Des Aéroports								
Morocco Mall								
Additional Site Visit*								
Data Analysis and Writing								
Recommendation Development								

Figure 13: FirePRO Project Group Timeline (*time permitting)

We expect to spend the first week in Morocco in orientation with our site members. During our second week, we will assess any sitemaps provided by FirePRO and work with FirePRO to develop the checklist and scaling of our semi-quantitative analysis. Weeks 3, 4, and 5 will consist of site visits. We have blocked out week 6 for any additional data collection necessary to our project. Throughout our site visits, we will work on analyzing our collected data and writing our report. The last two weeks of our project will be spent developing our deliverables for FirePRO. Our deliverables will most likely take the form of recommendations on sectors to focus on or systems and trainings to market to specific sectors.

Chapter 4. Conclusion

Our team will work under the guidance of FirePRO Engineering to evaluate current implementation of fire safety codes in public and workplace environments and identify gaps between fire safety applications present and the corresponding fire codes. In order to accomplish our goal, we will be visiting three sites (Office National Des Aéroports, Morocco Mall, and TAQA Morocco). While visiting these three sites, we will be investigating the fire safety systems present, comparing fire safety between sites, and documenting the social dimensions of fire safety in public and workplace environments. The result of our project will be a deliverable to FirePRO Engineering, most likely in the form of recommendations.

We are confident that the methods for accomplishing each of our goals are some of the most efficient means of collecting data, but welcome any comments regarding specific aspects of our methods such as interview and survey questions. We understand that our site visit schedule must be flexible, as FirePRO will schedule our site visits with their clients. However, our team would still like to complete all data collection by the end of week 5.

Although we have had weekly meetings with FirePRO throughout the last seven weeks, we are looking forward to meeting our FirePRO Engineering team on-site. We hope that through our project, we will not only help FirePRO by providing useful deliverables but will also improve the standard for fire safety in aviation, commercial, and industrial sectors throughout Morocco.

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Appendix A: Interview Questions for Airport Managers

Interview Preamble:

We are a team of students from the United States studying fire safety in Moroccan airports. We would greatly appreciate if you could answer a few questions for our project with FirePRO Engineering.

The purpose of this interview is to gather knowledge on the facility's fire safety systems. Our team will make the best possible fire risk mitigation recommendations, if any, to FirePRO for Moroccan airport environments using your answers to these questions. Your answers are valuable to our project data and we appreciate your time. If comfortable, we would like to document your name and the department you work for in the airport.

Interviewee name:
Facility name:
Department name:
Time:

1. What fire safety systems are used at this airport facility (i.e. fire sprinkler, fire curtain, smoke detector, or exhaust system)?
    a. How many of these fire safety systems are required by ICAO?
    b. How many of these fire safety systems are additional precautions?
    c. Does your facility have an emergency evacuation plan?
    d. What types of fire safety trainings are employees expected to complete?
    e. Are you expected to provide fire safety trainings to all airport employees?
    f. Which employees take which trainings?
    g. How often are employees expected to retake training courses?
2. Who conducts inspections of the fire safety equipment in this facility?
3. How often is the safety equipment checked and updated?
4. How often do you conduct fire drills or emergency evacuations?
5. Do all fire incidents need to be reported? (Yes/No)

. If yes to #5, who is informed of the fire incident?

Appendix B: Interview Questions for Building Managers at Shopping Malls

Interview Preamble:

We are a team of students from the United States studying fire safety in Moroccan commercial sites. We would greatly appreciate if you could answer a few questions for our project with FirePRO Engineering.

The purpose of this interview is to gather knowledge on the facility's fire safety systems. Our team will make the best possible fire risk mitigation recommendations, if any, to FirePRO for Moroccan commercial environments using your answers to these questions. Your answers are valuable to our project data and we appreciate your time. We will be specifying the location at which this interview took place in order to keep track of our data, but we will not be including your name to respect confidentiality.

Interviewee name:
Facility name:
Time:

1. What fire safety systems are used at this shopping center (i.e. fire sprinkler, fire curtain, smoke detector, or exhaust system)?
    a. How many of these fire safety systems are required by Moroccan fire codes?
    b. Are any of these fire safety systems required by the shopping center's insurance company?
    c. How many of these fire safety systems are additional precautions?
    d. Does your facility have an emergency evacuation plan?
    e. What types of fire safety trainings are employees expected to complete?
    f. Are you expected to provide fire safety trainings to all mall employees?
    g. How often are employees expected to retake training courses?
2. Who conducts inspections of the fire safety equipment in this facility?
3. How often is the safety equipment checked and updated?
4. How often do you conduct fire drills or emergency evacuation?
5. Are there any additional fire code protocols that restaurants in the food court need to follow?
6. Which stores in the mall sell products that increase the risk of fire (not inclusive of restaurants in the food court)?

. About how many shops in the mall sell some sort of flammable/combustible material? Please provide examples.

7. Does the mall's population density affect civilian and workplace fire safety?

. If so, how drastically?
    a. What are the popular times to visit the mall during the week?
    b. What are the popular times to visit the mall on the weekend?
    c. During the busiest time of day, approximately how long does it take to travel to a nearby fire exit?

Appendix C: Interview Questions for Supervisors at Factory Plants

Interview Preamble:

We are a team of students from the United States studying fire safety in Moroccan industrial sites. We would greatly appreciate if you could answer a few questions for our project with FirePRO Engineering.

The purpose of this interview is to gather knowledge on the facility's fire safety systems. Our team will make the best possible fire risk mitigation recommendations, if any, to FirePRO for Moroccan industrial environments using your answers to these questions. Your answers are valuable to our project data and we appreciate your time. We will be specifying the location at which this interview took place in order to keep track of our data collected, but will not be including your name for confidentiality purposes.

Interviewee name:
Facility name:
Time:

1. What fire safety systems are used at this factory plant (i.e. fire sprinkler, fire curtain, smoke detector, or exhaust system)?
    a. How many of these fire safety systems are required by Moroccan fire codes?
    b. Are any of these fire safety systems required by the shopping center's insurance company?
    c. How many of these fire safety systems are additional precautions?
    d. Does your facility have an emergency evacuation plan?
    e. What types of fire safety trainings are employees expected to complete?
    f. Are you expected to provide fire safety trainings to all factory employees?
    g. How often are employees expected to retake training courses?
2. Who conducts inspections of the fire safety equipment in this facility?
3. How often is the safety equipment checked and updated?
4. How often do you conduct fire drills or emergency evacuations?
5. Do all fire incidents need to be reported? (Yes/No)
6. If yes to #5, who is informed of the fire incident?

Appendix D: Survey Questions for Travelers in Airports

All conducted surveys will be anonymous, since there is no importance in surveyors' names. We hope for all of our surveyors to be honest and thorough in their responses. The purpose of these surveys is to acquire strong representations of the populations we are surveying.

The purpose of this oral assisted survey is to gauge your sense of fire-safety in this airport. We will be recording the time, and the section of the airport we are in right now. Your name will not be included in our study. Your answers are valuable to our project data and we appreciate your time.

Facility name:

Facility area:

Time of day:

Interviewer:

Translator name:

1. How frequently do you travel to and from this airport? (First time here, weekly, monthly, yearly, or occasionally)
2. On a scale from 1 to 5, how safe do you feel in the airport when it comes to fire safety?

1	2	3	4	5
(not safe)		(somewhat safe)		(very safe)

3. Why?
4. Take a look around and tell us which fire safety systems you see.
5. What type of fire prevention methods would make you feel safer?

Appendix E: Survey Questions for Airport Employees

The purpose of this survey is to investigate fire safety applications in airport settings. To respect confidentiality, we will not record your name. Although, we will record the facility at which we conducted this interview, and your job title. Your answers are valuable to our project data and we appreciate your time.

Facility Name:
Employee job:
Translator's Name:

1. How often do you work at the airport? What shifts (night, day, red-eye, weekend, weekday, etc.)?
2. When is the busiest part of a typical day (weekend and weekday?
3. Where is it the busiest area of the airport?

Emergency fire exits:

1. How far away is the nearest fire exit to where you work?
2. Are you aware of the escape routes you need to take in the event of a fire?

Fire extinguishers:

1. How far away is the nearest fire extinguisher?
2. Do you know how to use the fire extinguisher? If so, did you have to take a course to learn how to use the fire extinguisher?

Other fire safety systems:

1. Does the airport have fire alarm systems?

Appendix F: Survey Questions for Mall Customers

The purpose of this survey is to gauge the social dimensions of fire safety in commercial sector, and investigate fire safety practices that can be improved upon in public commercial settings. The survey is confidential. Your answers are valuable to our project data and we appreciate your time.

Location in mall:
Time of day:
Interviewer:
Translator name:

How frequently do you shop at this mall (Weekly, monthly, yearly, occasionally, or first time)?

How long do you usually stay when you shop here (less than 30 minutes, 1-2 hours, 2+ hours)?

How far are you from the nearest emergency exit?

Do you think the mall is overly-crowded at times?

If there were a fire incident, how long do you think it would take you to exit the mall?

Appendix G: Survey Questions for Industrial Employees

The purpose of this survey is to investigate fire safety applications in factory settings. For confidentiality reasons, we will not record your name. Although, we will include your job title in our survey data. Your answers are valuable to our project and we appreciate your time.

Facility name:
Surveyor's job title:
Translator's name:

Objective Questions
Did you undergo safety training when you were first hired for the job?

Does your workplace host fire drills? If so, how often?

Did you receive special training on how to use a portable fire extinguisher?

Do you feel like this facility is up-to-date in safety standards? (Yes/No)

Why or why not?

Have you ever experienced a fire incident in the workplace?

If so, what fire protocol(s) did you follow?

Subjective Questions
How many people do you think can safely fit in this facility?

Are there certain rooms in this building that you think are too crowded at times?

What types of fire safety systems are imperative to your workplace safety?