Evaluation of Fire Safety Applications in Aviation, Commercial, and Industrial Environments in Morocco

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Abstract

This report is a documentation of our team's process in analyzing the fire safety systems present in the aviation, commercial, and industrial environments in Morocco. Our project also includes a comparison of Moroccan and international fire codes (mainly United States National Fire Protection Association codes) as well as a testimony to the current social problems in Morocco regarding the transition from Moroccan to international fire codes. We presented the results of our analysis as recommendations both to FirePRO Engineering as well as to future project teams looking to improve the non-fire safety application side of fire safety development in Morocco. In addition to these recommendations, our team has also developed a checklist template to determine fire risk for future use by FirePRO Engineering on site assessments.

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Executive Summary

The Kingdom of Morocco is investing in the remodeling and building of new infrastructures to modernize the country. Morocco currently utilizes French fire code and labor laws and is working towards implementing additional fire codes from the United States National Fire Protection Association (NFPA) in new building projects. Throughout our eight weeks in Morocco, our team has had the opportunity to investigate current fire codes and their implementation by visiting and learning more about the aviation, commercial, and industrial sectors. Our project analyzed how fire safety codes are implemented in establishments built in the past. Thus, our team found great importance in finding ways to enhance fire safety code implementation in existing aviation, commercial, and industrial environments.

Our goal was to evaluate current technical implementation of fire safety codes in public and workplace environments in Morocco and investigate the social matter surrounding fire safety awareness. Our sponsor, FirePRO Engineering, is interested in practicing successful global fire codes to ensure optimal safety for its clients.

The project's first objective was to investigate fire safety applications and systems present in aviation, commercial, and industrial environments. We utilized two checklists that we adopted from a study in China and one checklist from FirePRO Engineering to evaluate fire risk levels and conduct risk analysis in different areas within an establishment (Zhang et al, 2016). Using these checklists, we collected qualitative data on multiple factors (quality or presence of systems, areas and densities of fire safety applications, facility type, etc.) and assigned quantitative values to describe each factor's risk level. Every factor's numerical output is then entered into two equations, both of which result in a calculation representing the risk to the building structure (R_b), and to the lives and properties in the assessed area (R_p). We used the two risk assessment values to compare the levels of fire risk in different areas of each establishment we visited. Specific factors in the three checklists highlighted which fire safety systems can most effectively improve the fire safety conditions in each of these areas.

Although a comprehensive risk rating determines a site's overall fire safety, the risk rating cannot suggest direct recommendations. Our team and FirePRO engineers decided to focus on the specific fire safety factors that align with FirePRO's expertise; doing so can result in better and more effective recommendations. The two sites we analyzed for technical data are the

Morocco Mall and Mondi Group (specifically, Mondi Pap Sac Maghreb). We reviewed the two risk ratings for each area within the sites, and developed visual representations of the improvable fire safety applications for both sites. We found that for these site visits the basic fire safety applications and technologies were all present. Both Mondi Group and Office Chérifin des Phosphates (OCP) had specialized fire safety systems for the fire risks unique to each site. For instance, Mondi Group had an encapsulated micron aerosol agent system, or EMAA system, for their chemical storage room. Our team had planned to analyze the fire systems present in the Mohammed V International Airport in Casablanca and OCP Jorf Lasfar; we were not able to gain full access to these two facilities because we did not obtain the necessary security clearance. The OCP fire department had specialized equipment for fighting common chemical fires within OCP. We also found that the OCP fire department had certain firefighting systems that most Moroccan fire departments do not have, such as the hydraulic rescue tool, "jaws of life."

Our second objective was to compare Moroccan and international fire safety practices to determine best practices in all environments. On our site visits, we observed and learned of the differences between Moroccan and NFPA fire codes through observation, speaking with our sponsor engineers, and our interviews and surveys. One main difference between typical fire safety practices in the United States and Morocco is the fire exit sign. United States typically uses the illuminated red "exit" signs, whereas Morocco uses the International Organization for Standardization (ISO) green "running man" exit signs. The "running man" exit sign is a more effective form of an exit sign, mainly due to the visibility of the color green in event of a fire and the universality of the running man pictograph. However, through our site visit to the Morocco Mall, our team determined that in addition to having an effective exit sign, the sizing and placement of the sign is imperative to a well-marked evacuation route. Although the Morocco Mall had many exit signs throughout the facility, they were often placed too high or were typically too small. Our survey results reflected that most of our surveyed mall customers did not know where the nearest fire exit was or how long it would take to exit the mall. Mall managers can solve this problem with more explicit markings for evacuation routes.

Another difference between Moroccan and NFPA fire code is that Moroccan fire codes do not require sprinklers in buildings. We discovered this difference during our visit to Mondi Group. Sprinklers were present throughout the Morocco Mall, but not in the Mondi Group site.

The NFPA fire code puts an emphasis on sprinkler usage. Whether sprinklers are necessary in the environments we analyzed is not clear, but they may be helpful in case of a large fire.

Our third objective was to document social dimensions concerning fire safety within all three environments. We conducted surveys and interviews with workers in Mondi, the public, and company managers.

Our surveys with the shoppers in the Morocco Mall provided information on the fire safety awareness of Moroccan people in public spaces. Our interview with Mondi Group Africa's Managing Director, Hicham Jalal, provided our team with important social information on the role the government currently plays in assessing the presence and maintenance of fire safety systems in industry. Our meeting with the Office National Des Aéroports (ONDA) provided our team with a different perspective on fire safety and fire codes, as the United Nations International Civil Aviation Organization (ICAO) regulates the Moroccan airport fire safety, rather than Moroccan government. Lastly, our interview and surveys with the OCP fire department chief and firemen gave our team information on the resources that OCP has in case of fire, as well as the logistical issues in transitioning from Moroccan fire codes and standards to NFPA codes and standards. The largest difficulties in switching the fire codes are the insurance companies' expectation that fire department switch the systems and trainings immediately, rather than allowing a transition period, and the sudden inability to utilize systems and technologies that are not American fire code-approved (UL or FM approved).

In accomplishing our third objective, our team identified some social issues in Morocco around fire code education, fire code implementation, and adaptation to international fire codes. Through our surveys in the Morocco Mall, we believed that organizing a public fire safety education and awareness event in Morocco would be an important potential project, either for FirePRO Engineering or for future Morocco IQP projects. In our interview with Hicham Jalal from Mondi Group, we found that the Moroccan government does not conduct fire safety assessments regularly at Mondi Group. For this reason, we deduced that there is a possible lack of resources available to the Moroccan government for fire safety inspections.

Our fourth objective was to develop an Excel checklist template to aid FirePRO Engineering employees in future client site assessments. Our team utilized our adapted checklists for R_b and R_p to develop the template. These checklists help determine relative levels of fire risk,

as well as organize data that is helpful in determining which fire safety applications can contribute to a safer environment.

As a result of our findings, our recommendations to FirePRO are as follows:

1. Offer public fire safety education events in order to encourage change and improvement in fire safety awareness in Morocco
2. Encourage larger exit signs rather than smaller ones, and ensure placement of exit signs is conspicuous
3. Conduct post-project evaluations with clients to ensure the service delivered is satisfactory.

In addition to these recommendations to our sponsor, we would like to recommend the following for future projects (WPI projects or projects in Morocco):

1. Implement a volunteer fire department program in Morocco in order to increase the number of available firefighters, as well as to further promote the Moroccan National Initiative for Human Development
2. Organize a firefighting equipment redistribution or donation program to ensure that private companies with private fire departments are able to transition to NFPA code without wasting resources, as well as to provide surplus resources to Moroccan fire departments that may be in need of more firefighting equipment.

In summary, this project assessed the current technical implementation of fire codes in Morocco, as well as identified the social dimensions and the differences between Moroccan and United States fire safety. In addition to accomplishing our goal, our team developed a user friendly template for evaluating the fire risk in client sites and determining the fire safety applications most needed in the site. As a result, this project will serve as a basis for future standardized site evaluations, executed by FirePRO Engineering. This project will also aid FirePRO in determining the best-use of the technologies they provide to their clients. Lastly, this project suggests the possible areas for growth in Moroccan fire safety, and will serve as a foundation for fire safety resource and fire safety awareness projects in Morocco.

Table of Contents

List of Figures

List of Tables

Acronym Reference Table

AHP	Analytical Hierarchy Process
EMAA	Encapsulated Micron Aerosol Agent
ERP	Les Établissements Recevant du Public
FM	Factory Mutual (an American insurance agency and safety certification country)
ICAO	International Civil Aviation Organization
INDH	National Initiative for Human Development
ISO	International Organization for Standardization
IQP	Interactive Qualifying Project
NFPA	National Fire Protection Association
OCP	Office Chérifien des Phosphates
ONDA	Office National des Aéroportes
OSHA	Occupational Safety and Health Administration
QRA	Quantitative Risk Analysis
RFF	Rescue and Firefighting
SQA	Semi Quantitative Analysis
UL	Underwriter Laboratories (an American safety certification company)
WPI	Worcester Polytechnic Institute

Chapter 1. Introduction

Catastrophic building fires are strong catalysts for the assessment and revision of existing fire safety applications and construction protocols. On December 21, 2017 in Jecheon, South Korea, a sports center building fire resulted in 21 civilian deaths (Ho, 2017). The fire originated on the first-floor, in the piloti (column) structured outdoor parking lot, which also served as a public walkway for civilians to enter and exit the sports center. After a short few minutes, the fire spread to the upper stories of the building and restricted many civilians from using the parking lot as a means of evacuation. There was a set of emergency exit stairs in the establishment, but unfortunately many civilians did not have adequate time to access these stairs. Since the vehicles in the parking lot, the finishing materials of the building's interior, and the architectural structure of the building were highly vulnerable to fire, they all contributed to the fast spread of the flames. The gasoline in the vehicles was easily combustible and the interior finishing materials and the DryVit exterior of the sports center emitted toxic gas throughout the building. DryVit is a covering for building structures and consists of many materials including Styrofoam, a highly flammable material). Certain areas in the building had no windows (natural ventilation), to lessen the spread and effect of the toxic gas and had narrow, limited exits. As a consequence, the majority of the deaths from this sports center fire occurred in the second-floor women's sauna room.

The sports center fire in Jecheon, South Korea indicates that risk mitigation is vital in lessening the effects of catastrophic events. The architectural layout of the sports center did not prioritize fire safety. If the owner of the sports center had put in more than one exit and a well-designed and distributed ventilation system, he could have saved more lives in the fire accident. The sports center owner chose the flammable DryVit material for the exterior of the building "because of the cheap cost" (Ho, 2017). If property owners are more aware of the positive effects of effective fire risk mitigation, fire incidents will not be as threatening as this one was to the safety of people and properties.

Our team employed risk interpretation processes to target fire safety risk management in Moroccan public and workplace environments. FirePRO Engineering works as a liaison between clients and government-mandated and recommended fire and safety codes to promote optimal safety within the clients' establishments. FirePRO Engineering, our project sponsor, is an

engineering group headquartered in Casablanca, Morocco. The company specializes in four sectors of fire protection: engineering design, system installation, safety training, and specialized international products. FirePRO recognizes about the need for up-to-date fire safety applications for their clients, who are primarily from the aviation, commercial, and industrial sectors. FirePRO focuses on these three sectors because they hold high fire risk profiles.

Our team collaborated with FirePRO to conduct fire safety application assessments within the aviation, commercial, and industrial sectors through on-site observations and consultations with site staff. Our goal was to evaluate the current technical implementation of fire safety codes in public and workplace environments in Morocco and to identify social context surrounding fire safety in Morocco. Our objectives to meet our goal were 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 and analyze social dimensions concerning fire safety awareness within all environments
4. Develop an Excel checklist template to aid FirePRO Engineering in future client site assessments.

This project analyzed the current state of fire safety in Morocco through site assessments; interviews with company managers, university leaders, fire safety professionals, volunteer firemen, and fire department chiefs; it includes surveys of mall shoppers, industrial employees, and firemen. These methods served as part of our fire risk interpretation process.

As we have discovered, reducing fire risk in Moroccan establishments is no small task. Although, there are many ways in which fire risk mitigation practices enhance overall safety in aviation, commercial, and industrial sectors. These fire risk mitigation practices address awareness, education, and accessibility. Fire safety awareness of people in public and workplace environments plays an important role in preventing fires and optimizing egress in the event of a fire. Companies' education surrounding fire safety applications and systems and their implementation is vital in creating a safe environment in their establishment. Lastly, the

availability and distribution of fire departments and firefighters contribute to the safety of the people in these public and workplace spaces.

Chapter 2. Background

FirePRO tasked our team with addressing both the need and effectiveness of FirePRO's fire mitigation services as well as researching strategies to improve fire mitigation practices in Morocco's aviation, commercial, and industrial environments. The background chapter provides information that is useful in appreciating the environment surrounding our project's goals and objectives. To begin, the chapter discusses important background information about our sponsor FirePRO Engineering, Morocco's growing economy, the 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 identify 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 give us perspective on Morocco's utilization of fire risk mitigation. Bolded words throughout this chapter represent terminology defined in our Glossary.

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, and heat detection systems. 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 its clients in Morocco (FirePRO Engineering, personal communication, November 2017).

2.2 Economic Advancement in Aviation, Commercial and Industrial Sectors in Morocco

FirePRO's efforts to enforce fire risk mitigation are under increasing strain as Moroccan aviation, commercial and industrial sectors grow. The country has seen successful economic growth and development in past years.

There has been an influx of aviation passengers year to year. Morocco's aviation passenger traffic experienced a "sharp increase of 13.34%" from 2016 to 2017 (ONDA, 2017). The increase of people traveling by air in Morocco presents a need to determine if current fire safety at airports is adequate.

The commercial sector continuously contributes to a large portion of Morocco's job market. According to the *Royaume du Maroc Ministere de I'lndustrie, de I'lnvestissement, du Commerce et de I'Economie Numerique*, the commercial sector contributed 9.4% of the Kingdom's Gross Domestic Product in 2013. The commercial sector had 1.42 million employees (13.4% of working population in the Kingdom in 2013) and was the second biggest employer, second only to the agriculture sector (Ministry of the Interior, N.d.). Therefore, fire risk mitigation is vital to protecting the safety and security of Moroccans in workplace environments.

The industrial sector has also greatly contributed to Morocco's economy throughout the years. One of Morocco's traditional industries is the phosphate industry. Morocco is famous for its abundance of raw materials. Office Chérifien des Phosphates (OCP) is the leader of the phosphate industry in Morocco with OCP contributing more than 90% of the phosphate exports in 2017 (Ministry of the Interior, N.d.). In recent years, Morocco has also attracted the attention of international automobile companies. The development in the automobile industry was notable in Morocco from 2014 to 2016, which correlates with the 50% increase in export turnovers. The automobile industry contributed 40 billion dirham in 2014, and 60 billion dirham in 2016 (Ministry of the Interior, N.d.). Another up-and-coming industry is the building materials industry, which generated 37 billion dirham in export turnover in 2016. Main companies in the building materials sector include cement production companies, like Ciments du Maroc and Lafarge Maroc, whose headquarters are in Casablanca, Morocco (Ministry of the Interior, N.d.).

Overall, 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 increased profit in the aviation, commercial and industrial sectors and the advancement of these industries in the past few years prove that Morocco is experiencing successful growth.

2.3 Fire Risk Mitigation

Rapid economic advancement in aviation, commercial and industrial environments presents greater responsibility and risk. Risk mitigation is vital for all public and workplace sectors and is one of the most important aspects of fire protection. In order to save money, many entities do not prioritize the practices of risk mitigation. For many years, fire protection specialists received cooperation from management "based on the loss suffered by the industry" (Davletshina, 1998). Now, 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 (Davletshina, 1998).

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). Figure 1 provides one model for fire risk mitigation:

Figure 1: Diagram demonstrating codependent relationship of fire mitigation practices (Davletshina, 1998).

Fire code enforcement oversees 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 methods for reducing 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 do not have the knowledge 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. The National Fire Protection Association (NFPA) and the Occupational Safety and Health Administration (OSHA) are American organizations that promote social dimensions and technical applications of fire safety, and that influence global fire regulations. 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 United States is a leading country in fire protection, and many countries base their national fire standards upon American fire code practices, including Morocco.

2.4 Fire Safety Systems

2.4.1 Fire Detection Systems

Human Detection

One of the most effective fire detection systems is human detection. Humans are capable of feeling, smelling, hearing, and seeing fires. Nick Artim, a fire protection engineer who specializes in heritage protection, stated a "healthy person is able to sense multiple aspects of a fire including the heat, flames, smoke, and odors. For this reason, most fire alarm systems are designed with one or more manual alarm activation devices to be used by the person who discovers a fire" (Artim, N.d.). Although human detection can be very effective when people are paying attention to their surroundings, there are not always people present to detect fire. In addition, the human voice is not as loud and reliable as an alarm once the fire detector detects a fire.

Heat Detectors

Heat detectors are one of many automatic fire detection systems. Heat detectors have a thermistor which causes an alarm to go off after reaching 58° C (136° F). The heat reaches the thermistor through holes on the surface of the detector. Typically, owners of garages or kitchens install heat detectors to ensure that alarms do not sound when exhaust or cooking smoke is present (Safelincs, N.d.).

Another heat detection system is the linear heat detection system. Linear heat detection systems consist of two conductors braided together, each coated in thermoplastic. When the device reaches 88° C (190° F), the thermoplastic that separates the conductors softens, and the system short circuits. A device senses the short circuit, then the device sets off an alarm (Protectowire Fire Systems, 2015). Linear heat detection systems are unique in comparison to typical heat detectors; linear heat detection systems detect raises in temperature directly and across larger areas.

Smoke Detectors

There are two main types of smoke detection systems: ionization and photoelectric alarms. Ionization smoke alarms consist of two electrically charged plates with contained radioactive material suspended between them. The radioactive material ionizes the air between the plates, allowing current to pass. When smoke is present between the plates, the radioactive material cannot ionize and the current will not pass through the plates. The presence of smoke then results in a short circuit, which sets off the fire alarm (NFPA, 2014). Another smoke detection system is photoelectric detectors. Photoelectric detectors contain a light source and a light sensing device. In a normal state, the light source points away from the light sensor. When smoke enters the photoelectric detector, the smoke refracts the light source towards the light sensor, which sets off the smoke alarm (NFPA, 2014).

Flammable Gas Detectors

Flammable gas detectors are a type of electrochemical detector. These detectors have two sensors that determine the parts per million (ppm) of carbon monoxide gas in the air. Carbon monoxide is one of the most common byproducts of combustion and makes combustion of flammable gases detectable (Firewize, N.d.). When the ppm of carbon monoxide gas reaches a certain threshold, the fire alarm sounds (Equipco, N.d.).

Flame Detectors

Flame detectors detect ultraviolet or infrared radiation from flames. The system has an electrical circuit with an electromagnetic radiation receiver. When flames are present, the electromagnetic radiation receiver sounds when it detects a certain wavelength of radiation (Firewize, N.d.).

2.4.2 Fire Suppression Systems

Fire Extinguishers

The four main types of fire extinguishers are carbon dioxide (CO_2), water, foam, and powder. CO_2 extinguishers smother flammable liquid, combustible liquid, and electrical fires. Water extinguishers douse fires fueled by organic materials such as wood, paper, or cloth. Foam extinguishers put out fires originated from organic materials and flammable and combustible

liquids. Powder extinguishers are the most versatile type of basic extinguisher, as they are capable of putting out fires fueled by organic materials, flammable and combustible liquids, and gases (Marsden Fire Safety, N.d.).

Two other forms of fire extinguishing are wet chemical extinguishers and aerosol extinguishing systems. Both of these employ the use of potassium salts to slow and prevent the spread of fire (Safe Fire Direct, N.d.).

Sprinkler Systems

Sprinkler systems are a very effective form of fire suppression. Sprinkler systems attach to a pressured water supply and are only activated by heat. Figure 2 illustrates the structure of a sprinkler, including a water plug and a liquid-filled bulb that explodes at a particular temperature threshold.

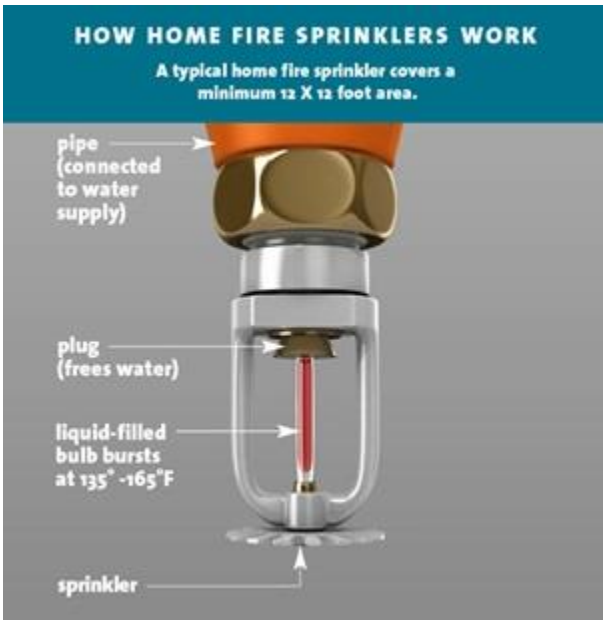

Figure 2: How Home Fire Sprinklers Work (NFPA, N.d.).

According to the United States National Fire Protection Association (NFPA), sprinklers are a very effective method of fire suppression. “Home fire sprinklers release approximately 10-25 gallons of water per minute. In a home without sprinklers, a fire is likely to grow to dangerous levels by the time the fire department is able to arrive” (NFPA, N.d.).

Sprinklers have two possible orientations: pendent and upright. Pendent sprinklers have the water source above the sprinkler, and are usually found indoors. Property owners can place

pendent sprinklers in suspended ceilings, which cover the sprinklers' water and electrical networks. Figure 2 depicts a pendant sprinkler. Upright sprinklers, on the other hand, face upward. In other words, the water source and network is below the sprinkler. Upright sprinklers work the best where there are no suspended ceilings (Ferrell, N.d.).

Fire Hoses (RIA) and Hydrants (PI)

Fire hoses and hydrants have pressurized sources of water which allow the user to direct the stream of water in one particular direction. Moroccans refer to fire hoses as RIA (*Robinet d'Incendie Armé*) and fire hydrants as PI (*Poteau Incendie*).

Encapsulated Micron Aerosol Agents

Encapsulated Micron Aerosol Agents (EMAA) are a newer technology in fire suppression with low toxicity and low negative impact on the environment. EMAAs interrupt the chemical process that occurs in the presence of fire. The U.S. Air Force and Spectrex Inc. developed EMAAs because EMAAs' per unit mass is six times more powerful than the traditional extinguishing agent (Kibert and Dierdorf, N.d.).

2.4.3 Cultural Differences Between United States and Moroccan Fire Exit Signs

Many of the fire safety professionals and industry managers our team spoke to have hold United States fire codes and technology standards in high regard. In the article *The Big Red Word vs. the Little Green Man*, Julia Turner speaks on the world's transition from the traditional exit sign to Yukio Ota's green "running man" exit sign (see figure 3 below):

Figure 3: ISO Emergency Exit Sign, original design by Yukio Ota of Japan (ISO, N.d.)

The Japanese fire safety association held a competition for Japan's next emergency exit sign design. Yukio Ota submitted his "running man" exit sign to the competition and won. Ota later submitted his design to ISO (International Organization for Standardization) for consideration (Turner, 2010). Many places around the world, including Japan, Australia, and countries in the European Union, use this "running man" exit sign (Egress Group, N.d.). Ota's exit sign has many benefits, including the use of pictogram to avoid the problems associated with language barriers. Another benefit that Ota's sign presents is the use of the color green. Many studies have pointed to green being the most visible color to the human eye. In addition to this, red signs may be harder to see in the presence of fire, as the color of flames in buildings is often red or orange (Chidlow, 2012).

2.5 Current Moroccan Fire Safety

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.

2.5.1 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 safety of people in 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 protects employees through the fire prevention and protection practices required for employers to

enact. An example of these prevention and protection practices is the necessay trainings for employees. Articles *R. 4227-1 to R. 4227-41, R. 4227-55 to R. 4227-57* on the *Règlement Sécurité* website describe the industry trainings required by the labor law (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, the managing director 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).

Although the Moroccan Fire Code includes the French Labor Law and some of the NFPA codes, there are some major differences between the Moroccan code and the United States NFPA codes. For example, Morocco has not adopted the NFPA sprinkler codes (NFPA 13, 13D, 13E, 13R, and 16). There are eleven sections in the Moroccan fire code regarding sprinkler system usage, but no section mandates the use of them.

2.5.2 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. ICAO assigns a category number to each airport based on 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 took 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.

2.5.3 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 (Ministry of the Interior, & General Director of Civil Protection, 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.

2.5.4 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 3). Out of the one hundred and fifty-five present in the plant, fifty-five did not make it out alive. 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 4: Fire at Mattress Factory in Casablanca, Morocco (Abdennebi, 2008)

Additionally, our team researched the fire that occurred in 2002 in the Sidi Moussa prison, killing 49 and injuring 90. The incident brought into question 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 (Ministry of the Interior, & General Director of Civil Protection, n.d.). For the factory fire incident mentioned above, the factory did not follow the exit door requirement closely and consequently, people died and suffered injury 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.

2.6 Stakeholders

For the aviation industry, our main stakeholders were airport managers, airport employees, airport firefighters, and travelers. In the commercial sector, our stakeholders were mall managers and shoppers. Lastly, our stakeholders in the industrial sector were industrial managers and workers.

Table 1 is a summary of our stakeholders.

Table 1. Stakeholders table for aviation, commercial, and industrial environments

Environment	Stakeholder Group	Interest	Assets
Aviation	Airport managers	Liability, protection of expensive equipment, protection of building structure	Control and knowledge of airport fire safety, knowledge of ICAO fire safety assessment
	Airport employees	Personal safety, job requirements	Thoughts/opinions on current fire safety
	Airport firefighters	Personal safety, job requirements	Knowledge of airport fire safety
	Airport travelers	Personal safety	Thoughts/opinions on current fire safety
Commercial	Mall managers	Liability, protection of business, protection of building structure	Control and knowledge of mall fire safety, knowledge of government fire safety assessments
	Shoppers	Personal safety	Thoughts/opinions on current fire safety
Industrial	Industrial managers	Liability, protection of goods/product, protection of building structure	Control and knowledge of industrial fire safety, knowledge of government fire safety assessments
	Industrial workers	Personal safety, job requirements	Thoughts/opinions on current fire safety
	Industrial firefighters	Personal safety, job requirements	Knowledge of facility fire safety

2.6.1 Managers

Throughout the aviation, commercial, and industrial sectors, managers have high impact over the fire safety systems in their facility. Although fire safety systems in each sector are dependent on the ICAO, Moroccan government, or company safety requirements, managers have large influence in determining which fire safety systems, required or not required, to install in the establishment.

In the aviation sector, managers have a strong understanding of the airport's fire safety systems, employee trainings, auditing processes conducted by the International Civil Aviation Organization (ICAO). Airport managers have high interest in maintaining the quality and functionality of fire safety systems in their establishment to prevent legal disputes, damage to expensive equipment (such as planes, plane parts, or any tarmac equipment), and damage to the building structure.

In the commercial sector, mall managers are knowledgeable and in control concerning the fire safety systems and trainings present and offered in the mall. They also have knowledge regarding government-mandated safety inspections. Mall managers have an interest in maintaining the fire safety systems in the mall in order to prevent legal disputes and damage to the building structure and to promote and maintain business with the shops within the mall.

In the industrial sector, industrial managers are knowledgeable about and in control over the fire safety systems present in the facility. The managers also have an understanding of the government-mandated safety inspections. Industrial managers have an interest in preventing legal disputes and damage to both the building structure itself and the goods and products within.

2.6.2 Airport and Industrial Employees

Airport and industrial employees have valuable knowledge of the fire safety systems and trainings present in the facility. They also have their own thoughts and opinions regarding their own personal safety in the facility. Depending on the trainings the employees take, their job may include a responsibility to respond to emergencies such as fires. The main interest of employees in the airport and in industry is to respond to the fire (if necessary) and protect their personal safety.

2.6.3 Airport and Industrial Firefighters

Airport and industrial firefighters have some knowledge of the fire safety systems in the facilities as well as an extensive knowledge of how to respond to fire emergencies. Their main interests involve performance to the best of their ability as well as in their personal safety in their workplace.

2.6.4 Travelers and Shoppers

Airport travelers and mall customers are important stakeholders because they have minimal to no knowledge about the present fire safety systems in the airport or mall, respectively. Because of their outsider perspective, travelers and shoppers provide important input on fire safety within these public establishments. The main concern of travelers and shoppers is their personal safety.

2.7 International Studies on Fire Safety

2.7.1 Studies in the Aviation Sector

Airport terminals around the world handle large volumes of passengers everyday. 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). We found two studies from United Kingdom and Hong Kong in which researchers presented technical findings to improve fire safety in airport terminals.

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 a large amount of passengers, so high-ceiling designs will aid the movement of people and provide a better sense of spaciousness in the terminal. However, noncompartmental design lacks in 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 should have 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” strategy. Beever suggested 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. A flashover is most of the combustible materials in an enclosed area reached ignition simultaneously. In Chow’s computational fluid dynamics simulation, the low ceiling of the cabins reduced the time between ignition 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 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).

There is little research on airport terminal cabins pertaining to Morocco. Although Moroccan airports’ passenger capacity doesn’t compare to that of the Osaka Airport and Hong Kong Airport, Morocco still 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 indicates the need to assess airport fire safety in Morocco.

2.7.2 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 developed their evaluation method from 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. For instance, while calculating the firefighting factor, the original Gustav's method only takes into account the physical distance between the building and fire department. Zhang and Dong added weightings to include the firefighting experience of fire brigade and the presence of the outdoor fire hydrants to compute the firefighting factor (Zhang et al, 2016). Such revisions show their priorities in evaluating fire safety conditions and thus make their methods more comprehensive. 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 mall in Dalian, including increasing smoke extraction capability and adding fire evacuation maps in the mall. (Zhang et al, 2016). Section 2.8.2 discusses their methods in detail.

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 provides more reliable evaluations of fire risks, it would require complex mathematical modelling background and extensive data. 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).

2.7.3 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 in a three-year period from 2010 to 2012, 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 stated in an interview that, “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 2.5.4.

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 researchers based their numerical weighting scheme 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 one technique for numerically representing a facility’s rating of risk mitigation.

2.8 Background Information on FirePRO Clients in Aviation, Commercial, and Industrial Environments

FirePRO designated certain companies for us to visit in order to understand the types of clients the company serves in the aviation, commercial, and industrial sectors. We visited the Office National des Aéroports, the Morocco Mall, Mondi Pap Sac Maghreb, and OCP Jorf Lasfar. Descriptions of the FirePRO clients are below.

2.8.1 Aviation Sector Client: Office National des Aéroports

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).

2.8.2 Commercial Sector: Morocco Mall

The Morocco Mall, built in 2011, contains more than 350 retail shops, offers more than 600 international fashion and design brands, and extends over 10 hectares of land. The superstructure is 250,000 m^2, or about the size of 46 football fields. The Morocco Mall expects to receive more than fifteen million visitors a year, and provides 26,000 Moroccans with jobs (Morocco World News, N.d.). Figure 5 shows a map of the Morocco Mall.

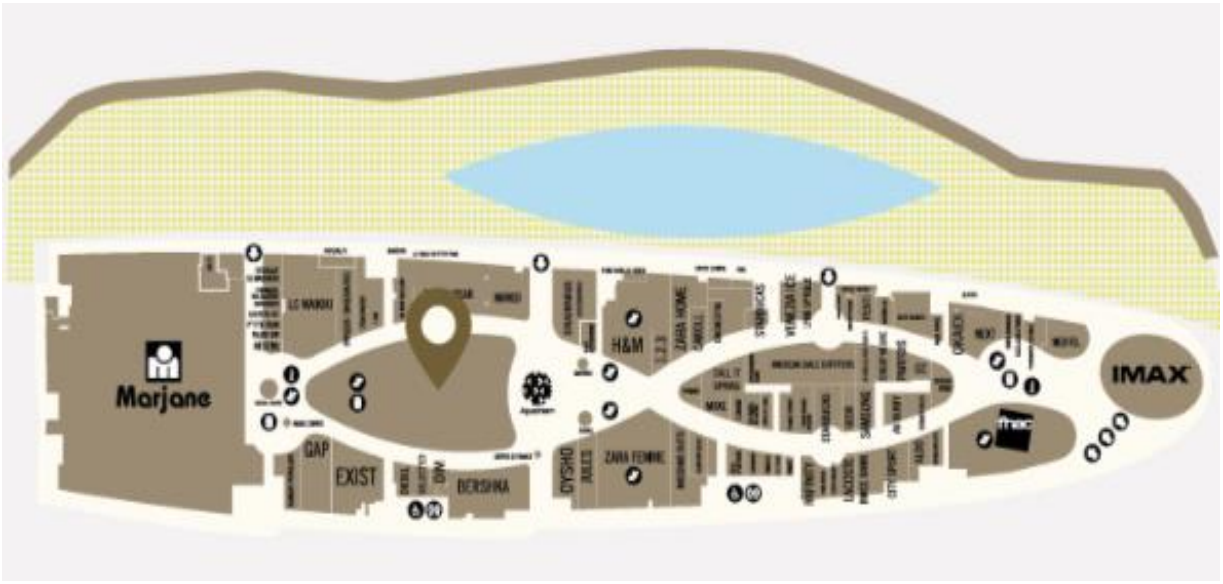

Figure 5: The Morocco Mall layout map.

Fire risk mitigation is crucial for superstructures like the Morocco Mall, due to the large social capital involved.

2.8.3 Industrial Sector Client: OCP

Office Chérifien des Phosphates (OCP) is a major integrated group that produces and exports phosphate products. Its headquarter is in Casablanca, Morocco. OCP has four mining sites and two processing platforms in Morocco. It extracts phosphate rock and transforms the raw material into phosphoric acid. It then processes the phosphoric acid to make its finished products such as fertilizers and purified phosphoric acid (OCP, n.d.). In 2016, OCP exported 1.8 million metric tons of phosphoric acid, which accounts for 47% of the global market share. One processing platform is in Jorf Lasfar, close to El Jadida (OCP, 2017).

2.8.4 Industrial Sector Client: Mondi Group

Mondi Group is an international company that specializes in innovative and sustainable packaging and paper solutions (Mondi Group, 2018). A variety of global brands rely on the company's products across many applications including cement packaging, pouches, retail boxes, and paper. Key customers of Mondi Group's products are from the following industries:

agriculture, automotive, chemical, building and construction, food and beverages, home and personal care, medical and pharmaceutical, office and official printing, packaging and paper converting, pet care, retail and eCommerce, and shipping and transport. Mondi Group has 56 production sites across 32 countries. Each production site specializes in at least one of six areas of Mondi Group products: packaging paper, fiber packaging, consumer packaging, uncoated fine paper, pulp, and forestry.

There are two Mondi Group production sites in Morocco, both of which are fiber packaging sites. Our team visited the Mondi Pap Sac Maghreb fiber packaging site in Casablanca, Morocco. Mondi Group's production site in Casablanca produces pasted valve bags, made of high quality materials to endure high-speed filling through valves on spout packers (Mondi Pap Sac Maghreb, 2018). Valve bags are useful for several materials within the building materials and food industry, including cement, plaster, pet food, minerals, and more. The packaging facility consists of storage, production, office and parking zones. Figure 6 is a map of the Mondi Pap Sac Maghreb.

Figure 6: Intervention map of Mondi Pap Sac Maghreb

2.9 Risk Analysis Methods

Our project includes extensive work in evaluating fire risk within the aviation, commercial, and industrial environments. Our team looked at different methods from the global literature to determine the one that best suits our project's goal.

There are three types of methods: qualitative, semi-quantitative, and quantitative. According to Laura-Diana Radu, a researcher from Universitatea Alexandru Ioan Cuza in Romania, qualitative risk assessment methods can identify assets in detail and provide a simple and rapid assessment. Semi-quantitative methods describe risks using a relative scale. An example of a relative scale is: reasonable, relatively reasonable, partially reasonable, and not reasonable. Semi-quantitative methods input qualitative data and convert the data into numerical values. Quantitative methods develop models from extensive past data and employ mathematical models to predict risk level (Radu, 2009).

2.9.1 Perspectives on Semi-Quantitative Analysis vs. Quantitative Risk Analysis

One of the main methods of assessing risk is Quantitative Risk Analysis (QRA). QRA is the process of calculating frequencies of certain occurrences and probabilities of certain risks to determine the overall level of risk. With this information, the assessor can determine how to decrease this risk (Aven, 2008).

The common problem with QRA is that the method is purely based on probability. In the article *A semi-quantitative approach to risk analysis, as an alternative to QRAs* from the University of Stavanger, Norway, author Terje Aven discusses the two main problems involved with basing risk analysis completely on probability (Aven, 2008). Firstly, probability is a proportion representing the number of times an event occurs per a certain number of iterations. Probability is never an exact representation of the likeliness of an event occurring; probability is merely a best-guess. Secondly, probability is a measure of uncertainty about future events seen through the eyes of assessors (Aven, 2008). The QRA process is unavoidably subjective, as the process relies heavily on the determination of factors by the assessor (Aven et al, 2005).

Taking both of these problems into account, Aven determines that QRA is not always a good analysis of risk. In his paper, Aven states, "The approach acknowledges that risk cannot be adequately described and evaluated simply by reference to summarizing probabilities and

expected values." Avon's idea of "seeing beyond the standard probabilistic risk results of a QRA" takes the form of semi-quantitative analysis. By relying less on probabilities and expected values, semi-quantitative analysis presents a more socially and societally-based idea of risk.

In another article by Aven, he and his colleague V. Kristensen from University of Stavanger in Norway discuss various perspectives on risks (Aven et al, 2005). Aven and Kristensen recognized certain pitfalls of the semi-quantitative risk analysis. For example, risk weightings and evaluations are not factual since researchers determine the weightings for risks (in creating a rubric) and assess the level of risk on-site. Their decisions rely on past statistics as well as the knowledge available to them, and are, therefore, not completely based on fact (Aven et al, 2005).

Despite certain drawbacks of semi-quantitative analysis (SQA), we believe that SQA remains the most appropriate for this project. Given that some of our data may be qualitative while our sites are different sizes, we want to make sure our observations are relative rather than quantitative. Our decision to use SQA rather than QRA is also related to our group's skill set. QRA requires a large amount of mathematical analysis that we do not have sufficient time or skill to use effectively.

The next section discusses a study that successfully used SQA in assessing fire safety in shopping malls.

2.9.2 Successful Examples in Using SQA in Fire Risk Analysis

There are a few studies that implement semi-quantitative methods in fire risk analysis. Our team found a successful study in China. Nan Zhang and Sihui Dong proposed semi-quantitative methods to evaluate fire safety in large shopping malls and made safety recommendations to a shopping mall in Dalian, China (Zhang et al, 2016).

In their article, they applied a semi-quantitative method to convert numerous qualitative data to two rating for risks. Their first risk rating is, $\mathbf{R_b}$, describes the risk of fire damage on the building structure itself. The authors use $\mathbf{R_b}$ **to** help determine if the building needs additional safety measures to protect the building structure. Their second risk rating, $\mathbf{R_p}$, describes the risk of fire damage on lives and property in the building. $\mathbf{R_p}$ gauges if the building needs additional safety measures to protect the lives and property in the building (Zhang et al, 2016). They created and utilized their checklists to collect qualitative data during site visits to the mall. The

checklists included conversion tables. These researchers converted the qualitative data from these conversion tables into the two risk ratings, $\mathbf{R_b}$ and $\mathbf{R_p}$. The detailed data conversion tables used in this study are in Appendix G and Appendix H. The fundamental equations that define the two ratings are:

$$R_b = \frac{(Q_m \cdot \mu + Q_i)F \cdot S \cdot C}{W \cdot R_i \, (L_0 + L_i)}$$

Equation 2.1

$$R_p = \frac{Tf}{KEH}$$

Equation 2.2

To employ these two risk ratings, $\mathbf{R_b}$ and $\mathbf{R_p}$, one strategy is to place the coordinates ($\mathbf{R_b}$ and $\mathbf{R_p}$) on one of the four quadrants (see Figure 7). Researchers decided on the 2.9 threshold lines for ratings by visiting different malls to determine what conditions are acceptable and what conditions are unsafe. In section 4.2.1.6 , we included further explanation on how this system might not be the most helpful metric in our case and how we constructed another measuring scales based on the original checklists. Both risk ratings, $\mathbf{R_b}$ and $\mathbf{R_p}$, are lower than 2.9, then the site has sufficient fire protection safety. If the ($\mathbf{R_p}$, $\mathbf{R_b}$) data point is above the blue line and/or to the right of the orange line, then this method indicates that the building is in need of additional fire protection systems for building . With the graphical results, Zhang and Dong made recommendations to the commercial establishment, some of which included increasing smoke extraction capability and adding fire evacuation maps in the building (Zhang et al, 2016).

A sample configuration for an environment with insufficient fire protection is: in a hospital with polystyrene insulation, no smoke alarm, and no active smoke extraction system, inspectors would give it a $\mathbf{R_p}$ rating of 6.0. This value would signal to the inspector that the hospital does not have sufficient fire protection.

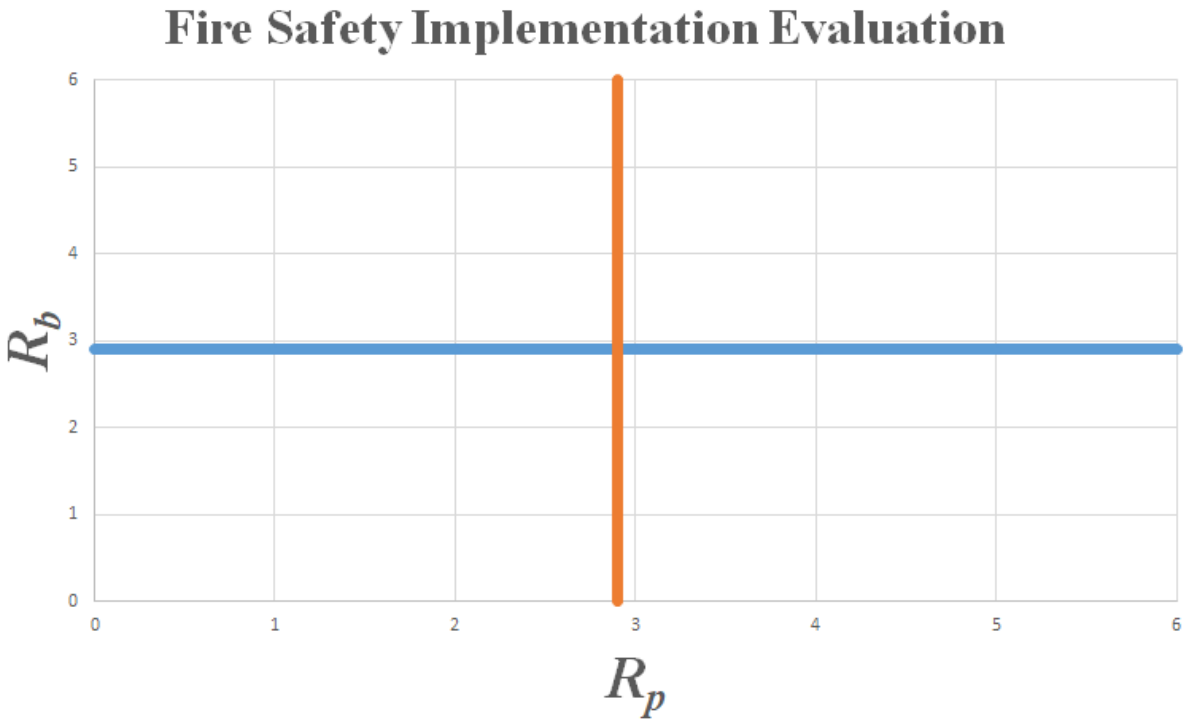

Figure 7. Quadrants comparing **risk of fire damage on a building (R_b)** and **risk of fire damage on lives and property (R_p)**.

Scholars like Aven and Kristensen would likely argue against the accuracy of the numerical schemes of Zhang and Dong's study. Nevertheless, Zhang and Dong's final recommendations did not only come from the **R_b** and **R_p** risk ratings, but also came from closer examination of the qualitative checklists on what went wrong. The numerical scheme could offer a consistent standard for purpose such as relative comparison of fire risk. The quantification process required a comprehensive list as a reference to record raw data. This list served as another reference to help researchers to identify what improvements the fire safety managers should implement and determine which future recommendations to make for a building, as Zhang and Dong did in their study (Zhang et al, 2016).

Calculating R_b

To calculate **R_b**, we use the formula shown in the previous section. First, consider the numerator of **R_b**. Factor **Q_m** and **Q_i** are **mobile and immobile fire load factors**, respectively, and **μ** is the **flammability factor for mobile fire load**. Researchers for the study mentioned in section 2.7.2 assigned the flammability factor for common objects in a building (Zhang et al,

2016). Together, the sum in the parenthesis indicates the total fire load in the building. **F** is the **fire ignition source factor**, which measures the potential sources of ignition present in the building. Factor **S** is the **building area factor**. A larger building area corresponds to the possibility of a larger-scale fire. Factor **C** is the **confinement factor**. The confinement factor measures the design and maintenance of the ventilation system. A building with better-designed and better-maintained ventilation systems would have a lower **confinement factor**, resulting in a lower rating for the **risk to building (R_b)**. Now, consider the denominator of R_b. Factor **W** is the **building fireproof factor**. A large **W** value indicates a building that can withstand fire longer before structural failure; it contributes to a lower R_b risk rating. Factor R_i is the **fire spread reduction factor**. R_i measures how quickly fire can spread in the building. It is not feasible to time how quickly fire spread in the actual environment because of the destruction it would cause. Hence, the researchers used an alternative measuring standard: a building with large amount of flammable goods piled loosely across the room would receive a low R_i score. Factor L_o and L_i are **firefighting factors from outside and inside**, respectively. A building with an advanced fire department in close proximity would have a high L_0 value. Multiple qualitative criteria including experience of firefighters and the technical level of firefighting equipment make up an "advanced" fire department. A building with a more complete firefighting system would have a high L_i value. We can put the calculated R_b value on the y-axis of the graph in Figure 5.

Calculating R_p

In the calculation of R_p , the factors T and f are the **smoke toxicity** and the **user characteristic values**, respectively. The **smoke toxicity factor** defines how toxic the smoke of the present materials is when burning. The checklist considers common building materials, such as wood, cloths, and plastics. A higher **smoke toxicity** value indicates more toxic material present in an establishment in the event of a fire; therefore, the **risk to the lives and properties (R_p)** in the space is greater. The **user characteristic value** (**f)** describes the characteristics of people in the building as well as the purpose of the space. A lower value for the user characteristic value corresponds to lower-maintenance audiences such as office workers who know the building's landscape, whereas a higher value for **f** corresponds to a reduced-mobility audience like people in a hospital, who may not know the building's landscape. A higher **f** value contributes to a higher value of **risk to lives and properties in the building (R_p)**.

The factors **K**, **E**, and **H** are the **automatic fire alarm factor**, **evacuation capacity factor**, and the **ventilation and smoke extraction factor**, respectively. A higher value for all three of these factors contributes to a lower **risk to lives and properties in the building (R_p)**.

2.10 Summary

This chapter highlights the current status of fire safety in aviation, commercial, and industrial environments throughout the country of Morocco. The case studies reviewed in this chapter provide the motivations to further investigate fire safety in the aviation, commercial, and industrial sectors. This chapter includes a discussion of other research papers that considered effective methods to utilize in our project such as semi-quantitative techniques. In the next chapter, we will discuss our methods involved in assessing the risk in aviation, commercial, and industrial environments.

Chapter 3. Methodology

Aviation, commercial, and industrial site assessments addressed the following objectives to determine the implementation of fire safety codes and to identify social matter surrounding fire safety in Morocco. These were our objectives:

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 and analyze social dimensions concerning fire safety awareness within all environments
4. Develop an Excel checklist template to aid FirePRO Engineering in future client site assessments.

Our team visited four different sites in Morocco: Office National des Aéroports (ONDA, aviation sector), Morocco Mall (commercial sector), Mondi Pap Sac Maghreb (industrial sector), and Office chérifien des phosphates (OCP, industrial sector). The following sections outline the details of our methods used to accomplish our objectives. The descriptions of bolded terms throughout this chapter can be found in the Glossary.

3.1 Map Fire Safety Applications and Systems

Our team visited a sample of representative sites in the aviation, commercial, and industrial sectors to investigate fire safety applications and systems. These site visits included visual and written documentation. One team member was responsible for taking photos of the fire safety systems and evident fire risks present on-site with a phone camera. Examples of the fire safety systems documented in photographs include fire hoses, fire extinguishers, sprinkler systems, heat detectors, and other firefighting equipment. Each team member recorded observational and technical notes on a checklist during the visits; there are three checklists. Checklist No. 1 evaluated the risk of fire damage to the building structure and checklist No. 2 assessed the fire damage to the lives and properties in the building. We translated Checklists No. 1 and No. 2 from a previous study in China. In their study, Nan Zhang and Sihui Dong included a comprehensive list of criteria for analyzing fire safety systems and building conditions (Zhang

et al, 2016). The team worked with FirePRO engineers to make minor changes to Checklists No. 1 and No. 2 to cover expected fire risks in all three environments that were not previously mentioned in Zhang and Dong's original checklist. For example, our team added a Fuel Source section to provide a more accurate representation of fire risk, specifically in industrial environments.

FirePRO engineers provided Checklist No. 3. Checklist No. 3 determined whether fire safety applications in the building were within legal ranges of distance according to NFPA, French, and Moroccan fire codes. Appendix AA includes this FirePRO checklist. All group members were present for the interviews with site managers and firemen at Mondi Group and OCP. During our visit to ONDA, our team was able to discuss the differences between Moroccan and ICAO fire codes, but were not able to conduct our planned interviews. We did not conduct interviews with fire personnel at the Morocco Mall since FirePRO and our team did not acquire the necessary clearance. Morocco Mall is not a client of FirePRO, but the building was an example of a large-scale commercial building with many required fire safety applications.

Our open-ended interviews with site staff at Mondi Group and OCP built a profile of fire safety systems at both locations, as well as the social aspects of fire safety in industrial Morocco. We chose open-ended interviews because we wanted to further refine the questions we were asking and to collect any additional information mentioned in conversation. In the book *Researching the City*, Kevin Ward speaks of different types of interviews. Talking to important interviewees and obtaining as much information as possible "(their position in networks of power, their particular expertise or area of responsibility)" is vital for successful open-ended interviews (Ward, 2014). Our interviews with the Mondi Group site manager and OCP fire chief helped us gather information about their responsibilities in keeping the facility fire safe and functional.

David, Lisandra, and Jillian conducted the interview at Mondi Group without assistance, as Mr. Jalal spoke English. At OCP, the full team, including the FirePRO engineers, was present for the interview. The FirePRO engineers translated the interview questions from English to Darija, then translated the responses back to English. Our team discussed all of the answers prior to completing the interview to ensure that the responses answered our questions completely. The team took turns in asking interview questions, and each of the team members took notes. David recorded the conversations with permission from the interviewee.

We conducted our discussion with ONDA in French, with our sponsor, Mr. Zouheir Yakine, translating the discussion at every convenient pause (about every 15 to 30 seconds). All members of our team were present, as well as our advisor, Professor Bethel Eddy. Our team took notes throughout the meeting, and David audio-recorded the discussion with permission from the ONDA staff.

In addition to providing us with site-specific technical data, our interviews with Hicham Jalal and Mohammed Kherraz (OCP Fire Chief) provided our team with very important perspectives on development around fire codes in Moroccan industrial environments. These interviews were the source of our most valuable social data, as the interviews were open-ended. Our team asked additional questions on any important social topics mentioned during the interview to gain a better understanding of the problems at hand. We conducted our surveys at Morocco Mall and Mondi Group to determine how safe the public and employees, respectively, felt in the two environments, and to provide information on Moroccan fire safety awareness. Our interview with the OCP fire chief and surveys with OCP firemen yielded a better understanding of how their fire department functions and the standard OCP's insurance company holds them to, as a private industrial company.

3.1.1 Aviation Sector

Our team visited the *Office National des Aéroports* whose headquarter is in the Mohammed V International Airport in Casablanca. Unfortunately, we were not able to conduct our visit to the airport due to security restrictions. However, our team was still able to hold a discussion session with the staff from *Academie Internationale de l'aviation Civile* (AIAC) and ONDA.

We planned to conduct face-to-face interviews with airport managers at the Office National des Aéroports during our site visit. The purpose of these interviews was to further investigate ONDA's present fire safety systems. The questions written for each interview target the reasons why all the fire safety systems in the airport facility are present and the interviewee's awareness and education on fire safety procedures. The questions also address the maintenance schedules for all present fire safety systems. The topics discussed in the interview investigate the current implementation of fire safety systems, and the social dimensions associated with working in an airport. We chose these interview questions to address how a facility that follows

international fire codes may differ in technical and social dimensions compared to facilities that follow local fire codes. Appendix A includes the interview questions for the airport managers.

To gain a better understanding of the equipment and training process for the firemen in the airport, our team also developed an interview that we meant to conduct with an airport fire department chief. This interview involved questions regarding the fire safety systems present in the airport, the training process for firemen, and the airport's advanced technological resources. Unfortunately, we were not able to conduct this interview. Appendix J includes the interview questions for the airport fire department chief.

3.1.2 Commercial Sector

Our team visited the Morocco Mall in the outskirts of Casablanca, Morocco. Our visit took place on January 17th and January 18th. On our first day, we spent about five hours at the mall collecting data for our checklists in the underground parking lot and the first floor. We also took pictures of strong and poor fire safety practices on these two floors, and conducted 10 surveys. On our second day, we completed our checklists for the third floor dining area, took pictures of strong and poor fire safety practices, and conducted our remaining 10 surveys. A mall employee informed us that our team could not conduct an interview with the mall manager or any fire personnel, since the Morocco Mall is not a FirePRO client.

Our study documented the variety and distribution of all fire safety systems through photographs. We followed Checklists No. 1, No .2, and No. 3 to document fire safety systems present in the parking lot, first floor, and restaurant floor.

3.1.3 Industrial Sector

Our team visited Mondi Group in Casablanca, Morocco on January 23rd, 2018, and OCP in El Jadida, Morocco on February 14th. Prior to our site visit to Mondi Group, we analyzed the site maps provided by FirePRO from past fire system installation projects. With these sitemaps, our team picked the following investigation areas: outdoor storage area, indoor storage area, office building, production area, and chemical storage room. One team member documented the variety and distribution of all fire safety systems through photographs.

Our 30-minute interview with Mondi Group Africa's Managing Director, Hicham Jalal, addressed safety equipment inspection routines in the production facility, emergency evacuation

drills, and fire application updates. Each interview question focused on topics we believed may provide valuable information. For instance, questions 2 and 3 focus on the inspection and maintenance schedules. Question 5 focuses on post-incident reporting procedures. Appendix C includes these interview questions.

At OCP, our team was able to document the firefighting equipment present at the OCP fire department. Our visit could not include the site outside of the fire department due to clearance restrictions, and therefore this meant not completing our three technical data checklists.

Additionally, we were also not able to conduct our interview with the manager at OCP due to clearance restrictions. The interview questions are the same as the questions from our interview with Hicham Jalal at Mondi Group. However, the team conducted an interview with an OCP fire department chief, Mohammed Kherraz. This interview mainly provided social data (see section 3.3.3). This interview also provided our team with technical data, such as the systems present throughout OCP and the trainings required for firemen. Appendix H includes the interview questions.

3.2 Compare Best Practices for Moroccan Fire Safety Implementations

Our team compared Moroccan and international case studies in order to establish best practices for Moroccan fire safety systems in aviation, commercial, and industrial settings. We studied FirePRO's past projects and conducted content analysis to compare and contrast case studies within each environment.

We accomplished our first objective through interviews, on-site observations, and visual documentation. To accomplish our second objective, we applied a semi-quantitative method to convert numerous qualitative data into two ratings--one for **risk of fire damage on the building (R_b)**, and one for **risk of fire damage on lives and property in the building (R_p)**. This section elaborate on our data collection methods for our second objective, including our semi-quantitative **R_b** and **R_p** checklists.

3.2.1 Aviation Sector

The investigation of fire safety applications and systems in the aviation sector (refer to Chapter 3.1.1) provided qualitative data as well as social dimension data on fire safety. Our second objective is heavily data-focused. Our team worked with FirePRO to develop and add to

the two semi-quantitative checklists utilized in a previous study in China (see Section 2.9). We based our modifications to the two-semi quantitative checklists on international best practices of fire codes (NFPA, French Labor Law, Moroccan Fire Code, and Chinese Building Code). Our team intended to analyze the Mohammed V International Airport, but because of clearance issues, we could not access into the airport.

3.2.2 Commercial Sector

Our team worked with FirePRO to compare our qualitative data to international qualitative data to determine the best feasible practices in Moroccan commercial environments. We investigated three different sections in the Morocco Mall: the underground parking garage, the ground floor, and the third floor dining area. We chose not to perform a full investigation of both floors of the parking garage and assumed that both floors had the same condition of fire safety. Similarly, our site visit did not investigate the second floor of the mall--we assumed the second floor was similar to the ground floor. Both the ground and second floors of the mall have the same types of shops, the same general shape, and the same material fire risks. Our assumption that both floors are about the same comes from the spacing of fire suppression and detection systems. For instance, both floors would receive about the same score in damage to people and damage to building if all of the fire detectors, fire extinguishers, fire hoses, and sprinklers had similar spacings are both floors.

3.2.3 Industrial Sector

The acquired checklist data assisted in the evaluation of fire safety systems at our industrial site subjects, Mondi Group and OCP. The fuel source subsection of variable **F**, called the **fire source factor**, was especially relevant to these sites. Mondi Group had diesel present on-site for refueling forklifts and other machinery. Because OCP is a phosphate production facility, there were many different flammable or toxic chemicals, such as ammonia or sulfur.

We chose these two FirePRO clients to analyze best practices of Moroccan fire codes given the differences in specific insurance regulation. These two sites were useful in demonstrating different perspectives on the implementation of Moroccan fire codes within the industrial sector.

3.2.4 Methods for Investigation of Worldwide Fire Safety Systems and Project Development

Near the beginning of our project in November, our team set up an interview with WPI Fire Protection Engineering Professor, Kathy Notarianni. In our interview, our team learned a large amount about international fire codes. Professor Notarianni stated the United States has very advanced fire code, which many countries are trying to adopt. In particular, many countries are adapting NFPA 101: Life Safety Code. We discovered that the United States is currently learning from the Australian and Japanese performance-based fire codes.

We also discussed the development of fire codes in our meeting. In countries such as England, scientists develop the fire codes for the government, and then the government applies the fire codes throughout the country. Alternatively, in America, individual states determine which fire codes to follow from the NFPA recommended fire codes. Scientists are not the only authors of NFPA codes; manufacturers and builders also contribute to the development of fire codes in the United States. (Notarianni, Personal Communication, 2017).

3.3 Document the Social Dimensions of Fire Safety

To document the social dimensions of fire safety awareness in aviation, commercial, and industrial environments, our team collected data through surveys and open-ended interviews. For our surveys, the project chose respondents using the sample of convenience method. Surveys can indicate broader trends; interviews, on the other hand, explore deeper into the reasons behind trends (Ward, 2014). Therefore, our investigation used surveys to collect as many responses as possible regarding fire safety awareness in the public and workplace environments. We decided to use interviews as a method to investigate the root problems of fire safety and fire code implementation in Morocco.

3.3.1 Aviation Sector

Our team intended to survey airport employees and travelers at the Mohammed V International Airport, and interview the fire department chief and manager of the airport. Due to security reasons, we were not able to enter the airport to gather our data on the social dimensions in the aviation sector.

We created the surveys for airport employees in order to understand the facility's work environment, emergency fire exit accessibility, and fire extinguisher knowledge. We translated the survey into French in order to include a larger demographic of travelers. Figure 8 below shows our first three objectives and their associated methods. Our survey questions for airport travelers and airport employees are in Appendix D and Appendix E, respectively.

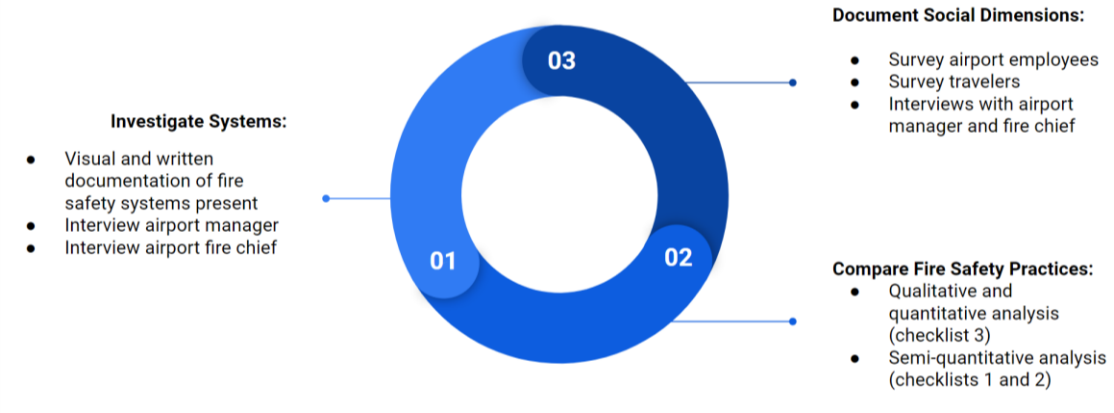

Figure 8: Methodology Strategy for Aviation Sector

Our team was not able to interview the airport manager, the airport fire chief, survey airport employees, or survey travelers. Thus, we did not complete any of our third objective planned methods for the airport environment. Although, we participated in a discussion with the airport training facility employees on fire safety and safety protocols in the event of varying emergencies.

3.3.2 Commercial Sector

To accomplish our third objective for the commercial sector, we surveyed 20 customers in the Morocco Mall. The survey informed our team of the customers' average time at the mall, the general understanding of population density, and the fire exits throughout the mall. These surveys were anonymous to protect the identities of the mall customer survey subjects. The surveys usually took between 5 and 10 minutes to perform. David and Mouad Barih, a FirePRO Engineer, translated the Morocco Mall surveys prior to our site visit. One of our survey subjects required an English survey, which our team provided. Figure 9 below shows our sequence of objective and associated methods. Appendix F includes our survey questions.

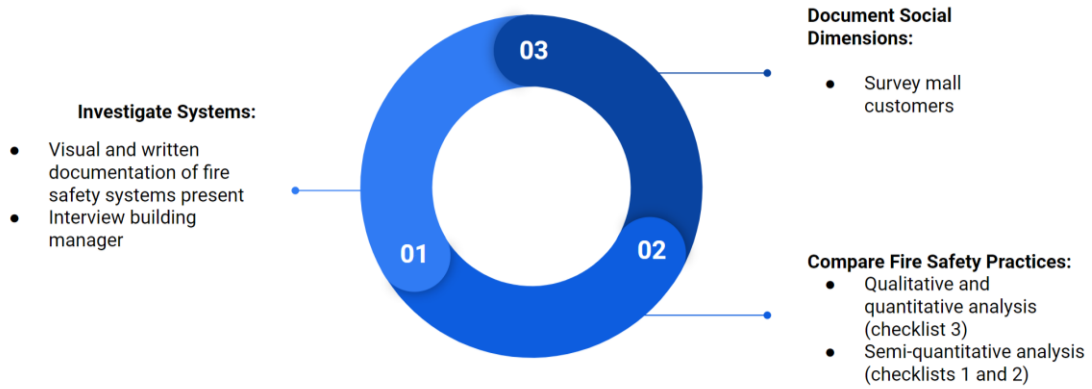

Figure 9: Methodology Strategy for Commercial Sector

3.3.3 Industrial Sector

Our team surveyed 20 industrial employees at Mondi Group. We surveyed the industrial employees to gather information on their employment safety trainings, workplace fire safety applications, and experience with fire incidents. We conducted these surveys anonymously in order to prevent any issues between supervisors and employees. These surveys took between 5 and 10 minutes to complete. Our team is concerned about the bias that took place at Mondi Group, because one of the managers helped conduct five surveys. To prevent including bias in our data analysis, we marked the surveys conducted by the manager.

Figure 10 below displays our third objective and associated methods for our Mondi Group visit. Appendix G includes our survey questions. David and Mouad translated our Mondi Group employee survey prior to the site visit.

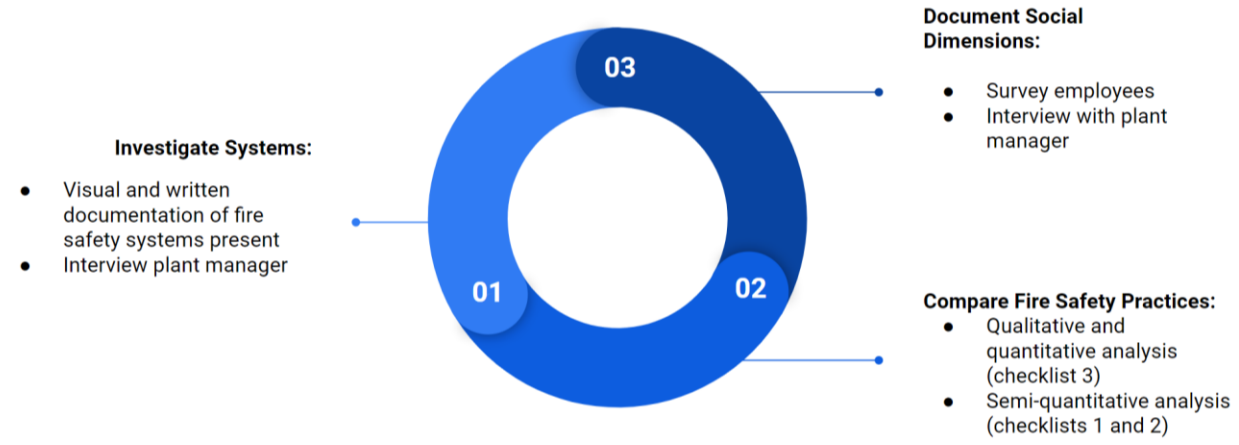

Figure 10: Methodology Strategy for Mondi Group

On our visit to OCP, our group conducted six surveys with OCP firemen. This survey includes questions on field experience, trainings, past fire incidents, and work schedule. These surveys took 5 to 10 minutes each. David and Mouad translated the OCP firemen surveys prior to the site visit. Appendix I includes the survey questions.

Figure 11 exhibits our performed methods for our visit to OCP.

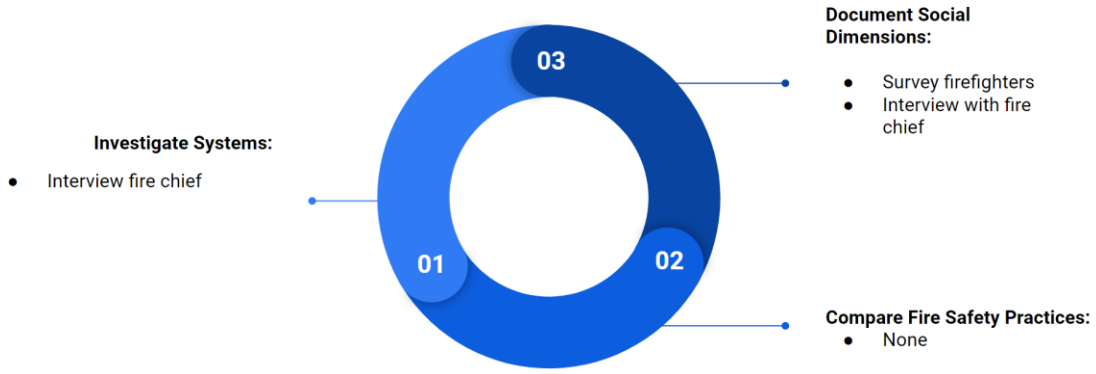

Figure 11: Methodology Strategy for OCP

In addition to the surveys, our open-ended interviews with Hicham Jalal of Mondi Group and Mohammed Kherraz of OCP provided us with social-oriented information. Appendices C and H include the sets of interview questions our team prepared for the visits to Mondi Group and OCP. Since our interviews were open-ended, we were able to gauge the social status regarding fire safety and request further details when necessary.

3.3.4 Feasibility of a Volunteer Fire Department or Volunteer Firefighter Program in Morocco

During the process of developing our recommendations, our team discussed with our sponsor, Zouheir Yakine, the possibility of recommending a volunteer firefighting program for Morocco. Consequently, near the end of our project, we sent email surveys to two United States volunteer firefighters. The purpose of these final interviews was to investigate the extent to which a volunteer firefighter program in Morocco might benefit the Kingdom. One of our interview subjects had only been a volunteer firefighter for a short time, and was relatively young. The other had been a volunteer firefighter for many years. This lead to designing and conducting two different interviews: one for student-age volunteers and one for general volunteers. The interview for student-age volunteers involves more in-depth questions regarding interest in a career path in fire protection. The two volunteer firemen responded to our email survey through email. Appendices L and M include the sets of interview questions for student-age volunteers and general volunteers, respectively.

3.4 Develop a User-Friendly Semi-Quantitative Checklist in Excel

Due to the comprehensive nature of the three checklists used during our site visits, FirePRO Engineering wants to implement them in their client site assessments. Our sponsor requested that our team create a user-friendly, macro-enabled Excel checklist template for checklists No. 1 and No. 2.

The checklist template produces a scatter plot and a radar plot for the FirePRO engineers to interpret. Both the scatter plot and radar plot signify which areas of fire risk need improvement. The scatter plot provides an overview of the risk to lives and properties in the building, and the risk to building structure. Meanwhile, the radar plot communicates which active fire safety applications can decrease the fire risk of an establishment. In summary, the scatter plot provides FirePRO's client with an overall visual representation of how safe their establishment is, and the radar plot indicates how FirePRO can assist the client in improving their establishment's overall safety through the addition of active fire safety systems. Originally, our team decided to create a semi-quantitative checklist and scatter plot graph in Excel to

represent our risk data. In addition to this graph, we decided to create a three-axes radar plot to clearly indicate to the user which areas of fire safety application to prioritize.

The first graph in the Excel checklist template is a scatterplot R_p and R_b graph. The scatterplot does not regard the 2.9 R_p and R_b axis threshold from the Dong and Zhang study, because the threshold is ineffective in providing a true representation of fire risk. For example, an establishment that has no fire safety applications that contains people who cannot easily evacuate (such as a hospital or kindergarten) receives a fire risk rating below the 2.9 threshold; this fire risk rating is appropriate by the study's standards. On the other hand, if we consider an establishment that has no fire safety applications and that holds people that can easily evacuate, the establishment receives a lower risk rating according to the 2.9 threshold. We determined an establishment with no fire safety applications should not deserve a positive fire risk rating, with the assistance of our sponsor. Fire safety mitigation practices are important to decreasing the risk of fire, and are thus valued more in our analysis of aviation, commercial, and industrial sites in our R_p and R_b scatter plot graph. The FirePRO Engineer will use the R_p and R_b scatter plot graph to show the client how much risk is present for the people and property within the establishment versus the building structure. In most cases, the risk to people and property within the site carries more weight than the risk to the building structure. The farther away from 0 the (R_p, R_b) point is on the x-axis, the less safe the client's establishment is for the people and property in the building; our team believes the scatterplot graph holds great significance in marketing for a safer environment for employees and the public.

The second graph in the Excel checklist template is a radar plot graph. Through reflection, the R_p and R_b scatter plot graph did not fully meet the needs of FirePRO and the objectives of our project. So, our team developed a new tool (a radar plot graph) to successfully analyze the aviation, commercial, and industrial sites we visited and provide FirePRO with useful information for each site. Our design goal for the radar plot graph was for FirePRO engineers to understand and highlight to a client which specific forms of fire protection the establishment can improve in. Refer to the radar plot template in figure 12:

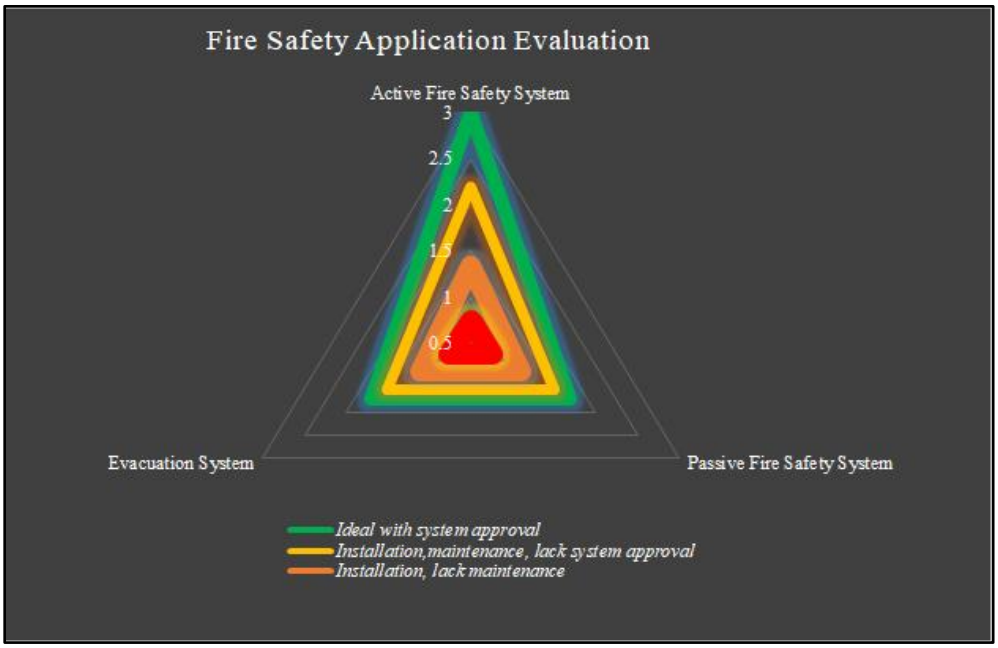

Figure 12: Radar plot developed by FirePRO engineers and our team

The three axes of the radar plot are the following: evacuation system, active fire safety system, and passive fire safety system. These three axes are the fire safety applications and systems that FirePRO specializes in providing advice and recommendations.

A Moroccan establishment with ideal fire safety system applications and systems is not common today. For example, the active fire safety system axis accounts for sprinkler systems, smoke detectors, fire extinguishers, fire hydrants, and smoke extraction systems. Many establishments in Morocco abide by the French labor and fire code laws that do not require sprinkler systems. Because sprinkler systems in Moroccan establishments are rare and the active fire safety systems axis on the radar plot accounts for sprinkler systems, many establishments will never have a perfect score on this axis. However, FirePRO engineers might suggest installation of sprinkler systems. To account for the laws that may affect the placement of a client's establishment on the radar plot, our team created levels of risk using a green-yellow-orange-red scaling. The green level is the best case scenario for an establishment which implies the evaluated location has all ideal fire safety systems in place. The yellow level indicates that the area may require installation maintenance and may lack system approval. The orange triangle represents an area that requires installation and maintenance. Lastly, the red area means that the assessed area is definitely not safe and is in need of major improvements in fire safety.

Overall, our team developed the user-friendly, semi-quantitative checklist tool in Excel for two reasons: to effectively and clearly represent our data collection process for the commercial and industrial market sectors we visited and analyzed, Morocco Mall and Mondi Group respectively, and to provide FirePRO Engineering with a potential useful tool for future client site assessments.

Chapter 4. Results and Analysis

This chapter covers our team's results and analysis from our site visits. We discuss the risk values for Morocco Mall and Mondi Group, which we gathered through the use of our SQA checklist. The chapter discusses our visual data and observations from our site visits to Morocco Mall and Mondi Group. The last section includes our interview data and analysis from our interviews at Mondi Group and OCP, our open-table discussion with ONDA, and our survey results from the Morocco Mall, Mondi Group, and OCP.

4.1 Results from Morocco Mall

This section presents data analysis and data outcomes from our commercial site visit to Morocco Mall in Casablanca, Morocco. Section 4.1.1 investigates the semi-quantitative analysis process for three locations in the mall: underground parking garage, ground floor atrium and shops, and third floor dining area. In addition, section 4.1.1 presents comparative analysis among the three locations within the Morocco Mall to better understand best practices of fire safety applications and systems within the commercial establishment. Section 4.1.2 investigates our social dimension data results from our surveys with Morocco Mall customers.

4.1.1 Semi-quantitative Analysis

This section covers the semi-quantitative analysis of our technical data from the Morocco Mall site visit. Our analysis includes an overarching interpretation of R_p and R_b, as well as an in-depth analysis of the individual factors that contributed to the Morocco Mall risk factor scores. This section highlights the factor values that are unique and noteworthy for each location. Appendix V includes the complete data set from the R_b and R_p checklists.

4.1.1.1 Underground Parking Garage

This project examined the underground parking garage using the checklists for R_b and R_p. The mobile fire load factor was 1.6--notably higher than other locations because of the presence of cars and fuel. There was an area where people stored building material and other items such as paints. These items are highly flammable and they increase the fire source factor for this location

to 1.47. This also contributes to a higher toxicity factor of 1.75. Overall, the fire risk rating to the building structure (R_b) is 1.192. The fire risk rating to the lives and properties in the parking garage (R_p) is 0.968.

Although both of the risk ratings are lower than the 2.9 risk threshold calculated by Dong and Zhang's study explained in the background chapter (section 2.9), our team observed two practices in the Morocco Mall that do not support optimal fire safety.

Figure 13: Electric wires hanging in Morocco Mall underground parking garage

Figure 13 shows electric wires falling out of a metal frame. Although our visit did not include an interview with the Morocco Mall maintenance personnel, this photo suggests that there is room for improvement in the maintenance of electric wiring in the underground parking lot.

Figure 14: Blocked access to hose reel in Morocco Mall parking garage

Figure 14 shows a car parked in front of an emergency hose reel. The parking signs on the ground signified a no-parking zone, as access to the emergency hose reel is imperative in the event of a fire. The mall implemented the no-parking zone to ensure access to the hose reel for fire fighters in case of a fire. However, figure 14 shows that mall officials may not enforce this fire safety rule effectively. This photo also reflects the lack of public responsibility regarding fire safety in the Morocco Mall underground parking lot.

4.1.1.2 Ground Floor Atrium and Shops

Our site visit included an examination of the ground floor atrium and shops using the checklists for R_b and R_p. The mobile fire load factor was 1.1 this time, notably lower than other locations. Because of the spotlight usage in the decorative palm trees, it contributes to the fire source factor value of 1.458. At the ground level, exits to leave the building are conspicuous. Our team assumed the emergency announcement system was fully functional because we heard announcements for prayers during the day. Together, these factors contribute to a value in evacuation capability factor of 1.547. Overall, the fire risk rating to the building structure (R_b) is 1.195. The fire risk rating to the lives and properties on the ground floor (R_p) is 0.698.

Although both of the risk ratings are lower than the 2.9 threshold, our team observed one practice that serves as a potential fire hazard. There were live palm trees in the grand atrium of the Morocco Mall.

Figure 15: Light strands on decorative palm trees in Morocco Mall ground floor atrium

Figure 15 displays the live palm trees as decoration. These palm trees are quite flammable, as the trees can dry up if mall workers do not water the tree regularly. Figure 15 also shows that the mall wrapped strings of light bulbs around the trunk of the trees and put spotlights close to the top of the trees. The lights are on from sundown until closing of the mall, so the lights are on for about four hours everyday. Any defects in the strings of light strands and the overheating of spotlights are the potential sources of ignition. The fire risk also depends on the whether the light bulbs have certification from companies such as UL or FM. We were not able to investigate the maintenance schedule or to check for flaws in the wirings, but we believe this is not the best practice to have in a public commercial space.

4.1.1.3 Third Floor Dining Area

We performed a checklist examination in the dining areas on the third floor of the mall. The mobile fire load factor was 1.4, a value that falls between the risk values for the underground parking garage and first floor shopping area. There was a high density of wooden furniture in the dining area. The exits signs to the emergency stairs are not clearly visible in this area, impairing mall customers' ability to locate the nearest exit(s). Thus, the dining area received a score of 1.32 for evacuation capability factor. Overall, the fire risk rating to the building structure (R_b) is 0.591. The fire risk rating to the personnel (R_p) is 0.904.

In the dining area, our team observed a large presence of public announcement speakers, pendant sprinkler systems, and smoke detectors. These systems helped the dining area to get a lower fire risk ratings. The public announcement system and smoke detectors contributed to the low fire risk rating to lives and properties (R_p), and the pendant sprinkler system contributed to the low risk rating to the building structure (R_b). Figure 16 shows the installation of these three fire safety applications on the ceiling of the dining area walkway.

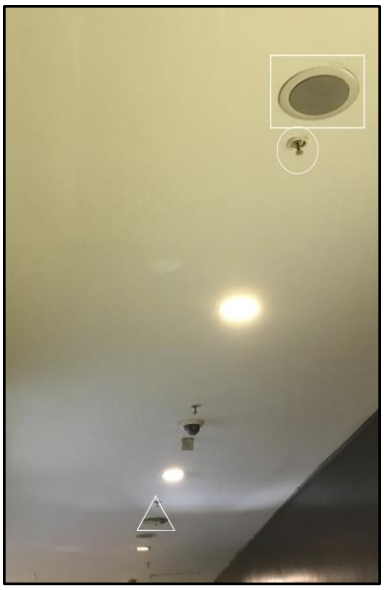

Figure 16: Public announcement system (rectangle), pendant sprinkler system (circle), and smoke detector (triangle) in dining area of Morocco Mall

These fire safety systems can detect a fire early and suppress the fire. The public announcement system is critical during an evacuation process because it can keep everyone informed on the best evacuation route.

4.1.1.4 Fire risk rating comparison for three analyzed locations in Morocco Mall

The three locations our team analyzed in the Morocco Mall each received an R_p and R_b risk rating score. Figure 17 is a scatter plot graph of the R_p and R_b coordinates for the three locations.

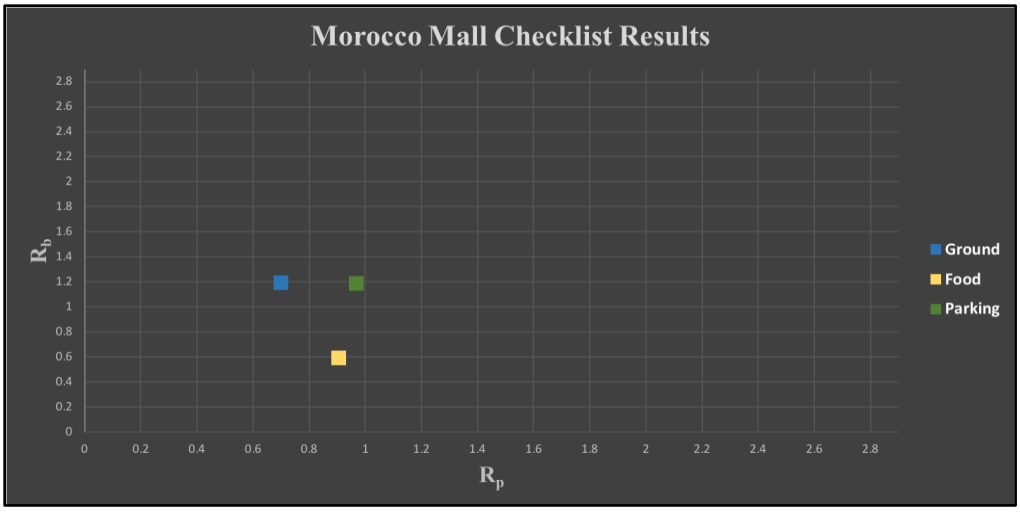

Figure 17: Morocco Mall checklist results.

Out of the three locations in the Morocco Mall, the underground parking garage was the least fire-safe for the lives and properties present (R_p). The third floor dining area has higher risk to the lives and property than the ground floor, while the ground floor atrium and shops area presented the least risk to lives and properties. The ground floor atrium and shops and the underground parking garage had similar risk to the building structure. Overall, the three Morocco Mall locations were fire safe according to the original study's 2.9 risk threshold.

4.1.1.5 Fire Safety System Evaluation

Although the fire risk graph in Figure 17 demonstrates that the overall fire risk ratings R_b and R_p are both below the 2.9 threshold, we could not easily identify how FirePRO could use these two metrics to provide expert advice to further improve fire safety conditions through the installation of fire safety systems. Our team selected five factors from a total of fifteen factors in the checklists. We selected these five factors because they pertain to the products FirePRO sells and installs. Table 2 lists the names and descriptions of these five factors.

Table 2. Factors on fire safety application

Factor	Description
L_i, Building firefighting capability factor	Included four components: fire detection, automatic fire suppression system, indoor hose reel, and extinguisher.
K, Automatic fire alarm factor	Evaluated design, maintenance, and system approval of fire detectors, it merges into L_i to calculate subscores for fire detection system.
E, Evacuation capability factor	Included clarity of evacuation route signs, functionality of evacuation stairs, emergency lighting systems and emergency announcement system.
C, Confinement factor	Evaluated the natural ventilation in a location, it also considered the fireproof material used for installations such as fire doors that can withstand fire for a certain period of time.
H, Ventilation and smoke extraction factor	Evaluated the presence and functionality of forced smoke extractors and forced ventilation.

These five factors directly pertain to our sponsor's system installation expertise. FirePRO engineers aided in sorting the five factors into three categories: active fire safety system (L_i, *K*), passive fire safety system (*C*, *H*), and evacuation system (*E*). We graphed the data on a radar plot

to show three axes simultaneously. The best case scenario receives score of 3 in active fire safety system and 1.7 for both evacuation system and passive fire safety system. The ideal score for active fire safety system is different from the ideal scores for passive fire safety and evacuation system because these values are the same as the assigned values from Dong and Zhang's study. Our team decided to keep the values since FirePRO emphasizes on active fire safety system. The green triangle in Figure 18 below marks the best case scenario. Figure 18 displays the current installation of fire safety systems.

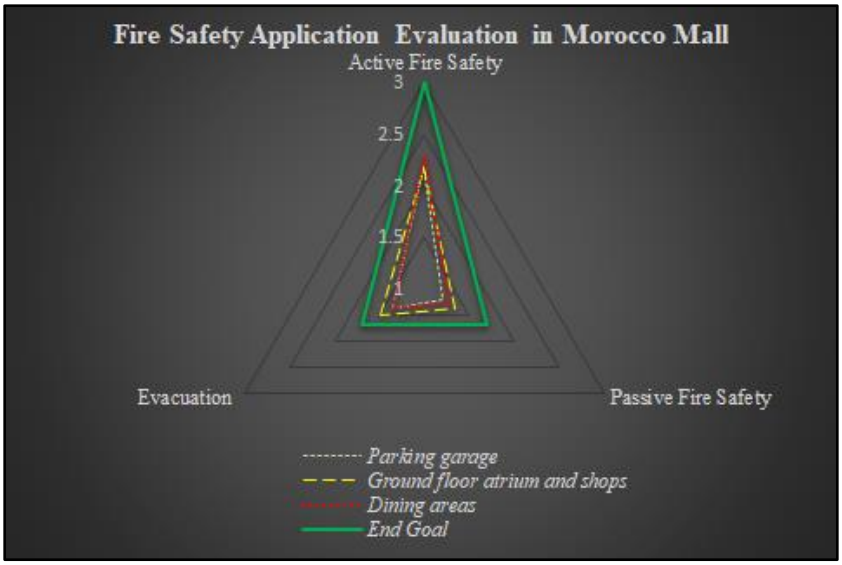

Figure 18: Fire safety application evaluation in Morocco Mall

Upon examination of the radar plot for fire safety application evaluation, we recognized that the Morocco Mall dining area has the most complete active fire safety system among the three locations and the ground floor shopping area has the most complete passive fire safety systems. The active safety systems value for the third floor dining area is reflective of our observation that the ventilation system is most effective on this floor. The evacuation value for the ground floor correlates to the easier access to the emergency exits.

Besides suggesting which location had the most complete fire safety system, figure 18 reveals which of the three categories of fire safety applications in a specific location requires the most improvement. The underground parking garage (grey dashed line in Figure 19) lacks in the passive fire safety and evacuation system categories. Because the parking garage is underground, it requires a better-maintained forced ventilation system. Among the three categories of fire safety applications, the ground floor's shops (yellow dashed line in Figure 19), passive fire safety systems are less prevalent. These locations would benefit from having more windows to enhance

natural ventilation. The third floor dining area (red dotted line in Figure 19) has strong active fire safety systems, while its exit signs (evacuation) and ventilation system (passive) have room for improvement.

4.1.2 Mall Customers Survey Results

Our team conducted surveys on the third floor dining area of the Morocco Mall. Our sample size was 20 mall customers. The purpose of these surveys was to determine the sense of safety customers have in the Morocco Mall. We chose to survey on the third floor in the dining area because finding customers to survey would have been more difficult in any other location.

Although we only surveyed on the third floor dining area of the Morocco Mall, most of our surveyed audience was not at the mall just to eat. Figure 20 presents the reasons why our 20 survey subjects were at the mall.

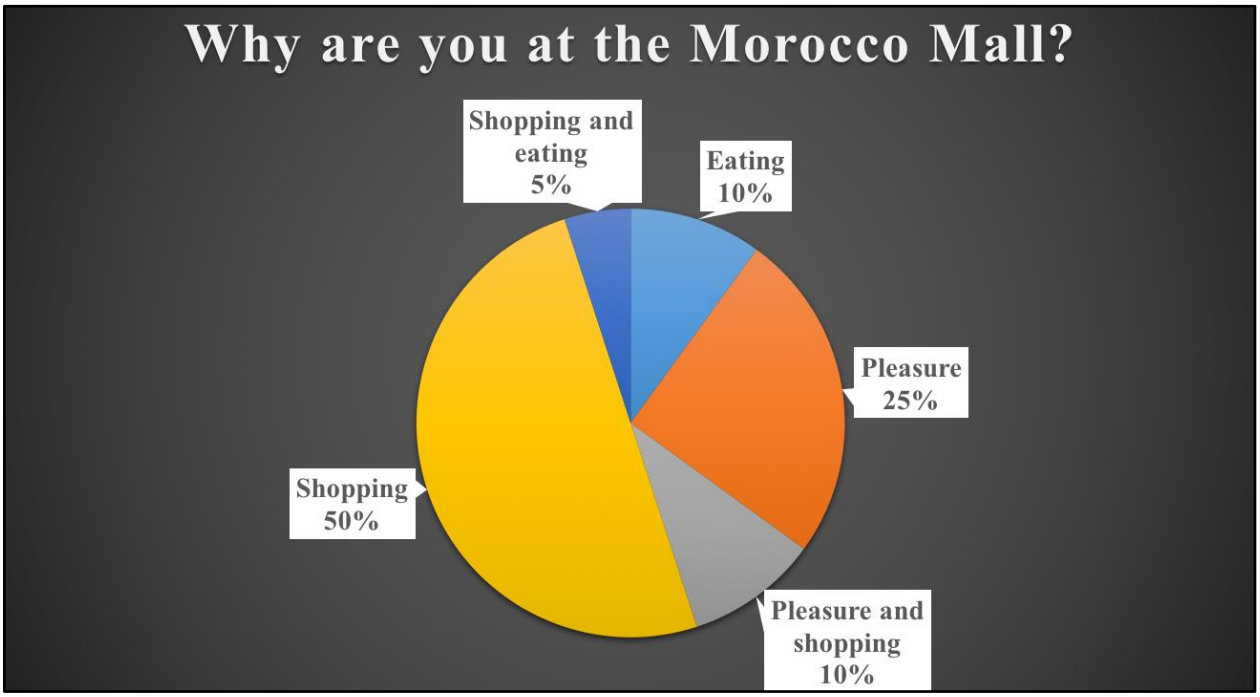

Figure 19: Frequency of occasion for visiting Morocco Mall.

By asking the mall customers why they were at the mall, we gained a better understanding of our audience. Figure 19 indicates that the survey subjects' responses were a reasonable representation of the population that would travel throughout the mall, even though

we conducted our surveys in the third floor dining area. We observed that only 10% of our survey subjects were in the mall to eat.

Our survey also asked the survey subjects how frequently they visit the Morocco Mall. The options were as follows: weekly, monthly, yearly, occasionally, or first time. Our team's hypothesis was the more you visit the Morocco Mall, then the more aware you are of your fire safety. A large portion (45%) of the survey subjects responded saying that they visit the mall occasionally. The two next most-answered results were "monthly" and "weekly". Our team was not surprised to learn that none of our subjects visit the mall on a yearly basis, as the mall provides important resources and is a popular location for socialization. Figure 20 below summarizes the frequency in which our mall customers visit the Morocco Mall.

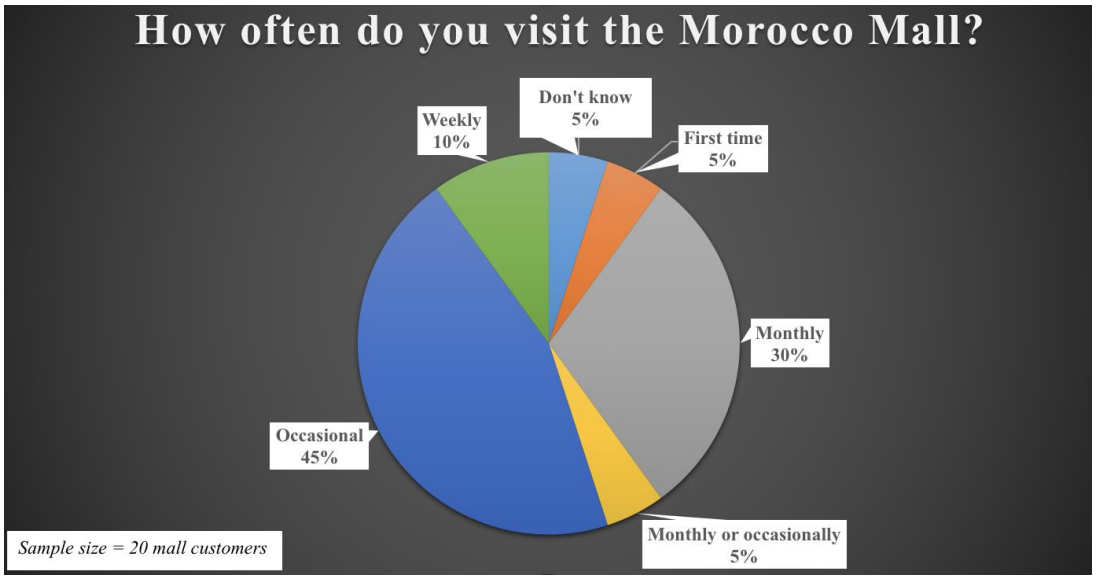

Figure 20: How often surveyed mall customers visit the Morocco Mall

Figure 21 below shows the frequency pie chart that represents data from our survey question that asked how safe the surveyed mall customers felt in the Morocco Mall with regard to fire safety. Only 55% of the survey subjects responded saying that they felt safe in the mall, and only 10% of the subjects responded with "I don't know".

Figure 21: Mall customers' sense of fire safety in the Morocco Mall

Our team further analyzed the reason for why a significant portion of these subjects felt unsafe in the mall. It is worth noting that we asked this survey question last (after the questions about fire safety systems present and details on evacuation), which may have provoked the subjects to think about the risks present in the large public environment.

Our team inquired how long the mall customers thought it would take to exit the building. Of our 20 survey subjects, 40% responded by saying they could exit the mall in 5 minutes or less. Figure 22 displays the distribution of how long mall customers believed it would take them to exit the Morocco Mall in the event of fire.

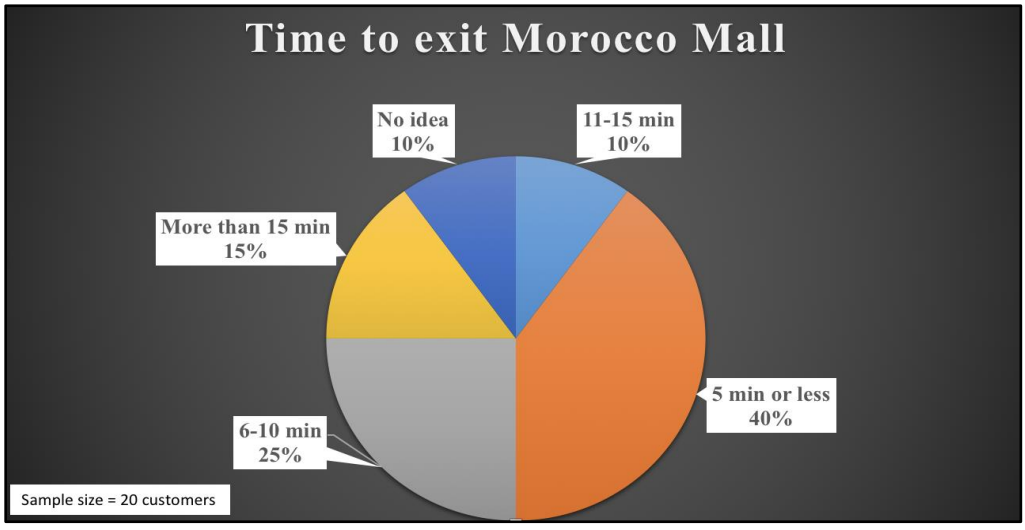

Figure 22: Pie chart of perceived escape time

Exits in Morocco must be within 50 meters, so exiting a space in 5 minutes should be feasible if the space is not too crowded. According to one of our survey answers, the Morocco Mall likely gets crowded at times, so distance to exit plays a large part in the amount of time to exit the mall.

We compared the perceived distance and perceived time to exit in figure 23 below.

Figure 23: Morocco Mall estimated time to exit by estimated distance to exit

This figure implies that people who thought they were 5 minutes or less from the exit thought they were closer to an exit. This is a logical finding. The rest of the responses were not as logical. Our team believes that when we asked where the closest exit was, some of the survey subjects may have been thinking of the mall exit rather than the nearest fire exit. On the other hand, this data may be a reflection of the fire safety awareness of the general public in the mall.

One of the major differences between Moroccan and American fire safety equipment and applications is the conspicuity of fire exit signs and doors. Although Morocco implements the ISO green "running man" exit sign, we found on our visit to the Morocco Mall that the size and placement of the exit signs were problematic. The signs were very small, about .5 ft^2 and located towards the ceiling inside the mall. In addition, the owner of the mall did not paint the emergency exit door to bright colors to clearly indicate that they were exits. Our team concludes that the unawareness of the mall customers in the Morocco Mall regarding the distance and time to fire exits may be due to the size and placement of the signs, as well as the lack of marking on the fire exit doors. This unawareness may also be a reflection on the quality of fire safety education available to the public.

4.1.3 Morocco Mall Team Observations and Site Visit Comparison

Overall, our team found that Morocco Mall is not a good example of well-implemented fire safety and technologies. While documenting the fire safety systems and fire risks in Morocco Mall, we found possible badly-placed or maintained systems and their associated risks. One positive aspect of the Morocco Mall was the presence and placement of sprinklers, especially on the top floor food court area. Lastly, the mall customers were generally unaware of the fire safety systems, especially concerning the location of fire exits.

4.2 Results from Mondi Pap Sac Maghreb

Our team visited Mondi Pap Sac Maghreb in Casablanca, Morocco, on January 24th, 2018. We were able to gather all technical and social data as we planned. Prior to our visit, our team hypothesized that Mondi Group would implement more fire safety codes than those required by Moroccan law. We believed this to be true because Mondi Group has multiple production sites around the world, and every production site is highly flammable given the packaging and paper goods the site produces. Below is our technical semi-quantitative analysis and social dimension data results from our site visit. We evaluated the individual semi-quantitative data acquired from each area within Mondi Pap Sac Maghreb's production site and then we compared them amongst themselves. We gathered the social dimension data through 20 surveys with employees at Mondi Pap Sac Maghreb and an interview with Hicham Jalal, Managing Director of Morocco And Cote d'Ivoire Mondi plants.

4.2.1 Semi-quantitative Analysis

This section presents the semi-quantitative analysis of our technical data from Mondi Group. Our analysis includes an overarching interpretation of R_p and R_b, as well as an in-depth analysis of the individual factors that contributed to the Mondi Group risk factor scores. This section highlights the factor values that are unique and noteworthy for each location. Appendix W includes the complete data set from the R_b and R_p checklists.

4.2.1.1 Chemical Storage Area

The chemical storage room resides on the side of the production facility. There is one door leading directly to an outdoor open space, making the evacuation process in this area rather straightforward. This contributes to a high evacuation capability factor of 1.623. Mondi stored their chemicals in separately packed containers, which helps slow down the spread of fire in case of an accident. As a result, this location earned a high value of 2 for the factor on fire spreading (R_i). The R_i factor is in the denominator of the equation so a higher value indicates lower risk. The building firefighting factor (L_i) in this room is 2.612, due to the installation of automatic detection and the EMAA (Encapsulated Micron Aerosol Agents) suppression system. Overall, the fire risk rating to the building structure (R_b) is 0.185. The fire risk rating to the lives and properties in the chemical storage area (R_p) is 0.528. We used formulas and metrics from Dong and Zhang's study to determine the two scores. These are excellent scores that demonstrates low risks.

The observational data we obtained indicates that the chemical storage area has low fire risk and is fire safe. Even before entering the chemical storage area, our team noticed fire safety apparatus including a fire hose, a ventilation and smoke extraction system, fire siren and a sandbox in the vicinity of the room.

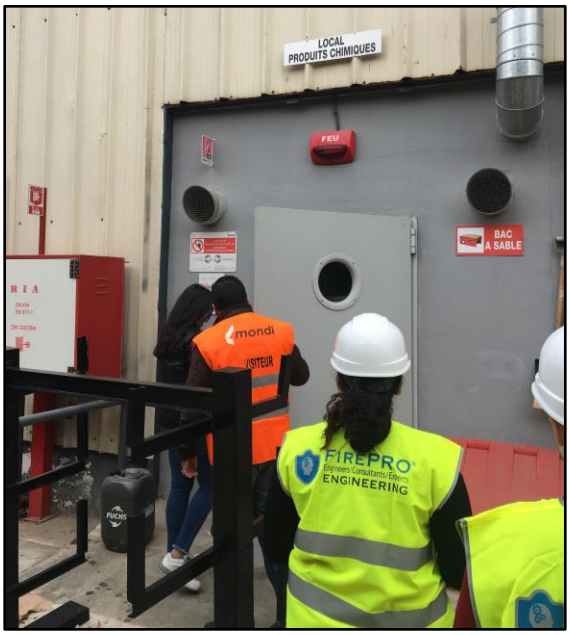

Figure 24: Photograph of the outside of the chemical storage area

Figure 24 is a picture of the outside of the chemical storage room. When our team entered the chemical storage area, there were EMAA extinguishing systems, heat detectors, and smoke detectors. The fire safety applications in this area were appropriate for the room's chemical environment, since EMAAs interrupt the chemical process that occurs in the presence of fire. FirePRO Engineering provided our team with a checklist that helped determine that the fire safety applications in the chemical storage area were within legal distances from other detectors and the walls of the room.

4.2.1.2 Production Area

In the production zone for the paper bags for cement, the mobile fire load factor received a score of 1.600, as a result of the large amount of flammable materials. The building firefighting factor is 1.227. This low value corresponds to the lack of automatic suppression system in the production zone. The only firefighting equipment in this zone is manual fire extinguishers. The ventilation factor receives a high score of 1.7, due to the usage of ventilation fans. Overall, the fire risk rating to the building structure (R_b) is 0.282. The fire risk rating to the lives and properties in the production area (R_p) is 0.813.

The production area was large and presented many fire risks along with many fire risk mitigation technologies. Figure 25 displays the workplace safety rules in the production area.

Figure 25: Risk awareness signs outside of the main production area entrance

Before anyone enters the production area, employees must abide by the protection equipment rules (blue signs in figure 25) and respect the security instructions (red signs in figure 25). These signs serve as a preventative measure or risk mitigation tool; the person entering the

production area will be highly aware of the extent of the area's processes and their actions in this space. Our team also took note of the active fire safety applications in the production area, specifically the fire hoses. There was a fire hose present every 30 meters in the production area. Figure 26 is a picture of the fire hoses they use in this space.

Figure 26: Fire hose in the production area of Mondi Pap Sac Maghreb

The fire hoses were red, therefore the hoses were easy to see and distinct amongst the machinery. Our team saw this fire safety application as effective and necessary, given the high paper content in the production area. Although there were many fire safety applications in the production area, our team noticed a practice that affected the R_p risk rating score, or the risk present to the lives and properties in the production area. This is shown in figure 27, and described below.

Figure 27: Exit signs in the production area leading to a corner of two walls rather than an exit

Figure 27 includes two exit signs. One of the green exit signs is on the far right, and the other is above where the FirePRO engineer is standing. These two green exit signs guide the persons in the production area towards the corner of two walls, or a machine, and not an exit. In the event of a fire, a person seeks guidance on where to exit the building. If there were a fire in the production area, these signs would send people towards a non-existent exit. Thus, the lack of effective exit signs cause the production area to have a higher risk rating for R_p. In other words, the production area is safest for the building structure and not for the lives and properties in the area. Although there were few non-effective fire safety applications, most of the applications were effective and up to date. Our team observed heat detection wires and fire extinguishers in the production area as well. The heat wires ran through the production area and were mid-air, above the machinery. There were also large fire extinguishers every 30 meters, so employees could access them in the event of a fire.

4.2.1.3 Administration Office Area

The office area's automatic fire alarm factor had a value of 1.7 because the office area has functional fire detection systems on every floor. The total building area is small and the evacuation route is clear, so the evacuation capability factor received a score of 1.667 out of 1.7. Overall, the fire risk rating to the building structure (R_b) is 0.103. The fire risk rating to the lives and properties in the administration office area (R_p) is 0.889. The higher R_p value is due to the

lack of a ventilation system, the existence of insulation material, and the usage of propane tanks in the kitchen.

The administration office area at Mondi Pap Sac Maghreb was smaller than the production facility and it had sufficient amount of fire safety applications. In the administration office, our team took note of smoke detectors, a fire panel, fire extinguishers, and exit signs. Figure 28 shows the fire system panel located in the administration office.

Figure 28: Fire panel in the Mondi administration office

The fire panel is in the administration office because fire safety panels must be in a low fire risk area. This is because in case of a fire, the employees must still have access to the fire safety panel. The fire panel undergoes frequent maintenance and inspection, since Mondi Pap Sac Maghreb contains many raw materials and products that are highly flammable. The fire panel at Mondi Pap Sac Maghreb was the only panel our team saw out of all of the sites we visited.

4.2.1.4 Outdoor Storage Area

In the outdoor storage area, the fire load factor receives the highest score of 4 due to the large amount of flammable materials present at this location. The area has no automatic detection system in place, which decreases the automatic fire alarm factor (K) to the lowest value of 1. The lack of fire detection systems also decreases the building's firefighting equipment factor to a low

value of 1.302. Overall, the fire risk rating to the building structure (R_b) is 0.739. The fire risk rating to the lives and properties in the outdoor storage area (R_p) is 0.841.

Figure 29: Large quantity of raw materials and paper in the Mondi outdoor storage area

Figure 29 demonstrates that the outdoor storage area contained large quantity of paper raw materials. The mass of each roll of paper material is 1,300 kg. Large masses of densely stacked paper rolls contribute to the high value for the fire load factor in this area.

Figure 30: A fire hose next to the Mondi outdoor storage area

Figure 30 shows a fire hose reel next to the outdoor storage area. There was one fire hose every 20 meters. Therefore, if there were a fire in the outdoor storage area, firefighters could utilize more than one hose. There was also a fire hydrant next to the outdoor storage area and the fire lane. This fire hydrant connects to the nearby water reservoir, which holds 245 cubic meters

of water. Mondi Pap Sac Maghreb has their own water reservoir since they are in the outskirts of Casablanca; the production site is far from the main city's water pipeline. Figure 31 displays the underground water reservoir signage. Figure 32 displays the fire hydrant that connects to the water reservoir. Note there is a fire hose in the metal box that connects to the fire hydrant, right behind the fire hydrant.

Figure 31: Mondi Pap Sac Maghreb water reservoir that contains 245 cubic meters of water

Figure 32: Water hydrant and attachable hose located next to the outdoor storage area

A sprinkler system is not available for the outdoor storage area because of the lack of a building structure, but fire extinguishers, fire hoses, fire hydrants, and a water reservoir is present. As the items in the outdoor storage area are highly flammable, this space presents high risk for the surrounding building structures. This area presents low risk to the lives and properties in the area because there were many walkway paths that lead away from the outdoor storage area to enable fast evacuation.

4.2.1.5 Indoor Storage Area

The indoor storage area is a space where Mondi Sac Maghreb stores their finished products. The mobile fire load factor received a score of 2.8 out of 3.0 as a result of the large amount of flammable materials inside the production zone. Figure 33 shows the four levels of shelves densely packaged with large quantities of cement paper bags. The building firefighting factor is 1.87. This low value corresponds to the lack of automatic suppression systems in the production zone. The ventilation factor receives a high score of 1.7 due to the usage of ventilation fans on the facility walls. Overall, the fire risk rating to the building structure (R_b) is 0.434. The fire risk rating to the lives and properties in the indoor storage area (R_p) is 0.511.

Figure 33: Finished valve bag products stored and wrapped for shipping

The indoor storage area contained finished fiber paper packaging products. The high density of the fiber packaging products compared to the volume of the indoor storage area contributes to the high R_p value, or the risk to the lives and properties in the space. During our site visit, our team took note of the natural and forced ventilation, the linear heat detection systems, fire doors, and fire extinguishers. In figure 33, there is a large fan, or the forced ventilation system. There is a fan for every aisle of stacked product. Overall, there were more fire safety applications in this area in relation to the four other Mondi areas we analyzed given the high occupancy of fire risk.

4.2.1.6 Comparison among the five areas analyzed in Mondi Pap Sac Maghreb

During our Mondi Pap Sac Maghreb site visit, we evaluated the fire safety applications in the chemical storage area, production area, office area, outdoor storage area, and indoor storage area. We evaluated all five of the areas we visited at Mondi Pap Sac Maghreb using our fire safety implementation evaluation checklists. In figure 34, R_p, the x-axis on this graph, represents the fire damage to the lives and properties in the building. R_b, or the y-axis, represents the fire damage to the building structure. Each data point on the Mondi Pap Sac Maghreb Risk Assessment Graph represents a specific area's R_p and R_b risk assessment.

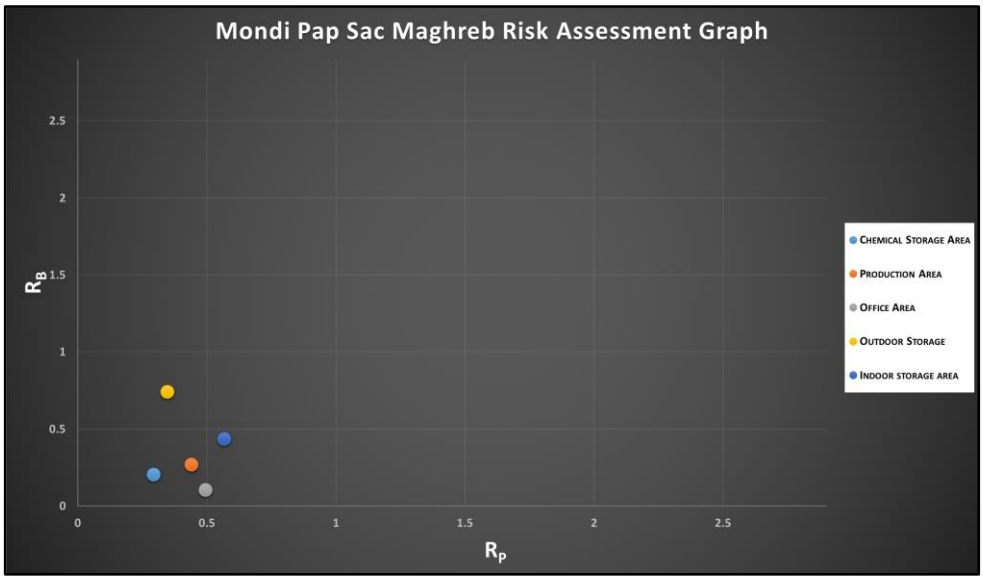

Figure 34: Risk Assessment Graph of Mondi Pap Sac Maghreb's Chemical Storage Area, Production Area, Office Area, Outdoor Storage Area, and Indoor Storage Area

All of Mondi Pap Sac Maghreb's site areas are under the 2.9 risk threshold line. Therefore, every area of the production site that our team assessed is fire safe when we used the tools from Dong and Zhang's study. While this results indicate that all locations are safe, it did not effectively evaluate the completeness of fire safety systems. Our team found a scenario where this risk assessment graph cannot generate appropriate warnings. The simulation we did was on R_p. If an office building (f = 1) has no fire detection or fire alarm (factor K = 1), no ventilation and smoke extraction system (H = 1), and the worst evacuation routes and exits (E = 1), the maximum R_p value is 2.0. This value does not exceed the 2.9 threshold, which is not convincing at all considering a building with no fire safety system at all. This case demonstrated that this rating depends heavily on user characteristic factor, which is a factor that a fire

protection company cannot alter. The information from the risk ratings are valuable when inspecting overall fire safety condition, yet our team needs a modified metric that is more suitable to FirePRO, who is interested in room for improvement in fire safety system installations.

4.2.1.7 Fire Safety System Evaluation

Although the fire risk graph in figure 34 demonstrates that the overall fire risk ratings R_b and R_p are both below the 2.9 threshold, our team could not easily identify where FirePRO can further improve Mondi's fire safety conditions through the installation of fire safety systems. Figure 35 displays the current installation of fire safety systems in each of the five locations compared to the ideal end goal (shown in green).

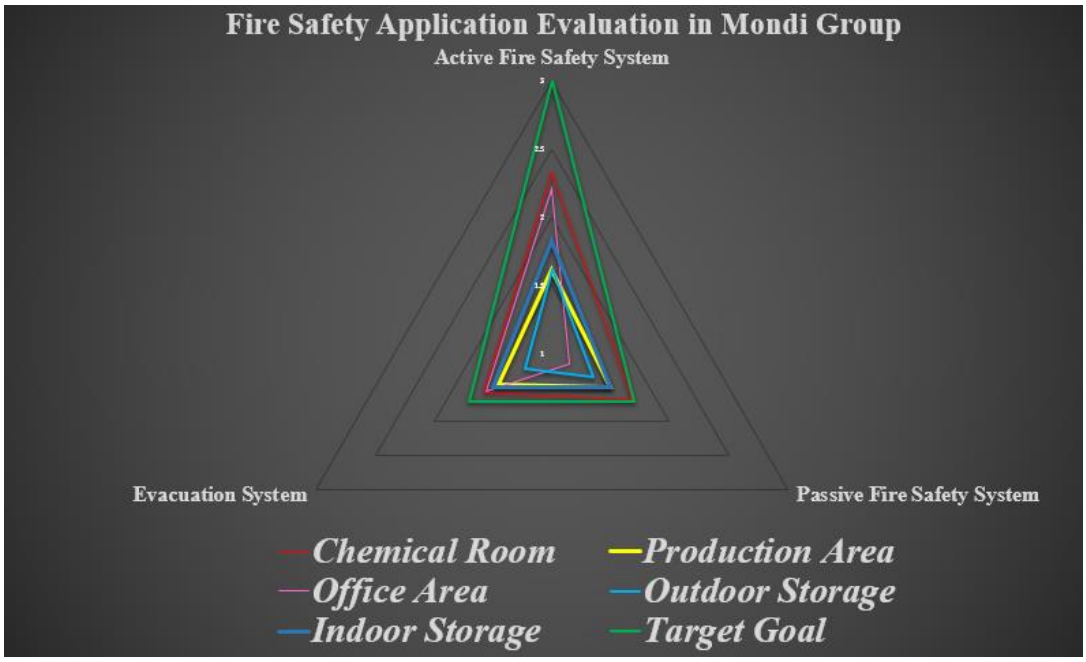

Figure 35. Fire safety application evaluation in Mondi Group

Figure 35 identifies that the office area has the most complete active fire safety systems and evacuation systems among the five Mondi locations. The graph reflects our observation of the extensive presence of numerous smoke detectors and sprinklers in the office building on both floors. The indoor storage area and production area had the most complete passive fire safety systems among the five locations. This result is due to the forced ventilation system in these two locations of the facility. Figure 35 also depicts that the office area (pink solid line in Figure 35) has strong active fire safety systems, yet the office area requires improvement in its passive fire

safety systems. Our recommendation is to install a forced ventilation system in the office building to extract smoke in case of fire, especially in the kitchen area, where a propane tank is located below the sink.

Figure 35 suggests to viewers the completeness of the three categories of fire safety applications in a specific location. The chemical storage room (red dashed line in Figure 35) had strong active fire safety systems, but the area lacked in passive fire safety systems. Theoretically, the room did not have much natural ventilation, however, our team realized the unventilated space could be subject to the chemicals inside the room. Hence, more ventilation to favor fire safety could have negative impact in preserving the chemicals. Therefore, we would not recommend changes to the current setup.

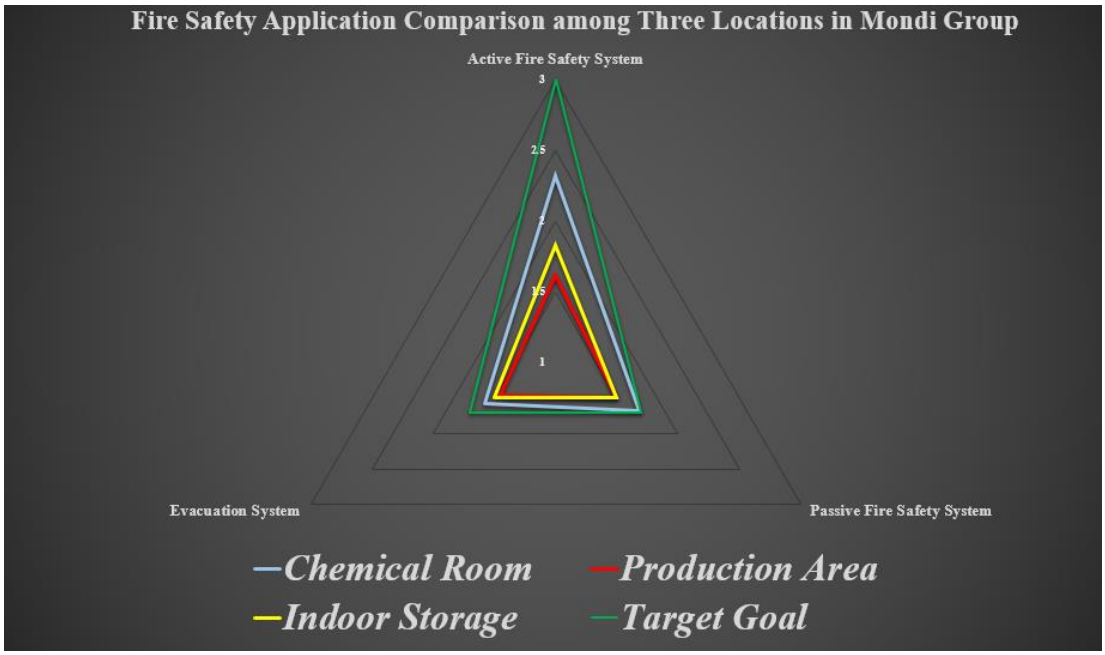

Figure 36. Fire safety application comparison among three locations in Mondi Group

Figure 36 compares the current fire safety applications in production area (red line in Figure 36) and indoor storage area (yellow line in Figure 36) against the applications in chemical room (blue line in Figure 36). We found a difference in the completeness of active fire safety systems among the three locations. Mondi installed the full EMAA suppression system in its chemical room. Automatic suppression can put out a fire before the fire escalates in scale. However, there is no automatic suppression system in the production area or in the indoor storage area dedicated to the finished products. A fire in these areas could inflict considerable

damage to the company. The results shown in this radar plot indicate that the two areas would benefit from having an automatic suppression system. If these two areas install an automatic suppression system, the level in active fire safety systems can meet the fire safety level of the chemical room (blue line in Figure 36).

4.2.2 Mondi Employee Survey Results

We surveyed 20 employees at Mondi Group to collect data on the fire safety systems present in the establishment as well as the fire safety awareness and quality of fire safety education of the employees. Although we surveyed 20 Mondi Group employees, a Mondi Group manager conducted five of our surveys. Thus, the possibility of bias may exist in our answers. We only considered the non-bias responses in our affected graphs and we specified the sample size for each graph.

As discussed in the methods chapter, the survey respondents all worked the first shift and our data may not be representative of the other two shifts. Our data analysis process takes this into consideration.

The first survey question for Mondi Group employees was “did you undergo fire safety training when you were first hired for the job?” The results for this survey question can be found in figure 37. The sample size considered for this pie chart is 15 Mondi Group employees.

Figure 37: Pie chart exemplifying Mondi Group employees who have and have not participated in fire safety training

The majority of the employees said they have participated in fire safety training, but our team was expecting all employees to answer yes to this question. The Moroccan Labor Law requires all employers to train their employees in basic fire safety and first aid training. The difference in responses may be due to the wording of the question; in other words, maybe all of the Mondi Group employees took the training(s), but not when they were first hired. If the question was fully understood, figure 37 conveys a small degree of discrepancy in Mondi Group's fire safety trainings.

We also asked the Mondi Group employees if they had received training on how to use a portable fire extinguisher. We considered the 15 non-biased survey responses for this pie chart because the five biased responses to this question were all "yes". The results can be found in figure 38 below.

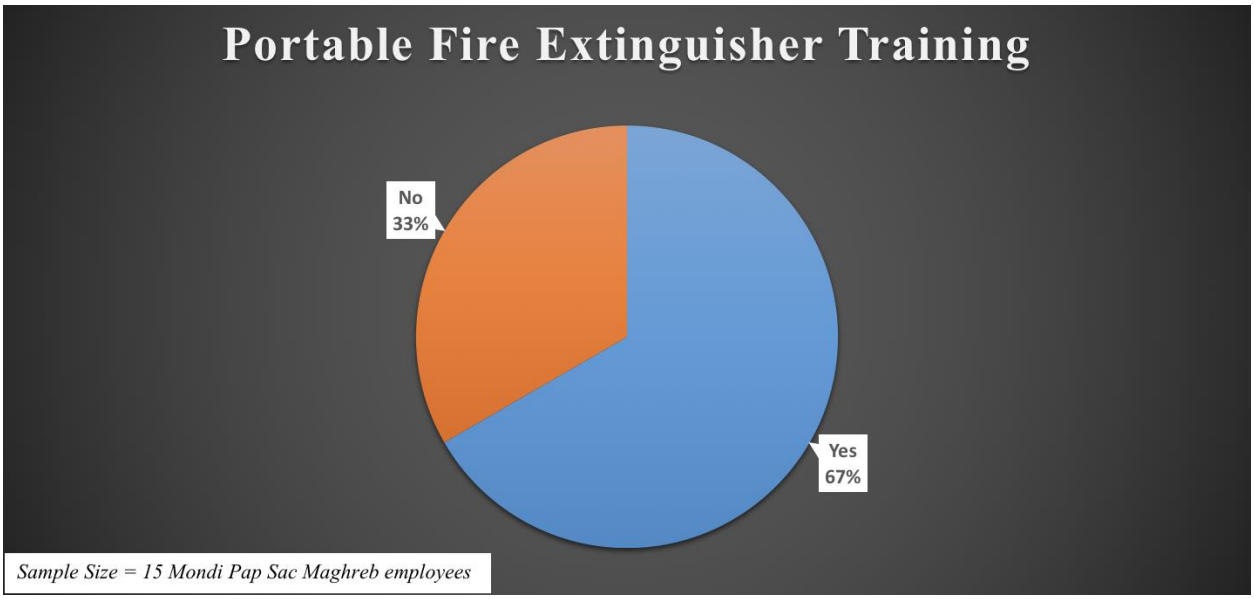

Figure 38: Employees who have vs. have not undergone portable fire extinguisher training

Two thirds of the employees answered that Mondi has provided portable fire extinguisher training. Our team realized after collecting data that our intended question was about fire extinguisher training. We overcomplicated the question by adding the word "portable," assuming that all extinguishers are portable. On our visit to Mondi Group, we discovered that there are specific fire extinguishers that are meant to be portable and stationary. The portable extinguishers are secured on a moving cart with wheels. Therefore, our data for this question may not be usable.

Our next survey question was about fire drill participation. We only considered 15 surveys for the data graph in figure 39.

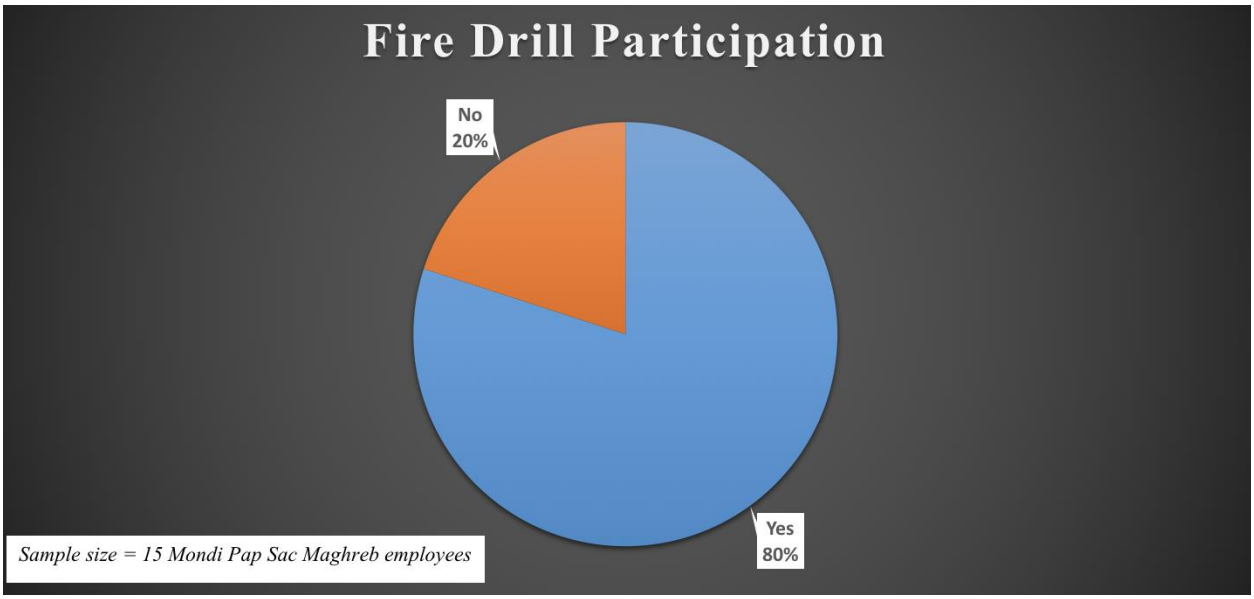

Figure 39: Fire drill participation by Mondi Group employees

Figure 39 indicates that fire drills may be less common than they should be at Mondi Group.

Our follow-up question was regarding how often fire drills occur at Mondi Group. The sample size for this bar graph is 12 employees. Refer to figure 40 below.

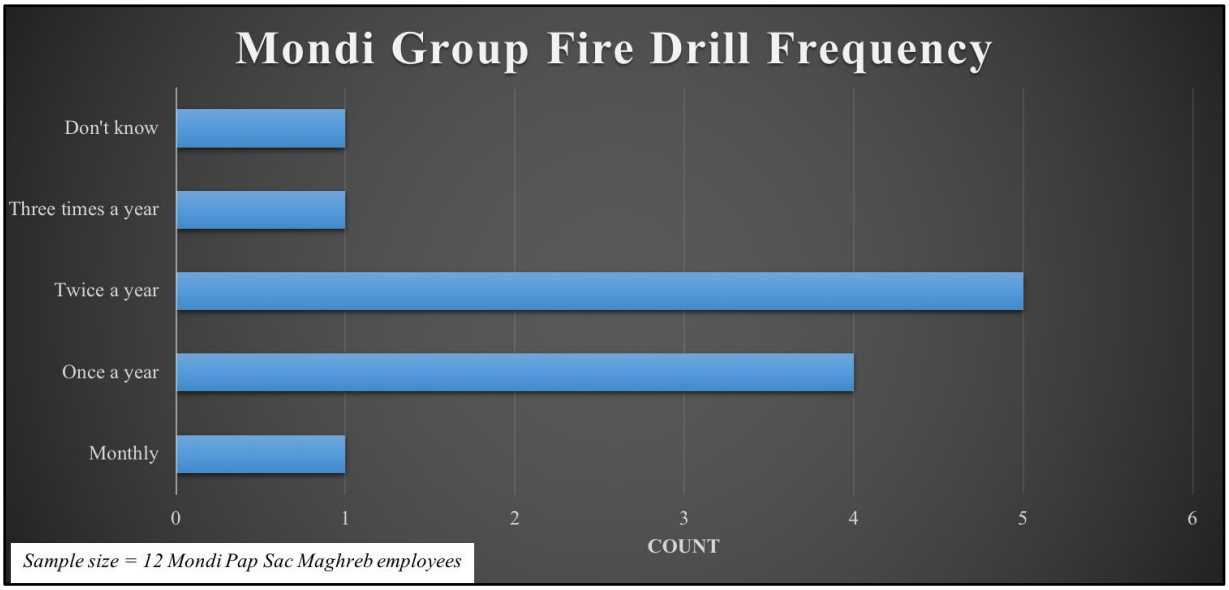

Figure 40: Mondi Group fire drill frequency according to the Mondi Group employees

Our sample size for this question was smaller because we only considered the survey samples that said “yes” in the previous question (refer to figure 39). Although the survey subjects who answered “no” in the previous question may have heard about a fire drill occurring, we did not want to assume this was the case. A difference in answers to figure 40’s survey question may be due to an inconsistency in fire drill frequency from year to year. There is also a chance that the employees misunderstood the question and answered how often they personally experience fire drills, rather than how often the facility performs fire drills.

Our last question for the industrial employees was regarding the fire safety systems present throughout the Mondi Group facility. Because this question is open-ended and it pertains more to personal knowledge, we considered all 20 Mondi Group employees for this graph. Our team counted the times each employee mentioned a fire safety system in constructing the count bar graph below in figure 41.

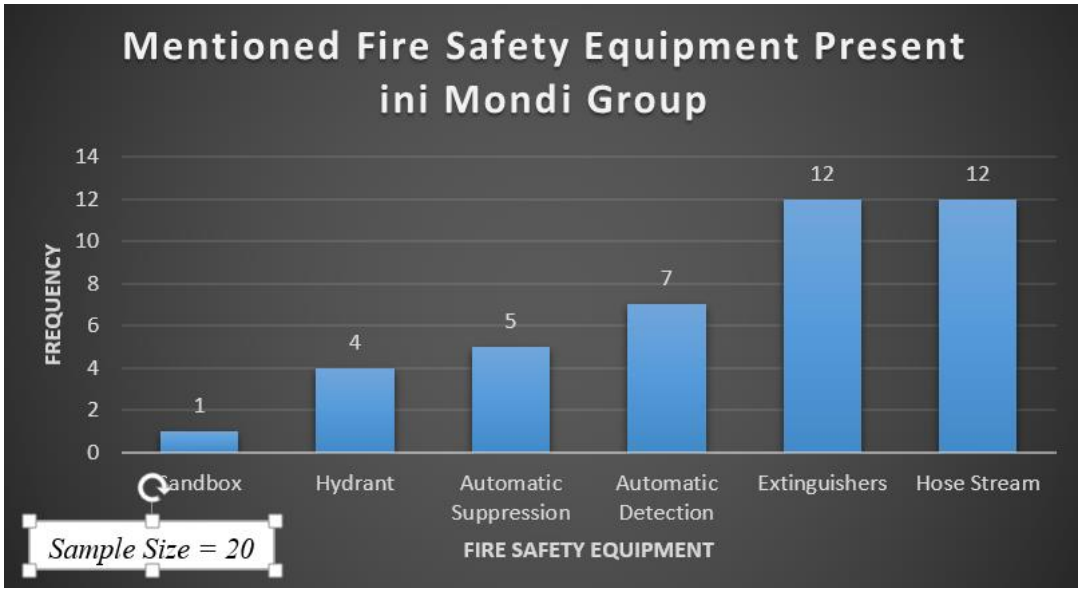

Figure 41: Fire safety apparatus present in the Mondi Group facility according to the site’s employees

Even though the presence of the Mondi Group manager may have introduced a bias in 5 of these questions, this question was an open-ended question to gauge the fire safety awareness of the employees. Every employee answered to the best of their ability no matter the surveyor, so there is no risk of bias for this question. The most common answers were “hose stream” and “fire extinguisher,” which are the most visible and marked fire safety technologies at Mondi Group.

We also wanted to display the number of systems recognized. The sample size for the number of systems recognized by each employee is 20 employees, since Figure 41 and Figure 42 are results from the same question. Refer to figure 42 below.

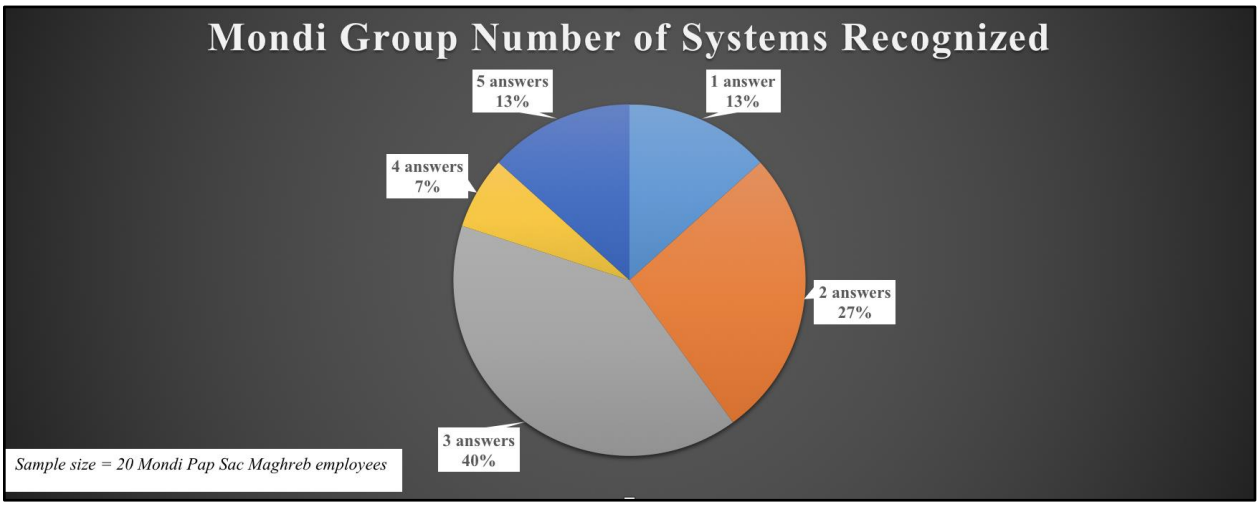

Figure 42: Number of fire safety systems identified by Mondi Group employees

As seen in the graph, the most common number of systems recognized are two and three. The average number of systems recognized is 2.8. Our team believes that the higher the number of systems identified, the higher the safety awareness of the survey subject.

4.2.3 Manager Interview Results

At the end of our visit with Mondi Group, we interviewed the Mondi Group - Africa managing director, Hicham Jalal. This interview took about 30 minutes and provided valuable information on the fire safety systems and trainings at Mondi Group, as well as information on government inspections and regulations.

Our team was very impressed with the fire safety systems and trainings at Mondi Group, especially after speaking to Hicham Jalal. He explained that Mondi offers many types of trainings; there is even a team trained and designated to respond to fire accidents at the industrial site. All employees are able to join this response team, but there are limits on how many people can join in order to optimize the ratio of number of responders to number of safely evacuated employees.

In addition to the trainings offered to the employees, our team was also very impressed with the separate water reservoir Mondi Group has for its fire suppression systems (hoses, hydrants, and sprinklers). In the interview, Hicham Jalal mentioned the special EMAA

extinguishing system Mondi Group has in their chemical storage room. After the interview, we made sure to visit the chemical storage room to inspect and document the fire safety systems present. Out of all of the locations analyzed at Mondi Group, the chemical storage room was the safest according to our risk assessment variables, R_p and R_b.

During the interview, our team discovered many gaps and possible negative factors in the Moroccan fire code. We discovered that if a town or city does not have a water line available for fire hydrants on a given property, the government does not require that property have fire hydrants and hoses. Our team believes this problem may be due to the lack of water availability in Morocco.

One of our interview questions was about government inspection and regulation of fire safety systems and applications. Government officials are supposed to visit company sites, such as Mondi Group, yearly for fire safety inspections. However, the government has not conducted a fire safety inspection in years, according to Hicham Jalal. He has been the manager at Mondi Group in Casablanca for about 10 years, and he stated, “To be honest. I don’t remember [when the last time government came to inspect our fire safety systems].” The infrequency of inspections may indicate a lack of available resources or government fire safety inspection workers.

4.2.4 Mondi Group Team Observations and Site Visit Comparison

Mondi Group had up-to-date fire safety implementation. Although the facility has high fire risk due to the paper product, the facility is well equipped with fire safety systems. In addition, their employees were generally aware of the fire safety systems present and most had participated in the required fire safety trainings. The inconsistency in answers regarding individual fire safety trainings as well as the fire drill frequency may be worth further review by FirePRO.

Out of the two sites we visited, Mondi Group was the better-scoring of the two. The risk values in the Morocco Mall were higher than in the Mondi Group facility, besides the outdoor storage area $\mathbf{R_b}$ for Mondi Group. The plentitude of active fire safety systems present in Mondi Group contribute to the low risk levels, despite the higher **user characteristic factor** for Mondi Group.

4.3 Results from Office Chérifien des Phosphates (OCP)

Our team was not able to acquire clearance to enter the production sites of Office Cherifien des Phosphates. Because OCP is an international chemical production facility, areas of the facility require consulate and local governmental approval. As our team was not aware of the clearance process in time, our team did not collect any technical data. However, we were able to speak with one member of OCP's top management team and the fire department at OCP Jorf Lasfar. In addition, Fire Chief Kherraz and his squadron gave us a tour of one of the three fire departments at OCP and learned about the available firefighting resources.

4.3.1 Fire Department Equipment Documentation

At the OCP fire department, our team learned more about the fire extinguishing and fire fighting technologies available on site. The following pictures are exemplary of their resources and technologies. Figure 43 is the entrance to one of the three fire departments at OCP. In this photograph, you can see that the fire department has six parking spots for the fire trucks, and available parking outside of the garage for other fire department vehicles.

Figure 43: Entrance to the fire department at OCP, four fire trucks are on site

The firefighters showed us the fire truck and the technologies they use in the event of a fire. Figure 44 is a picture of the inside of a fire truck.

Figure 44: Inside of the fire truck at OCP

There is space in this fire truck to adequately transport eight firefighters: two in the front and six in the back. Under the seats are life jackets and long rope that a fireman can use if a person were to fall in the water of OCP's dock. Figure 45 is a photograph of the foam tank in the OCP fire truck.

Figure 45: One ton foam tank located in the center of the OCP fire truck

The foam tank holds one ton of foam. The foam hose valves are on the back side of the truck. Figure 46 is a photograph of the hoses utilized for large fires.

Figure 46: Hoses in OCP fire truck used for large scale fires and extra valve replacements

The black hoses are for water, foam, or powder, and the yellow hoses are used for ammonia-based fires. Ammonia fires must be extinguished with water. The yellow hoses have small holes that create a water curtain or wall to prevent ammonia gas from spreading in a room or space. Another example of a unique piece of equipment at OCP is a hydraulic spreader, nicknamed “jaws of life.” Figure 47 is a picture of the hydraulic spreader used if someone gets stuck under or in a crashed vehicle.

Figure 47: Hydraulics firefighters use if a person is stuck in or under a crashed vehicle

The firefighters at OCP respond to fires and any other major emergencies on OCP's property or in nearby cities such as El Jadida. The firefighters stated that there are car crashes on the major highway in El Jadida that they respond to where they use tools like the hydraulic tool in figure 47.

Figure 48: Valve pumps in the back of the fire truck

All fire trucks at OCP have valve pumps in the back of the fire truck. In the event of a fire, the firefighters attach the hose to the appropriate valve. The valves in figure 48 are for powder, foam, and water.

Figure 49: Electric pole used to rescue an electrocuted person

Some areas of the industrial production facility have high-voltage electricity. To be able to rescue an electrocuted person, firefighters use an insulated pole as well as special boots that can withstand strong voltage. Figure 49 is a picture of Mr. Kherraz holding the insulated pole. Figure 50 is a picture of these special boots the firefighters would wear when addressing issues with high-voltage lines.

Figure 50: Rubber boots firefighters wear to withstand 20,000 volts of power when in a highly electric environment

The fire department also has their own powder, water, and foam fire extinguisher refill station. Thus, the OCP fire department is always fully prepared and equipped with functioning and full fire extinguishers. Figure 51 shows the refill station.

Figure 51: Fire extinguisher refill station at OCP fire department

4.3.2 Firemen Survey Results

On our visit to OCP, our team took the opportunity to survey six of the firemen. This sample size is small due to the unavailability of other firemen. Even though six survey subjects out of 24 firemen in the station is a low ratio, the responses were reasonably consistent and gave our team a representative indication of the training and expertise, as well as the social viewpoints of the firemen in the OCP fire department. The full survey data is in Appendix R.

We first asked the firemen how long they have been working at OCP. Table 3 below includes their answers.

Table 3: Number of Years of Experience as Firemen at OCP

Sample Subject Number	Years of Experience as Fireman at OCP (years)
1	32
2	9
3	32
4	12
5	30
6	19

All of the surveyed firemen have been working at OCP for more than six years, and they all noticed a change in fire code from French NF standards to NFPA standards, when OCP switched insurance company five years ago, which follows NFPA standards, but not the NF standards.

Our next set of answers from our survey was regarding the amount of time spent working per week. One fireman responded with forty hours per week, while the other five responded with more than forty hours per week. Additionally, all the firemen are always on standby when they are not working. Based on the survey responses, there are 24 firemen on standby at the station, which means between 140 to 160 firemen are on call at all times.

In general, the firemen responded saying that in case of a fire, the OCP employees are cooperative and knowledgeable in evacuating the building or area. The employees know their area's fire and emergency exits and the spaces that they must report to in case of evacuation.

4.3.3 Fire Chief Interview Results

On our visit to OCP, our team interviewed one of the eight OCP fire chiefs, Mohamed Kherraz. Our interview and surveys conducted at OCP were mainly centered around discovering the social aspects around fire safety and firefighting in Morocco. The production of phosphates at OCP presents a high fire risk, especially fire risk due to sulfur flammability. When interviewing Mohamed Kherraz, our team iniquired the date of the last fire in the facility. His answer was that day. The fire occurred in the seaport area of the facility and was a sulfur fire. Sulfur fires are typically fought with water and seem to occur often at OCP.

The OCP fire department is well equipped to handle the fires that occur due to the presence of the chemicals in the plant. On average, Kherraz responded that the OCP fire department fights about four fires within OCP a month. In addition to the fires and accidents within OCP, the OCP fire department respond to fires and emergencies in the El Jadida area. Kherraz said, on average the OCP fire department responds to about one fire accident or other accident outside of the OCP facility per month. The Moroccan government authorizes the OCP fire department to respond to fires nationally if there is fire at a national alert level. This is mainly due to the capability of the OCP fire department has over other local fire department.

The OCP fire department has between 140 and 160 firemen total, with 24 men at a station at any given time. There are eight fire chiefs, with one at the station during the day and none at the station at night. The firemen and fire chiefs that are not on-duty are always on-call in case of an emergency. On average, the OCP fire department can reach an OCP fire in five to ten minutes.

In addition to a well-equipped and fast responding fire department, OCP also has a large variety of fire safety systems installed throughout its industrial facility. The fire safety systems present in OCP include fire hose housings, fire hydrants, sprinklers and deluge systems, extinguishing foam, fire detection systems, fire suppression systems, and fixed and mobile fire protection equipments (such as hose stream hydrant monitor or extinguishers, respectively). OCP also has its own independent water reservoirs for firefighting and for industrial production. The water reservoirs must hold at least 12000 m^3 of water, a set amount that is designated only for firefighting. Fire chief Kherraz also pointed out the site's proximity to ocean which guarantees fire department's access to sufficient amount of water.

Fire chief Kherraz expressed to our team the frustrations that his department has regarding OCP's switch from Moroccan fire codes and standards to NFPA codes and standards. Although he did not seem to have any major problems with the American fire codes, Kherraz described that the differences in equipment approval and equipment storage procedure make it very hard for the fire department to switch to NFPA code immediately. The company is insured by FM Global, which is one of the large U.S. companies that does equipment and electrical fire approvals, the other big U.S. company being UL (Underwriters Laboratories). The insurance company required an immediate switch from Moroccan code to U.S. code. Kherraz told our team that "insurance [companies] needs to adjust to conform more to firefighter needs and resources." Prior to the required switch, the fire department had purchased new equipment but they could not use those equipment under NFPA code due to lack of FM or UL approval. These pieces of equipment should not be utilized by the OCP fire department for legal reasons, but are still functional.

The department also noticed some frustrating differences in fire department protocol in the U.S. code while undergoing their NFPA approved training in Casablanca. One of these differences was in the storage of the hose reels. The Moroccan code and French NF code allow firemen to coil the hoses on a reel, but NFPA code requires the hose to be folded, back and forth, "like a snake," as one of the FirePRO engineers said. The firemen, in fact, prefer the easier operation process from the French NF code.

4.4 Results from Office National des Aéroports (ONDA)

Our team was not able to receive authorization to access the Mohammed V Casablanca Airport due to a high alert warning for all Moroccan airports. We sent interview questions to the airport's fire department training head, whom we met on our visit to the International Academy of Civil Aviation (AIAC), although he did not respond.

On our visit to the AIAC, our team held a discussion with the academy's faculty. Our discussion involved important background information on the role played by the International Civil Aviation Organization in performing fire safety inspections. The AIAC faculty communicated that the ICAO is in charge of regularly inspecting the general safety of United Nations airports. Government personnel who conduct airport audits follow ICAO Annex 14 to inspect fire safety systems. The systematic inspections conducted by the ICAO of the United

Nations Airports (including the Moroccan airports) is a good contrast to the less-regular inspections conducted by the Moroccan fire departments for industrial companies, such as Mondi Group.

4.5 Results of Feasibility of Volunteer Fire Department Interviews

We were able to interview two volunteer firefighters from the United States, one from Connecticut and the other from Massachusetts. One of the firefighters we interviewed is currently a volunteer firefighter, and the other used to be a volunteer firefighter. The current volunteer firefighter is a young adult. We conducted these interviews specifically to gauge the feasibility and benefits of setting up a volunteer firefighting program in Morocco.

In both interviews, the team asked questions regarding their experiences as firefighters and their motivations for becoming volunteer firefighters. The younger volunteer responded that he felt volunteer firefighting would be a great way for him to give back to the community. Later in the interview, he also spoke of the different time commitments he has made to be a volunteer firefighter; he said that becoming a volunteer firefighter in Massachusetts requires a 120-hour certification program over six months. In addition to working as a volunteer firefighter, he works full-time on a private transport ambulance.

The retired volunteer firefighter we interviewed worked in a rural setting in Connecticut. He was a volunteer firefighter and a full-time design engineer at a bearing company. At the beginning of his volunteering, he underwent an informal mentorship program. This program consisted of job training and skill development through hands-on rescue experience. After 15 years of working at the fire department, he completed a training and certification course from the local county, as well as Red Cross and CPR courses.

Our team asked both volunteers if fire department uses volunteer firefighting as a training or mentorship program for full-time firefighting. The retired firefighter responded saying the time commitment of becoming a full-time (interior) firefighter is “severe.” He also explained to us that most of the volunteer firefighters that worked in the department had no desire to become full-time, as they had other full-time jobs in “private sector.” We asked the same question to the younger volunteer. He stated:

> Absolutely. We are lucky to have a department where we have full and part-time department members. Several departments have part-time training designated to train people 'in-house' to become full-time firefighters.

Although it is worth noting that older volunteers with rigid-schedule, full-time jobs often have no desire or time to become a full-time (interior or exterior) firefighter, younger volunteers with more fluid career paths may be open to volunteering as a means of becoming a full-time firefighter. The younger volunteer's response to our personal question about his future plans was as below:

> Due to the nature of my work and the state of Massachusetts, I am currently classified as "permanent, part-time," being paid for my duties. But the goal of being a full-time paid firefighter on a professional department is a major goal.

After considering all of these interview answers, our team suggest that implementing a volunteer fire department in Morocco would be beneficial to the unemployed. The unemployed people in Morocco have excess amounts of free time, therefore commitment is not a major concern. In terms of feasibility, Morocco can implement trainings and standards from the United States NFPA codes, such as NFPA FF I/II standards. Our team learned from our interviews with the volunteer firefighters that there are equipment restrictions involved with being a volunteer rather than a full-time firefighter. An example of equipment restriction is volunteer firefighters are typically not allowed to drive the large fire engines. This dynamic decreases the amount of training necessary, which ensures the firemen that use the advanced equipment are well educated on the usage. Having restrictions on specific equipment usage also reduces the responsibility and training time for volunteers compared to full-time firefighters.

The interview transcript with the two volunteer firefighters are in Appendices T and U.

4.6 Development of User-Friendly Semi-Quantitative Checklist Tool in Excel

The user-friendly, semi-quantitative Excel checklist template provides the FirePRO engineers with the opportunity to easily input acquired checklist data from site visits and determine the specific fire safety applications that need improvement within the establishment. Engineers can analyze a specific location and the entire establishment using this template. The

checklist template is easy to understand and utilize because we automated many of the processes, using programming, for the user. The following section outlines the functionality, structure, and usability of each Excel worksheet page. Appendix Z includes the Excel template. Our team included the complete Excel checklist template file in an attachment of our proposal.

The first Excel worksheet tab, "Scatter plot Graph & Radar Plots," is an interface for analyzing the overall fire risk of an establishment and its locations. In addition, the engineers can utilize this specific worksheet for marketing purposes. The Excel checklist template provides the appropriate graphics for analysis of at most three areas of an establishment. In the event that FirePRO engineers analyze more than three areas for a market sector, they can copy and paste the formulas and add graphics for the additional areas. At the top of the first Excel worksheet titled "Client risk assessment scatterplot and radar plot graph," there is a scatter plot titled "Establishment fire risk" that considers three possible locations' fire risk on the R_p and R_b axes. The blue tinted cells to the left of the scatter plot graphic represent the numerical R_p and R_b values for each respective location. The title above these blue cells instruct the user to insert the name of the location for clarity and organizational purposes. The FirePRO engineers must input all necessary data in Excel worksheet tabs named "Rb Calculations and Rp Calculations," "Rb Calculations (2) and Rp Calculations (2)," and "Rb Calculations (3) and Rp Calculations (3)," for each location's R_p and R_b values to appear; they do not need to manually input the R_p and R_b values since a formula is preset to compute the values for them. Secondly, the radar plot graph titled "Comparative radar plot for all analyzed locations" below the scatter plot graph focuses on three specific aspects of the checklists' factors. Specifically, the comprehensive radar plot considers the following categories: active fire safety, passive fire safety, and evacuation. This radar plot provides the FirePRO engineers with information for the establishment as a whole. They can comprehend if locations within the establishment do or do not prioritize certain types of fire safety, which locations definitely need improvement in fire mitigation technologies, and which axes require FirePRO's assistance in implementing more effective fire safety mitigation technologies. The red and green colors indicate the worst and best case scenario on the radar plot. The same is true for the graph's legend. There can be at most five triangles on the comparative radar plot: location 1, location 2, location, 3, best case scenario, worst case scenario.

Below the comparative radar plot, there are individual area radar plots. The FirePRO engineers can then focus on values from one specific location on each of the three axes of the

radar plot. For clarification, the tool computes all of the values for the three axes using formulas and the user does not need to manually enter this information. Once the user completes the appropriate information in the "User Interface for Radar Plot" Excel worksheet tab, the formulated calculations will appear to the left of the individual radar plot graphs. Above the blue cells is a title that prompts the user, as before, to insert the name of the location for organizational and clarity purposes. Three individual area radar plots are available in this template tool.

The second Excel worksheet tab named "User Interface for Radar Plot" is an interface for the user to input data using drop down boxes. The data in this worksheet is qualitative, so only words appear on the screen. The columns are the following: inspected safety system, and area one through seven. The inspected safety systems column is indicative of all of the fire safety systems considered in the three axes of the radar plot graphic. Three row categories make up the inspected safety systems: active fire safety systems, passive fire safety systems, and evacuation systems. The green color in the body of the table indicates where the establishment inspectors should place their cursor to access the drop down box values. The engineers must fill all of the cells in area one through area seven's columns in order for the conversion process of qualitative data to quantitative data; the data conversion occurs on a different Excel worksheet page, "Radar Plot Raw Data (DNT)." If the user does not fill all of the values in a column, the data conversion will not be complete and a radar plot graph will not appear on the first Excel worksheet, "Scatter plot Graph & Radar Plots." In addition, if the engineers have less than seven areas to assess, the missing input in the remaining area columns will not affect the radar plot graphics for the areas with entered information.

The third Excel worksheet tab named "Radar Plot Raw Data (DNT)" represents the raw radar plot data. The DNT in parentheses represents do not touch. The FirePRO engineers do not need to utilize this Excel worksheet tab for any reason, as its function is solely to compute the qualitative and quantitative data conversions. The leftmost table of the third worksheet calculates the data conversion for the entered data from the table the second Excel worksheet, "User Interface for Radar Plot." The table to the right of the data conversions represents the scaling for the radar plot axes. The possible values for the passive fire safety and evacuation axes are 1.0, 1.3, 1.5, and 1.7. This scaling is representative of the scaling used in the Dong and Zhang Chinese study discussed in our background chapter. The possible values for the active fire safety

system axis are 1.0, 1.5, 2.5, and 3.0. The scaling is unbalanced in the radar plot, although our team believes leaving the scaling as is is beneficial for the template's radar plot graphical model.

FirePRO focuses primarily on the installation and maintenance of active fire safety systems, so weighting this axis higher is indicative of their priorities and strongest expertise as a fire engineering Protection Company. The last table in the worksheet is the raw data for the comparative radar plot graphic on the first Excel worksheet page. The "best case scenario" and "worst case scenario" columns are fixed because of the scaling of each of the axes. Again, the "Radar Plot Raw Data (DNT)" Excel worksheet is the data conversion and raw data radar plot page, and does not require any modification by the user.

The fourth Excel worksheet page named "Rb Calculations" is where the engineer inputs client site assessment data for the fire risk associated with the building structure. The top of the worksheet displays the R_b formula with arrows pointing to definition command boxes from each factor. If the FirePRO engineers are unclear of the meaning of one of the factors, they can click on the grey command box to see the factor's definition on the screen. This function applies for every factor in the R_b formula. Below the formula, the "Value of R_b" is empty or present. When the "Value of R_b" is empty, there is a message that appears in bold red text to indicate to the user that there are values of factors missing in the equation; the message that appears in this case is "All values are not submitted!" The warning message disappears if the equation of R_b is properly computed.

Next are the inputs sections for each factor. Each factor's section includes a bolded blue title, a hyperlink to the factor's guide in another worksheet page, a note to assist the user, and a green drop down cell. If a FirePRO engineer is unsure of what value to input for a specific factor, there is a hyperlink that sends them to the factor's guide. All of the necessary cells to compute the R_b formula are in green. Beside the green cells, there are additional entry boxes, if needed. Only one cell entry for each factors' variables is necessary to complete the R_b equation. Although, if engineers did not gather acknowledge information on a client site assessment visit, the engineers may have to estimate answers for each variable. The additional entry cell, if used, will average values with the green entry cell. The average is then the representative value for the variable. The thin blue cells below the entry boxes for each factor represents the numerical conversion from the entered qualitative data to the respective quantitative data; the numerical conversions from the qualitative data to the quantitative data are preset. The "Value of [factor

name]" cell parallel to each factor's title contains a color scale that represents the extremity of risk with respect to that specific factor. The color scale works from left to right, and is either yellow or red. The closer the color scale is to the left of the cell, the less fire risk is present for that factor; the closer the color scale is to the right of the cell, the more fire risk is present for that factor. The yellow color scales are for factors that FirePRO Engineering may or may not be able to address for a client due to the complexity of the solution. The red color scales are representatives of the factors which FirePRO can address with clients to assist in reducing fire risk for the establishment. These factors are the ones that have practical and feasible solutions according to FirePRO's grand expertise in fire protection engineering innovative solutions. No color scale will appear if the factor holds the least amount of risk possible. Using the color scales, FirePRO engineers and clients have a visual of the extent of risk presented by each factor.

The fifth Excel worksheet page is for the "Rp Calculations." The "Rp Calculation" worksheet is structured similarly to the "Rb Calculations" worksheet described above. Although, there are some differences. One of these differences includes the change in equation and factors present in the R_p equation. The second difference is that instead of a red color scale for factors that FirePRO specialize in, the color scales are green. The change in color is due to the change in scaling of R_p's factors compared to R_b's. For clarification, the worst case scenario for each R_b factor is the highest possible number, while the worst case scenario for each R_p factor is the lowest possible number. To provide further explanation, we will analyze the possible values for the R_p factor, H, or the ventilation and smoke extraction factor. If we input the worst case scenario values for the design of smoke extraction system, the usability of smoke extraction system, and the type of smoke extraction/ventilation system, a green color scale does not appear. However, if we state the three categories are relatively reasonable, relatively complete and usable, and forced, respectively, the green color scale appears and covers about half of the "Value of H" cell. This indicates that for the ventilation and smoke extraction factor, or H, FirePRO can recommend improvements in the design and usability of the smoke extraction system. The closer the green scale is to the right side of the "Value of [factor]" cell, the safer the establishment is from fire.

After completing all necessary data entry for the "Rb Calculations" and "Rp Calculations" worksheets, the R_p and R_b scatter plot graphic is available for viewing and analysis on the first Excel worksheet page, "Scatter plot Graph & Radar Plots."

On top of that, there are two sets of copies of the “Rb Calculations” and “Rp Calculations” worksheets in case the FirePRO engineers would like to assess the fire safety of more than one area within an establishment.

After all three sets of the “Rb Calculations” and “Rp Calculations” pages, there are the “Rb Guides” and “Rp Guides.” These worksheets are the guides that the FirePRO engineers look at in the event that they are unclear of what values to enter for a factor. The hyperlinks accompanied with every factor in the “Rb Calculations” and “Rp Calculations” pages link to these two worksheet pages.

The Excel checklist template achieves full functionality of Checklists No. 1 and No. 2 in a user-friendly manner, and FirePRO engineers can be further improve it by adding more factors. In addition, with all of the graphical tools on the template, FirePRO engineers have the ability to recommend and market safety systems that clients may not even be aware of, such as sprinkler systems that are not required by Moroccan and French fire code laws.

Chapter 5. Conclusion and Recommendations

The goal of our project was to evaluate the current implementation of Moroccan fire safety codes in public and workplace environments and to identify social matter surrounding fire safety in Morocco. Our team addressed our goal through the investigation of fire safety applications and systems throughout the aviation, commercial, and industrial environments. We also researched international fire safety best practices and compared these practices to the current Moroccan fire safety best practices. Through our visits to OCP and Mondi Group, our team documented the social dimensions concerning fire safety and fire safety awareness. Lastly, our team developed an excel checklist template to aid FirePRO Engineering in future client site assessments.

Any recommendations our team has developed are through our site visits, surveys, interviews, deductions, and research. Our first recommendation to FirePRO Engineering is to offer public fire safety education events. Educating the Moroccan public will emphasize the importance of fire safety and may induce a greater sense of urgency to have high-quality fire safety systems in public and workplace environments and in residential homes.

Our second recommendation is to encourage the use of larger exit signs. Although the current international standards regard the “running man” design Morocco uses as the best exit sign design, part of the benefit of the sign is that the green color is easily visible to the human eye, even in the event of a fire. With larger signs, exits will be more noticeable and clearer to the people. This is the most important in public environments, where the people are generally unaware of where the nearest exit is. Another important application of fire safety for evacuation purposes is labeling the emergency exits with means other than exit signs. Our team noticed that Mondi Group painted their emergency exit doors red, and we believe painting the physical door in addition to having a larger exit sign may aid in improving egress.

Our last recommendation to FirePRO is to implement a periodic feedback survey on the service they provide to their clients. Constant feedback from clients is important to improving as a company and can lead to bigger business and networking opportunities. Concerning this last recommendation, Hicham Jalal brought up in our interview at Mondi Group. The feedback on employee and company service may lead to improved business for FirePRO, as well as easier collaboration between FirePRO and their clients.

Our team would like to recognize that fire safety in Morocco is far from perfection. Our project focused specifically on the aviation, commercial, and industrial environments. FirePRO Engineering as a company is very specialized in the fire safety application and training industry for these three environments. Many of the major problems we have run into throughout our project are due to government involvement in fire safety inspection and enforcement, fire department resources and response time, and quality of fire safety systems and applications in older buildings and homes. Our team recognizes that many of the problems regarding fire safety within the aviation, commercial, and industrial environments may be related to a lack of governmental resources available to these sectors. We believe there is much potential for Morocco to improve, grow, and become more fire safe.

For this reason, we would like to suggest two additional recommendations for future projects in Morocco, either for Moroccan residents and students, or for future projects for students from WPI (either Interactive Qualifying Project or Major Qualifying Project). Our first recommendation is to set up a volunteer fire department program. Setting up this program may not only help in reducing fires faster, but may also help to accomplish the Moroccan National Initiative for Human Development (INDH). One of the six main goals of the INDH is "the promotion of income and job-generating activities" (INDH, N.d.). Poverty is currently a large problem in Morocco. 8.9% of the population lives below the poverty line as of 2007 (World Bank, 2018). The INDH was put into effect in 2005 by King Mohammed VI of Morocco to address the problem of poverty and cost of living, as well as prevent social exclusion by encouraging productive activities (INDH, N.d.). Our proposition of starting a volunteer fire department program in Morocco would help to promote this initiative by allowing citizens to enlist as firemen, ergo providing a productive activity option for members of the Moroccan society. Volunteer fire departments can also serve as a training and mentorship program for Moroccan citizens that desire to become firemen. Both public fire departments as well as private companies or industries would have a skilled pool of candidates for fire protection to select from for jobs. This may also open up opportunities for less-privileged youth to work towards higher education at private universities for fire safety studies and trainings.

Our second recommendation for future projects in Morocco is to organize a donation or redistribution program for non-United States certified fire safety applications and technologies. One of the main problems in the OCP fire department that is preventing a quick transition to

American fire code is the surplus of French certified equipment left over. The equipment that the fire department has is still useable and in good quality (some of their equipment was brand new), but is not supposed to be used by the department per their insurance company's requirements to switch to American NFPA fire codes.

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Glossary of Terms

Automatic fire alarm factor (K):

This factor takes into account the design and usability of the fire detection system in the surveyed area. A lower fire alarm factor contributes to a lower risk to lives and property in the building.

Automatic fire detectors:

Automatic fire detectors ensure that action against fire can begin as promptly as possible. Some of the different types of detection of fire or gas include: human detection, flammable gas detectors, flame detectors, heat detectors, and smoke detectors. (Hazard Identification, Assessment and Control, Mannan)

Building area factor (S):

This factor takes the building area into consideration. A larger area contributes to a higher risk of fire damage to the building structure.

Building fireproof rating factor (W):

Nan Zhang and Sihui Dong used the fireproof rating factor in their R_b calculation. GB50016-2014 is the Chinese national standard which specifies the criteria a building must meet in order to get certain fireproof rating factor. It focuses on the building materials in different parts of the building and how long they can withstand fire before structural failure. There are four levels of rating, with level one being the best, which contributes to a lower risk of fire damage to the building structure.

Confinement factor (C):

The confinement factor is determined based on design, usability, and flammability of material for the smoke ventilation system. It is important to note that the sites we visit may have more than one type of ventilation system; for example, most sites have HVAC ventilation for everyday use, as well as forced convection ventilation that only operates in case of a fire.

A larger confinement factor contributes to a higher risk of fire damage to the building structure.

Containment of fuels:

The containment of fuels includes the quality of the container holding the fuel as well as any backup containment that might be necessary in case of a leak (such as sands for oils). In case of fire resulting from leaking fuels, it is best to cut off the flow of fuel first rather than fighting the fire. (Hazard Identification, Assessment and Control, Mannan)

Evacuation capacity factor (E):

This factor takes into account the difficulties that a person might run into while evacuating the area (the evacuation route) such as distance to an exit, the clearance of the route, and the design of the exits. It also takes into account the evacuation equipment present in the area and their functionality; we are specifically looking at: the quality of signs to the exit, the design of stairs, the usability and distribution of emergency lighting, and the effectiveness of the emergency announcement system.

A lower evacuation capacity factor correlates to a lower fire risk to lives and property in the building.

Factor on firefighting capacity of fire department (L_0):

This factor describes the firefighting capacity of the local fire department. In determining L_0, we consider the quality of the fire department equipment (advanced, relatively advanced, normal, or not advanced), the firefighting experience of the local department, the fire lane availability on-site (whether they have a fire lane, how big it is, if cars park in the fire lane normally, etc.), the usability of the outdoor fire hydrants, and the local station average response time.

A lower firefighting capacity of fire department contributes to a higher risk of fire damage to the building structure.

Factor on firefighting equipment in building (L_i):

This factor is determined by analyzing the usability of the fire detection systems, sprinkler systems, indoor fire hydrants/hoses, and the fire extinguishers.

A lower firefighting equipment in building value contributes to a higher risk of fire damage to the building structure.

Factor on reduction of fire spreading (R_i):

This factor is based on the presence and distribution of flammable goods in a room or area. The range we are judging each area on is from “flammable goods around the room” to “goods packed in containers, hard to ignite”.

A lower reduction of fire spreading value contributes to a higher risk of fire damage to the building structure.

Fire damage to building structure (R_b):

This rating describes the risk of fire damage on the building structure itself. R_b helps determine if the building needs additional safety measures to protect the building structure (Zhang et al, 2016).

Fire damage to lives and properties in building (R_p):

This rating describes the risk of fire damage on lives and property in the building. R_p determines if the building needs additional safety measures to protect the lives and property in the building (Zhang et al, 2016).

Fire extinguishers:

In Morocco, there are six classes of fire extinguishing, all represented by a letter.

A: Materials such as wood or paper

B: Flammable and combustible liquids (oils)

C: Flammable gases

D: Combustible metals

E: Electrical

F: Cooking oils

Fire source factor (F):

This factor takes into account all possible sources of fire in the area. The sources of fires we are investigating include: human fire source (smoking or prohibited behaviors related to fire), electrical fire source (electrical wiring maintenance and installation, lighting equipment application and usage time, electric appliance heat dissipation system and grounding condition and flammability of nearby materials, and quality and grounding of power transformation equipment), and fuel source (coal presence and protection and flammable and combustible fuel presence, protection, and containment).

Fire suppression systems:

Fire suppression systems help prevent the spread of fire in an area and can also aid in putting out the fire as well. Fire suppression systems include sprinklers, fire extinguishers, and fire hoses/hydrants.

Flammability factor of mobile fire load (μ):

This factor takes into account the flammability of the mobile fire load. The range of material is from wood and flooring to materials such as gasoline, alkyl (mainly fuels, which contain hydrocarbons), varnish, pure ethanol, and alkali metals.

A large flammability of mobile fire load contributes to a higher fire risk to the building.

Heat detectors:

Heat detectors are generally used in places where some sort of smoke or exhaust is regularly given off in the area that would set off a smoke detector. An example of a space like this might be a parking garage.

Horn strobe:

Horne strobes are a form of public announcement in case of a fire. Horn strobes include a loud siren (horn) and a strobe light.

Hose housing:

The hose housing is the box in which hoses are kept around the building. These hoses are often neatly rolled and ready for use. The hoses are connected to an emergency water supply in case of fire.

Hose stream:

The hose stream describes the pressure and speed of the water through the hose.

Immobile fire load factor (Q_i):

This factor takes into account the flammability of the immobile aspects of the building (support material, ceiling material, and wall material). A higher flammability factor corresponds to a higher fire risk to the building.

Mobile fire load factor (Q_m):

This factor takes into account the approximate weight per square meter in the area being investigated. A larger amount of weight per square meter contributes to a higher fire risk to the building, mainly due to the amount of material in a given space.

Monitor nozzles:

Monitor nozzles are water cannons that are meant for putting fires out quickly.

Protection of fuels:

The protection of fuels includes any precautions involved, such as keeping fuels out of direct sun or warm environments.

Smoke toxicity factor (T):

This factor takes into account the smoke toxicity of the mobile fire load in the surveyed area. A flammable material such as ethanol and natural gas gives off a lower level of toxicity when on fire, whereas plastics such as polystyrene, polyurethane, PVC, rubber, and neoprene give off a more toxic smoke when burning. A higher smoke toxicity factor contributes to a higher risk to lives and properties in the building.

Smoke detectors:

Smoke detectors are a form of fire detection that alert people in the area if there is a significant amount of smoke in the air.

Sprinklers:

There are two orientations of sprinklers that can be used: pendant and upright. Upright sprinklers are generally found in spaces where the sprinkler system is not concealed, such as a parking lot, whereas a pendant sprinkler is found hanging from the ceiling in buildings where the sprinkler system is concealed by walls and the ceiling.

User characteristic factor (f):

The user characteristic factor takes into account the building/structure type. The types of buildings include: office building, station, airport, mall, library, theater, museum, restaurant, industrial facility, apartment or house, hotel, bars, clubs, a hospital, a kindergarten, etc.
This factor is a summary of the general organization of the area as well as the activity of the people in the building. A better score is assigned to places like stations and airports because these facilities are more likely to have personnel who are specifically trained in directing traffic in case of a fire or in putting out a fire. A site such as a hospital or kindergarten would receive the worst possible score because the people within these facilities require assistance in evacuation.

Ventilation and smoke extraction factor (H):

This factor takes into account the design and usability of the smoke extraction system. A smoke extraction system only runs when there is a fire detected. The ventilation system extracts the smoke from the building using forced convection.

A lower ventilation and smoke extraction factor contributes to a lower fire risk to lives and property in the building.

Quantitative Risk Analysis (QRA)

Quantitative risk analysis is the use of probability in order to estimate level of risk.

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, exhaust system, etc.)?
    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. Do different locations in the airport have different emergency evacuation plans?
    e. If so, are employees trained on all of the different emergency evacuation plans?
    f. What types of fire safety trainings are employees expected to complete?
    g. Are you expected to provide fire safety trainings to all airport employees?
    h. Which employees take which trainings?
    i. 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 drills?
5. Do all fire incidents need to be reported? (Yes/No)
    a. 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.

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)?
    a. 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?
    a. If so, how drastically?
    b. What are the popular times to visit the mall during the week?
    c. What are the popular times to visit the mall on the weekend?
    d. During the busiest time of day, approximately how long does it take to travel to a nearby fire exit?
8. Is there a historical record of fires at the Morocco Mall?
9. Are there any accomodations made for the handicap and disabled in the event of a fire or emergency?

10. In the event of a fire, is there a public announcement displayed throughout the whole mall? Is this public announcement in the form of a text message, call or a voice announcement throughout the mall speakers?

(En Français)
Entrevue Préambule:
Nous sommes un groupe d'étudiants américains étudiants la sécurité incendie dans les sites commerciaux marocains. Nous apprécierions grandement que vous répondiez à quelques questions concernant notre projet.

Le but de cette entrevue est de recueillir des connaissances sur les systèmes de sécurité incendie. Notre équipe fera les meilleures recommandations possibles d'atténuation des risques d'incendie, pour les sites commerciaux marocains en utilisant vos réponses à ces questions. Celles-ci sont précieuses pour nos données de projet et nous apprécions votre temps. Nous préciserons l'endroit où cette entrevue a eu lieu afin de garder une trace de nos données, mais nous n'inclurons pas votre nom pour respecter la confidentialité.

Nom:
Nom de l'installation:
Heure:

1. Quels systèmes de sécurité incendie sont utilisés dans ce centre commercial (par exemple, sprinkler, rideau coupe feu, systemes de détection incendie, systeme de desenfumage)?
une.
a. Combien de ces systèmes de sécurité incendie sont requis par la reglementation incendie marocaine?
b. Certains de ces systèmes de sécurité incendie sont-ils requis par la compagnie d'assurance du centre commercial?
c. Combien de ces systèmes de sécurité incendie sont des précautions supplémentaires?
d. Votre établissement dispose-t-il d'un plan d'évacuation d'urgence?
e. Quels types de formation en sécurité-incendie les employés sont-ils censés compléter?
f. Êtes-vous censé de faire des formations sur la sécurité-incendie à tous les employés du centre commercial?
g. À quelle fréquence les employés doivent-ils refaire ces formation?

2. Qui effectue les inspections des équipements de sécurité incendie dans ce centre commercial?

3. À quelle fréquence les équipements de sécurité sont-ils vérifiés et mis-à-jour?

4. À quelle fréquence effectuez-vous des exercices d'évacuation d'urgence?

5. Existe-t-il d'autres codes de prévention d'incendies que les restaurants doivent suivre?

6. Quels magasins dans le centre commercial vendent des produits qui augmentent le risque d'incendie (n'incluant pas les restaurants)?
Environ combien de magasins dans le centre commercial vendent une sorte de matériel inflammable / combustible? S'il vous plaît donnez des exemples.

7. La densité de population du centre commercial a-t-elle une incidence sur la sécurité incendie des personnes et des milieux de travail? Si oui, comment drastiquement?

a. A quelle periode le centre est plus visité durant les jours de le semaine hors weekend?
b. A quelle periode le centre est plus visité durant weekend?
c. Pendant la période la plus occupée de la journée, combien de temps faut-il pour se rendre à la sortie de secours à proximité?

8. Quel est l'historique des incendies de votre établissement? S'est-il produit des accidents de feu majeur auparavant?

9. Offrez-vous une assistance spéciale aux personnes aux mobilité reduite en cas d'incendie?

10. En cas d'incendie, quel type d'annonce publique utilisez-vous? Message texte, email, diffusion?

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?
   Weekly Monthly Semiannually Yearly First time

2. Do you think the airport is overly-crowded at times?

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

4. 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)

5. Why do you feel this way?

(En Français)
Le but de cette enquête est d'évaluer votre sentiment de sécurité incendie dans cet aéroport. Nous allons enregistrer l'heure et la section de l'aéroport où nous sommes en ce moment. L'enquête est confidentielle. Nous espérons que tous nos visiteurs seront honnêtes et complets dans leurs réponses. Vos réponses sont précieuses pour nos données de projet et nous apprécions votre temps.
Nom de l'aéroport: Aéroport International Mohammed V, Casablanca
Zone de l'installation:
Heure:

1. À quelle fréquence voyagez-vous de et vers cet aéroport?

Hebdomadaire Mensuellement Semestriel Annuel Première fois

2. Pensez-vous que l'aéroport est parfois trop fréquenté? Pourquoi?

3. En cas d'incendie, combien de temps pensez-vous qu'il vous faudrait pour quitter le terminal?

4. Avez-vous pensé à la sécurité incendie lorsque vous entrez dans l'aéroport?
Si oui, sur une échelle de 1 à 5, dans quelle mesure vous sentez-vous en sécurité à l'aéroport en matière de sécurité incendie?

1	2	3	4	5
	(pas sûr)		(assez sûr)	(très sûr)

5. Pourquoi ressentez-vous cela?

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?
    a. 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:

1. What brings you in the mall?

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

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

4. How far are you from the nearest emergency exit?

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

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

7. When you walk into the mall, do you feel fire safe?

(En Français)
Le but de cette enquête est d'évaluer les dimensions sociales de la sécurité incendie dans le secteur commercial, et d'enquêter sur les pratiques de sécurité incendie qui peuvent être améliorées dans les milieux commerciaux publics. L'enquête est confidentielle. Vos réponses sont précieuses pour nos données de projet et nous apprécions votre temps.
Emplacement dans le centre commercial:
Heure:
Interviewer nom:
Nom du traducteur:

1. Qu'est-ce qui vous amène dans le centre commercial?

2. À quelle fréquence faites vous du shopping dans ce centre commercial (hebdomadaire, mensuel, annuel, occasionnel ou pour la première fois)?

3. Combien de temps restez-vous quand vous faites du shopping ici (moins de 30 minutes, 1-2 heures, +2 heures)?

4. À quelle distance êtes-vous de la sortie de secours la plus proche?

5. Pensez-vous que le centre commercial est parfois trop fréquenté?

6. En cas d'incendie, combien de temps pensez-vous qu'il vous faudrait pour quitter le centre commercial?

7. Quand vous entrez dans le centre commercial, vous vous sentez en toute sécurité par rapport à un incendie?

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?

(En Français)
Le but de cette enquête est d'étudier les systèmes de sécurité incendie dans l'usine. Pour des raisons de confidentialité, nous n'enregistrons pas votre nom. Mais, nous inclurons votre titre d'emploi dans nos données d'enquête. Vos réponses sont précieuses pour notre projet et nous apprécions votre temps.

Nom de l'usine:
Titre de l'enquêté:
Numéro de l'enquête:
Heure:

Avez-vous suivi une formation de sécurité lorsque vous avez commencé le travail?

Votre lieu de travail héberge-t-il des exercices d'incendie? Si oui, à quelle fréquence?

Avez-vous reçu une formation spéciale sur l'utilisation d'un extincteur portatif?

Avez-vous déjà eu un incendie sur le lieu de travail?

Si oui, quel (s) protocole (s) d'incendie avez-vous suivi?

Pensez-vous que cette installation est à jour par rapport aux normes de sécurité? (Oui/Non)

Combien de personnes pensez-vous pouvoir travailler en toute sécurité dans cette installation?

Y a-t-il des pièces dans ce bâtiment que vous pensez être trop peuplées à certains moments?

Quels types de systèmes de sécurité incendie sont essentiels à la sécurité de votre lieu de travail?

Appendix H: Interview Questions for Industrial Internal Fire Department Chief

What types of fire safety systems do you have in each area of the site?

What is the maximum amount of time it takes to reach a fire on-site?

How many firemen do you have in total? Do you think this is a reasonable number of responders?

Where does funding for the fire department within OCP come from?

How many firemen are standby at the station at any given time?

How many fire chiefs do you have in the department at any given time?

On average, how often do you deploy your firemen per month?

When was the last fire in the facility? What was the scale of that fire?

Training
How often do you recruit firefighters? What are the prerequisites?

How often do your firemen undergo fire safety training? Where did they get your training from?

Connection with city
Does the facility have its own water reservoir or is the sprinkler and hydrant system connected to the city water supply?

Have you ever asked the local fire departments for assistance in putting out a fire?

Appendix I: Survey Questions for Industrial Fire Department Firemen

We are interested in fire department's training level and experiences. This survey will remain anonymous and we value your answers!

1. How long have you been working at this site? How long have you been a fireman in general?

2. If more than 6 years: did you notice any major change in the fire code that OCP used when the company changed codes?

3. How often do you get firefighting trainings? Where do you get the trainings from?

4. How many hours do you work every week? How many firemen does your fire department have on standby at any given time? Do you think it is sufficient??

The following questions are relevant to your past experience in fire fighting and evacuation and we will appreciate if you can elaborate in details:

5. What are the main causes of fires that you have observed before? Design failure, human mistakes, lack of maintenance, or others (please specify)?

6. How knowledgeable and cooperative are the people inside a building during evacuation process?

Thank you for your precious time and we highly appreciate all your service to the community! Merci!

Questionnaire pour les pompiers du service d'incendie industriel (En Français)

Nous nous intéressons au niveau de formation et aux expériences du service d'incendie. Ce questionnaire restera anonyme et nous apprécions vos réponses!

1. Depuis combien de temps travaillez-vous dans ce site? Depuis combien de temps êtes-vous pompier en général?

2. Si plus de 6 ans: avez-vous remarqué un changement important dans le code de prévention des incendies qu'OCP a connu lorsque l'entreprise a changé de code?

3. À quelle fréquence faites-vous des formations de lutte contre l'incendie? D'où obtenez-vous la formation?

4. Combien d'heures travaillez-vous chaque semaine? Combien de pompiers votre service d'incendie a-t-il en réserve à tout moment donné? Pensez-vous que c'est suffisant?

Les questions suivantes sont en rapport avec votre expérience passée de lutte contre l'incendie et d'évacuation et nous apprécierons si vous pouvez élaborer en détail:

5. Quelles sont les principales causes d'incendie que vous avez observées auparavant? Défaut de conception, erreurs humaines, manque de maintenance ou autres (veuillez préciser)?

6. Dans quelle mesure les personnes à l'intérieur d'un bâtiment sont-elles bien informées et coopératives pendant le processus d'évacuation?

Merci pour votre temps précieux et nous apprécions hautement tous vos services à la communauté! Merci!

Appendix J: Interview Questions for Airport Fire Department Chief Mr. Fannan

General
What types of fire safety systems do you have in each area of the airport?

How long does it take for your firemen to reach a fire in the airport terminal? Tarmac?

How many firemen are standby at the station at any given time?

How many fire chiefs do you have in the department at any given time?

On average, how often do you deploy your firemen every month?

When was the last fire in the airport? What was the scale of that fire?

Training
What is the average number of years that your firemen has been in service?

Do your firemen have to be in service for several years before coming to your department?

How often do your firemen undergo fire safety training? Where did they get your training from?

Are the airport workers trained to use extinguishers or direct an evacuation in case of a fire?

Connection with city
Does the airport have its own water reservoir or is the sprinkler and hydrant system connected to the Casablanca water supply? What is the capacity of the reservoir?

Have you ever asked the local fire departments for assistance in putting out a fire?

(En française)
Quels types de systèmes de sécurité incendie sont installés dans chaque zone de l'aéroport?

Combien de temps prend-il pour que vos pompiers répondent à un feu dans le terminal de l'aéroport? Piste d'Atterrissage?

Combien de pompiers sont en attente à la station à tout moment donné?

Combien de chefs de pompiers avez-vous dans le département à tout moment donné?

En moyenne, à quelle fréquence déployez-vous vos pompiers par mois?

Quand a eu lieu le dernier incendie dans l'aéroport? Quelle était l'ampleur de cet incendie?

Quel est le nombre moyen d'années de service de vos pompiers?

Vos pompiers doivent-ils être en service pendant plusieurs années avant de venir dans votre département?

À quelle fréquence vos pompiers suivent-ils des formations en sécurité incendie? Où ont-ils eu ces formations?

Les travailleurs de l'aéroport sont-ils formés pour utiliser des extincteurs ou pour diriger une évacuation en cas d'incendie?

L'aéroport dispose-t-il de son propre réservoir d'eau ou le système de gicleurs et de bornes d'incendie est-il connecté à l'approvisionnement en eau de Casablanca? Quelle est la capacité du réservoir?

Avez-vous déjà demandé de l'aide à la protection civile pour éteindre un incendie?

Merci pour votre temps précieux et nous apprécious hautement tous vos services à la communauté! Merci!

Appendix K: Interview Questions for Professor Notarianni

We are working toward promoting and teaching fire safety in Morocco amongst Moroccan citizens.

Here are our objectives:

- Map out fire safety systems present across Morocco
- Document social dimensions on fire safety awareness
- Compare best practices using comparative models

General

1. You have been working in the fire protection field for a number of years, what made you go into the field of fire protection engineering?
2. How do you picture fire protection engineering as an integral part of society?
3. What is your experience in the industry, domestically and internationally?
4. What are the greatest differences you see in fire protection, while working/traveling to other fast-developing countries like Morocco?

Residential

1. From your experience, what are leading causes for urban residential fire accidents in the United States? What is the current situation on response time?
2. We are seeing many fire incidents caused by gas canisters in Moroccan local news, what are the regulation on its usage?
3. What would you suggest for the lower class residents of Morocco? What materials should they use to prevent fires? What's the safest way to cook food/heat homes?
4. In the case that a fire accident does occur in a High Density Urban residential area, what device in your experience is the most cost-effective in protecting lives and property before the firefighters get onsite?
5. There are a lot of old buildings in Morocco that are not kept up to date in terms of safety (fire exits, smoke detectors, fire extinguishers, etc.)
    a. What do we do in the US to keep old houses and buildings to-date in terms of fire codes and general fire safety?
    b. How often are US buildings checked and updated in terms of fire safety?
    c. If there are not enough exits for the building and an emergency exit is not feasible on the side of the building, are collapsible fire ladders sufficient/effective?

Commercial

1. What is the most common hardware store in other countries? Do you believe that accessibility to hardware stores that sell fire protective systems and applications is a part of the problem?

2. Similar question as the High Density area, what device or practice would you suggest as the most cost-effective way to protect lives and property before the firefighters get onsite?
3. Based on projects that you have worked on before, what are some possible resistance and their causes while we work on this project?

Thank you so much for allowing us to interview you. We really appreciate your time and your valuable information. We will keep you updated on the progress of our project.

Appendix L: United States Volunteer Firefighter Interview Questions (Student-Age Volunteer Firefighters)

Date: February 20, 2018

We are a team of three WPI students investigating in fire safety applications in Morocco. During our investigation process, we came across the idea of suggesting the implementation of a volunteer firefighter program in Morocco, and we would like to learn more about how this system operates in the United States and its benefit to the community.

Interviewee name:
Location of fire department:

1. How long have you been a volunteer firefighter? What motivates you to join the volunteer fire department?
2. Besides being a volunteer firefighter, do you have another occupation or are you pursuing education?
3. How many hours do you work every week? How often do you get dispatched to an emergency?
4. Do you feel that as a volunteer firefighter your skill set is sufficient for real life scenarios?
5. Did you have to go through a mentorship program in order to work as a volunteer?
    a. If yes, how long was the program?
    b. What trainings were you expected to complete?
    c. Were you allowed to use all fire fighting equipment in case of a fire?
6. Do you have any intention of becoming a full-time paid firefighter in the future?
7. Would you ever consider studying fire protection engineering or services outside of your required trainings for being a firefighter?
8. Is volunteer firefighting sometimes used as a training/mentorship for full time firefighting?
9. What is the most fulfilling part of your job as a volunteer firefighter?

Thank you for your time and we appreciate your service to the community!

Appendix M: United States Volunteer Firefighter Interview Questions (General Volunteer Firefighters)

Date: February 20, 2018

We are a team of three WPI students investigating in fire safety applications in Morocco. During our investigation process, we came across the idea of suggesting the implementation of a volunteer firefighter program in Morocco, and we would like to learn more about how this system operates in the United States and its benefit to the community.

Interviewee name:
Location of fire department:

1. How long have you been a volunteer firefighter? What motivates you to join the volunteer fire department?
2. Besides being a volunteer firefighter, do you have another occupation or are you pursuing education?
3. How many hours do you work every week? How often do you get dispatched to an emergency?
4. Did you have to go through a mentorship program in order to work as a volunteer?
    a. If yes, how long was the program?
    b. What trainings were you expected to complete?
    c. Were you allowed to use all fire fighting equipment in case of a fire?
5. Is volunteer firefighting sometimes used as a training/mentorship for full time firefighting?
6. What is the structure of your fire department (all volunteer or some volunteer)?
7. What is the most fulfilling part of your job as a volunteer firefighter?

Thank you for your time and we appreciate your service to the community!

Appendix N: Interview Transcript from Mondi Group Interview

During this interview, our team followed along the interview questions we prepared (in Appendix C). We spoke with Hicham Jalal directly in English. The content below is the transcript. Italicized parts are responses from Mr. Jalal.

Let's begin with our first question, to the best of your knowledge, what fire safety system are you using at your factory plants. How many of them are required by Moroccan Fire code?

I am not the expert of the Morocco fire code, but I have worked with FirePRO and other consultants when we are upgrading system. Moroccan fire code is similar to the French one, but in that way, you have to have obligation to have a network of extinguishing system, we have mobile extinguishing over the plant. You should also have a network of water, hose system.

Are sprinklers required?

Not the sprinklers, it is not required by Morocco law, In our case, the fire brigade is almost half an hour away from here, and I think we have capacity of almost two hours of water.

For example, the fire sprinkler is not mandatory by the law, to my knowledge, it's not mandatory. We also got visits from governing body, they never say it is mandatory. You need also to have detection system, in all public areas. We have also equipped the site with PI, hydrants. This depends on where you are located. We don't have all the facility of an industry area, so we need to build it ourselves. We have our own water reservoir, normally we should be connected to the public water network, but there is no public network.

Are any of these systems required by the insurance companies for Mondi Group?

Yes, The insurance, I mean, Mondi group as a company, a controlling body called global risk [department which] oversees the operation of all Mondi sites. Mondi follows high standard of protection. We are as a target, to first to comply with local regulations. If there is possibility to go further, we do it. For example, this is not insurance, this is advisory of consultants. They are doing regular visits to our plans. Making an audit of what we have plants, making recommendations. And this is also having an impact on our insurance premium fees.

So outside the requirement of the insurance company and Morocco Fire code, what fire safety systems do you have as additional precautions to protect your employees' safety as well as your plant?

For the time being, if I look what we have as fire protection, we have smoke detectors. Smoke detection in productions, offices. We have the hoses, also the hydrants, they are not required. It depends on where we are located. If you don't have the hydrants, you won't be insured. We also have fire extinguishers, which are also required by insurance company. This is what we have right now.

But if you look, what we have as additional precaution is also organization. This organization [rule] is that we have a plant where, you cannot smoke in the plant, this is minimizing the risk level. If you have equipment that is regularly checked, we are making the requirement as the additional precautions as we are taking, we collect surveys. The plant is

running 24 hours, 7 days a week, meaning there is always people watching the safety. The safety watch can react very quickly. When we are not in production, we require our company to do regular checks on the installations to see they are okay.

What fire safety trainings are employees expected to complete?

So we have firefighting trainings on how to use firefighting equipment, like the fire extinguishers and hose reel, on a yearly basis. We also have the first rescue team, and the second rescue team.

Are you expected to provide trainings to all employees, or only certain ones?

It is open to all employees. The usage of hoses and fire extinguishers, and we try to accommodate all the employees. For example, the first rescue team, you cannot have everyone on this team. The 1 and 2 rescue team requires a little more specific skills. Also the distribution of the people you select for rescue team, so they are not concentrated all in one shift, so you need to have 24 hours coverage. The best thing is to have everybody trained. But this would take too much time, several years. Being on the rescue team for a few years, I would step back and have someone else get trained. In that way, after sometime, we will have everybody trained.

How often are employees expected to retake trainings?

I need to confirm this. I believe we are doing this every year.

Is it only FirePRO who conducts the inspection at your site?

No, We have a checklists, it depends on how critical of the equipment. We conduct weekly check, or monthly check on the equipment. We are, of course, having contract with FirePRO for the installation.

Is there a governmental organizations that will come to your factory to check?

They should come but unfortunately over the last year, they have never come.]

In 2017?

No

Have they been here the year before, 2016?

No

Just curious, when was the last time they came and check?

To be honest, I don't remember. Unfortunately there is a gap in this field. If I look to our installation, and look to what they have outside, there is a gap, positive gap for us.

How often do you conduct fire drills or emergency evacuation?

Once per year.

Do all fire incidents need to be reported?

Absolutely.

To whom, which organization will be informed.

Here, thanks to god, have never any major accidents. We follow Mondi guidelines to report. We have a classification, fire accidents are quite important especially we are working with paper, and we are taking it very seriously. Last year, there were two incidents, and they were reported, and we are following the action plans after the incidents.

To Mondi headquarter?

Yes. But we have not experienced serious incident with injuries to authorities, [in which case] local government [will get informed by us].

Does your facility have evacuation plan?

Yes, we have an emergency meeting point. But also the evacuation plan displayed in three interest points in the factory.

That covers our questions, do you have anything to share with us about safety training in general?

We have difficulty here in Morocco, competent of knowledge. Not only sell the product, that's what everybody can do. It provides training and full control of the equipment. It is like going to a car dealer, you asked them what engine does the car have, and he said he did not know. I am not saying not to buy the car, but at least he was not the one that install it. In fire protection, if you have a company that does not have control or good knowledge of the equipment they install, then it does not comply 100%. This can not be seen until someday a major incidents happened and it would be too late. We need efforts from the Moroccan companies. I think the quality of the training improves over the last few years. Companies like FirePRO are among the good companies that we are working with. We see goods done, but there is also things to improve also. We have projects, like sprinklers, we are blocked since a couple of months, let's put it that way, because our project was ready. One group needs triple capacity of water, we are trying to find a way on how to do it. We have a good tool box of fire protection equipment. For us, we hope we never use the equipment. We train on how to use that, with the hope of never using them.

Is there anything on FirePRO that you think can improve?

I think maybe on the training of his [FirePRO's] people. We could see the level of expertise of his people is not the same, at least not in a narrow band. We refer to Yakine, We have an incident in the IT room. We lost a lot of material data, and money. Up till this point, we still don't know what happened. Hopefully there is an automatic extinguishing system. It is important for us to know what happened there. I understand that he depends highly on the suppliers, but it would be nice to know the root cause.

What to say more, on the people. It's the awareness of the people, I mean, you can have the best installation. Maybe one day, one guy is breaking the rules and everything can go very quickly. In the chemical storage room, it is state-of-art storage for chemical product, where we have automatic extinguishing system, smoke and heat detection.

We would like to thank you for letting us visit your industrial plant. We appreciate all your answers and we would give the best recommendations to FirePRO.

Appendix O: Survey Data from Morocco Mall Visit

Survey	Date	Occasion	Mall Frequency	Length of stay	Distance from emergency exit	Is the mall overcrowded at times?	How long to exit	Sense of safety
1	17-Jan	Pleasure	Occasional	More than 2 hours	10 m	Yes	5 min	Yes
2	17-Jan	Pleasure	Occasional	More than 2 hours	10 m	Yes	8 min	No
3	17-Jan	Eat	Occasional	More than 2 hours	10 m	No	3 min	No
4	17-Jan	Eat	Occasional	More than 2 hours	10 m	No	5 min	No
5	17-Jan	Shopping and eat	Monthly	More than 2 hours	10 m	Yes	15 min	No
6	17-Jan	Shopping	Monthly	More than 2 hours	Don't know	Yes	No idea	Yes
7	17-Jan	Shopping	Weekly	More than 2 hours	Don't know	Yes	No idea	Yes
8	17-Jan	Shopping	Monthly	More than 2 hours	Don't know	Yes	10 min	Yes
9	17-Jan	Shopping	Weekly	More than 2 hours	Don't know	Yes	1 min	Yes
10	17-Jan	Shopping	Occasional	More than 2 hours	Don't know	Yes	10 min	Yes
11	17-Jan	Shopping	Occasional	More than 2 hours	Don't know	Yes	10 min	Yes
12	18-Jan	Shopping	Monthly	More than 2 hours	50 m	Yes	5 min	Yes
13	18-Jan	Pleasure	Occasional	More than 2 hours	Don't know	Yes	10 min	No
14	18-Jan	Pleasure and shopping	Occasional	More than 2 hours	Don't know	Yes	15 min	Yes
15	18-Jan	Shopping	Monthly or occasionally	1 - 2 hours	20 m	Yes	10 - 20 min	No

16	18-Jan	Pleasure	First time	1 - 2 hours	Don't know	No	5 min	Don't know
17	18-Jan	Pleasure and shopping	Monthly	More than 2 hours	Don't know	Yes	30 min	Don't know
18	18-Jan	Shopping	Don't know	More than 2 hours	Don't know	Yes	30 - 40 min	No
19	18-Jan	Pleasure	Occasional	More than 2 hours	20 m	Yes	3 min	Yes
20	18-Jan	Shopping	Monthly	More than 2 hours	50 m	Yes	5 min	Yes

Appendix P: Survey Data from Mondi Group Visit

Part 1

Survey Number	Surveyer	Potential bias	Fire safety training	Fire drills	Fire drill frequency	Portable fire ext. training	Fire incident experience
1	None	None	Yes	Yes	Twice a year	Yes	Yes
2	None	Yes	Yes	Yes	Once a year	Yes	Yes, 2 months ago
3	None	Yes	Yes	Yes	Once a year	Yes	Yes, 2 months ago
4	M	None	Yes	Yes	Once a year	Yes	Yes
5	K	None	Yes	Yes	N/A	Yes	No
6	M	None	Yes	Yes	Twice a year	Yes	No
7	K	None	Yes	Yes	Twice a year	Yes	No
8	M	None	Yes	Yes	Monthly	No	No
9	K	None	Yes	Yes	Once a year	Yes	No
10	M	None	Yes	Yes	Three times a year	Yes	No
11	M	None	Yes	Never	N/A	No	No
12	K	None	No	Never	N/A	No	No
13	K	None	No	Never	N/A	No	No
14	M	None	Yes	Yes	Twice a year	No	No
15	K	Yes	Yes	Yes	Once a year	Yes	No

16	M	None	Yes	Yes	Twice a year	Yes	No
17	K	Yes	Yes	Yes	Four times a year	Yes	Yes
18	M	None	Yes	Yes	Once a year	Yes	Yes
19	K	Yes	Yes	No	No	Yes	No
20	M	None	Yes	Yes	Once a year	Yes	Yes

Part 2

Survey	Protocol	Fire safety up to date	Capacity	Rooms too crowded	Fire safety systems
1	Evacuation and intervention	Yes	Don't know	No	Automatic suppression, automatic detection, hose stream, hydrant
2	In another zone	Yes	Don't know	No	Fire extinguishers, hose stream, fire alarm
3	In another zone	Yes	Don't know	No	Fire extinguishers, hose stream, fire alarm
4	Evacuation	Yes	Don't know	No	Fire extinguishers, hose stream, ____
5	No answer	Yes	Don't know	No	Fire extinguishers
6	No answer	Yes	30		No answer
7	No answer	Yes	Don't know	No	No answer
8	No answer	Yes	Lack of people	No	Fire extinguishers, hose stream, sandbox
9	No answer	Yes	Don't know	No	Sprinkler
10	No answer	Yes	Don't know	No	Fire extinguishers hose stream
11	No answer	Yes	Don't know	No	Fire extinguishers, hose stream

12	No answer	Yes	Don't know	No	No answer
13	No answer	Yes	Don't know		No answer
14	No answer	Yes	Don't know	No	Fire extinguishers, hose stream
15	No answer	Yes	Don't know	No	Detection, automatic suppression, hose stream, hydrant, fire extinguishers
16	No answer	Yes	Don't know	No	Hose stream, fire extinguishers, automatic detectors
17	I used a fire extinguisher	Yes	Don't know	No	Detection system, automatic suppression
18	Evacuation and extinguisher use	Yes	Don't know	No	Fire extinguishers, hose stream, fire hydrant
19	No answer	Yes	Don't know	No	Add more fire extinguishers
20	general evacuation protocol	Yes	Don't know	No	Smoke detector, fire extinguishers, automatic suppression, fire hose, fire hydrant

Appendix Q: Interview Notes from OCP Fire Department Interview

Note that we used the questions lists from Appendix H. However, the interviewee Fire Chief did not speak English, so FirePRO engineer Mouad asked the questions in French and recorded the notes in English and French in parenthesis.

What types of fire safety systems do you have in each area of the site?

Hydrants (PI), Hose reel (RIA), foam extinguisher, sprinkler, deluge system, fire detection system (sdi), fire suppression system (seag).

Categorized into 2 parts. Fixed fire protection equipment (fixe) and portable fire protection equipment (mobile).

What is the maximum amount of time it takes to reach a fire on-site?

5-10 minutes within OCP site.

How many firemen do you have in total? Do you think this is a reasonable number of responders?

140-160 firemen in total,Yes

Where does funding for the fire department within OCP come from?

The funding comes solely from OCP.

How many firemen are standby at the station at any given time?

24 firemen are standby at the station, with everyone else on call at all time.

How many fire chiefs do you have in the department at any given time?

One fire chief will always be at the station during the day shift. For the night shift, they will not be at the station, but station can call in the chief at anytime.

On average, how often do you deploy your firemen per month?

4 times on average within OCP site.

When was the last fire in the facility? What was the scale of that fire?

The last fire happened this morning. It was a small fire at the sulfur site.

Training

How often do you recruit firefighters? What are the prerequisites?

This is the question more for the human resources staff at OCP.

How often do your firemen undergo fire safety training? Where did they get your training from?

There is a training session every month. Notional Prevention and Protection Center provides the training (CNPP).

Connection with city

Does the facility have its own water reservoir or is the sprinkler and hydrant system connected to the city water supply?

Yes, the facility has its own reservoir for both industrial production and firefighting purpose. A set amount of water is always on reserve in case of fire.

There is also the ocean, fire department can pump water from the ocean if it has to.

Have you ever asked the local fire departments for assistance in putting out a fire?

OCP fire department helped other communities once a month.

What are your opinions on the change of code from French code to NFPA code?

Insurance company, FM Global, asked them to change the code.

Can you give us one example of practice that is different in two codes?

RIA, the French code requires it hose reel to be rolled regularly, it is easy to roll and unroll. The NFPA requires it to roll back and forth in a snake shape, which is not so convenient for the firefighters to unroll.

The change happens too quick. We cannot change the code without changing the equipment. We just bought some equipment in NF standard, and we cannot use them because of the insurance. We should expect a long time for the complete change.

How long do you think the full transition can happen?

Very long time, it depends on the insurance company. If the insurance company switch the code again, another change will occur.

In this moment, we have this material in NF, it is in good shape, I don't need a second set. It is a waste of money, you understand? To change everything due to insurance is a lot of investment. Insurance should be able to work with different codes.

Appendix R: Survey Data from OCP Industrial Fire Department

Survey Tracking Number	How long have you been working here? (years)	Any major changes in the code	Frequency of fire training	Where do you get the training from	Weekly work hour
3	32	yes	No training except for the one when hiring	N/A	48
4	9	yes	1 year	Consulting Bureau and Protection Civile	44
5	32	yes	1 year	N/A	40
6	12	yes	3 years	Protection Civile	48
7	30	yes	NA	Protection Civile	44
8	19	yes	NA	Autonomous training,	42

Survey Tracking Number	Firemen standby at anytime	Sufficient ?	Main cause of Fire	Knowledgeable & cooperative
3	100	Yes	Friction, warming up, (for sulfur), Human factor,	Preventative Measures
4	100	No	Design failure, Human factors, Lack of Maintenance	Very good and coorperative
5	N/A	N/A	Lack of Maintenance	N/A
6	120	NA	Friction (for sulfur)	Direct Communication with the responsible person of the property
7	110	Yes	Friction (for sulfur)	N/A
8	127	Yes	Lack of Maintenance	very cooperative, people know where to go and what to do within their work area

Appendix S: Notes from Interview with Professor Notarianni

I. **What made you go into the field of fire protection engineering?**
   A. Went into fire protection engineering after high school. Didn't know what to major in. Was told to be a chemical engineering, went to wpi. Did not want to work in oil refinery, or anything like that. Requirement: take class outside of chemical engineering. Took fire chemistry. Exciting and easy. Loved the class, stayed for masters.
   B. Idea of using science and engineering for safety. More fun than a paper mill.

II. **What is your experience in the industry or in research (domestic and international)?**
   A. First job in insurance engineer. Look at plants and document issues. Go to different US businesses, very interesting. Good because wanted to work in research. Go into lab and compare fire detectors. Small scale project research. Would help with sales or development. Went to NIST—questions are big societal-wise
      1. Hospital rooms – do they need fire alarms?
      2. NASA – fire protection for tall buildings
         a) 3D model where load shuttle payload
      3. NAFAC, NAFC
         a) What do we do about wildfires? Etc.
      4. EPA, marine biologists
         a) Tested temps under water to see effect on fish, burning oil spills—is it effective?
      5. Oil wells set on fire (gulf war)
         a) Set aflame oil wells in ground. 500ft flames, didn't know how to extinguish. Used TNT to rob well of oxygen?
      6. Global warming—winds switching direction
         a) Fires moving quicker
         b) Engineers designing more heat shields

III. **Greatest difficulties in fire protection in developing countries?**
   A. Been overseas quite a bit
   B. US is ahead in fire codes. Other countries take NFPA101. US learning from Japan and Australia-performance based code
   C. India and Dubai to give talks
   D. What are the greatest differences in fire protection?
      1. Differences: 80% of fire deaths happen residentially, go to a lot of places in Europe that have more passive fire protection (closed space rooms)
         a) Sprinkler is active, heat-resistant walls are more passive
      2. Fire death rates – deaths per 1000 through an organization

E. Social
    1. Building construction differences
    2. Differences in fighting fires
        a) Other countries do more exterior fire fighting
    3. Fire codes and how they're developed
        a) England – a fire code, written by scientists for the gov, applies across whole country
        b) US – writes suggested codes, some states adopt and others don't or rewrite or consider parts but not whole
        c) RI fire code, retroactive – ever since fire in 2004. NFPA101 requires sprinkler system, etc. Would have been different in MA
        d) Written by scientists, manufacturers, building people (US code)

IV. Old buildings in Morocco

A. What is the best way to keep the old buildings up to date?
    1. Can't answer if you don't see bigger picture
    2. Install sprinkler system – usually best solution
        a) Expensive for old buildings because requires breaking down walls. Can put in side-wall sprinklers sometimes
    3. 5 stages
        a) Prevention – no smoking, no flammable materials
        b) Detect or suppress fire
        c) Fire department
            (1) Can shorten response
        d) Practice egress
        e) Action: ask for 5 stages of fire prevention from Prof. Notarianni

V. Majority of Moroccan homes are heated using gas canisters

A. (No gas grid)

B. Is there a safer way to heat a home using a gas canister?
    1. NFPA – call for statistics, what exists?
    2. Lots of data for the US!

C. Find past IQP's, which previous groups have been to morocco for fire-related iqps

D. America Burning – study about fpe. Spent a lot of money on fpe, but had one of the worst death rates

VI. Is your research for firefighters or residents?

A. Firefighters mostly, go into buildings

B. More stuff in rooms, fuel that burns faster/is more toxic, open concept rooms
    1. Firehose has not changed in 50 or so years, are failing
    2. US needed to improve fires, Notarianni currently working on improving fire hoses
    3. "Flashover"

a) Minute before, don't know it's going to happen
b) Develop a meter to give warning for this

VII. Address different terrains and different socioeconomic classes. What is most cost-effective technology for fire safety in Morocco?

A. Fire prevention and education
    1. Nearing Christmas, fires happen more often
    2. Electrical, tree, parties
B. Having a fire extinguisher
C. Fire extinguisher training units
    1. Teaches how to use fire extinguisher
D. BE MORE AWARE OF FIRE SAFETY – "education goes a long way"
    1. "Education and prevention are your first thing. All fires start small. Having a fire extinguisher in your kitchen is important."
    2. ***Education! Prevention, detection (smoke detectors. Decreased fire deaths in US)
        a) Make it cheaper, take up less space
        b) Mandated that it's in every home. Very cheap.
    3. US has funded smoke detector programs. Distribute and install fire detectors. Talk about fire prevention
E. "Try to prevent first. Combination of not teaching. Try to detect fires when they're small."
    1. What are the smoke detector laws in Morocco? Are very cheap. Should mandate smoke detectors.

Appendix T: Interview Answers from American Student-Age Volunteer Firefighter

We are a team of three WPI students investigating in fire safety applications in Morocco. During our investigation process, we came across the idea of suggesting the implementation of a volunteer firefighter program in Morocco, and we would like to learn more about how this system operates in the United States and its benefit to the community.

1. How long have you been a volunteer firefighter? What motivates you to join the volunteer fire department?

I started volunteering in some capacity at the fire department when I was 16, and I am 23 now, so 7 years now. I participated in a volunteer fire department consistently in college. I wanted to give back to the community. I never was in the military, and the Fire Department was something I could do with skills I already had and gave back to the community.

2. Besides being a volunteer firefighter, do you have another occupation or are you pursuing education?

I work full time on a private transport ambulance 4 day a week for 44 hours or full-time employment. I am odd because I got my liberal arts degree prior to joining the fire department. Some don't have degrees and others continue to pursue a degree.

3. How many hours do you work every week? How often do you get dispatched to an emergency?

I am guaranteed a minimum of 20 hours a week, not including call backs, responses and special events. I usually work anywhere from 12 to 48 hours in a week, with 60 to 80 hour per paycheck on a bimonthly paycheck. Depends on the definition of 'emergency'. My training allows me to respond to things people would consider emergency. However, I would say, non- serious medical, is 80%, Serious Medical 10%, Structure Fires 5% and Other Fire Related calls 5%. We can go a full 24 hour shift with not one call, or have six calls in a nine hour period.

4. Do you feel that as a volunteer firefighter your skill set is sufficient for real life scenarios?

Again, what is a 'real life' scenario? Do I feel that the skills I learned in the volunteer department help me in my job? Yes, without a doubt. Do I feel that the skills I learned help me out in the real world? Without a question.

5. Did you have to go through a mentorship program in order to work as a volunteer?

States have minimum acceptable training lengths to be certified as a Volunteer. Massachusetts is requires 120 hours minimum of certification. I also did an in house mentorship program prior to joining the fire department.

    a. If yes, how long was the program?

Massachusetts required 120 hours minimum, spread over 6 months on nights and weekends.

    b. What trainings were you expected to complete?

Every firefighter needs to be proficient in the NFPA FF I/II standards. These include SCBA and PPE familiarization, compliance, and proficiency, knowledge of hose streams, fire behavior, HAZMAT Awareness, Ladder, Hose and Tool Proficiency, as well as pumps and hydraulics, water supplies and systems and to a lesser degree, Engine Operations.

c. Were you allowed to use all firefighting equipment in case of a fire?

On the in house training, I was only allowed to use the air cascade system to fill air bottles as well as accountability tags. This was when I was 16 and in the in house training system. On the volunteer department in college I was not able to drive the engine, but I was able to drive other vehicles and was expected to know and use everything on the engine. I was limited in vehicle ladder usage at that job. My current job I am allowed to train on the department apparatus and have to be in- house certified to use the engines.

6. Do you have any intention of becoming a full-time paid firefighter in the future?

I would love to. Due to the nature of my work and the state of Massachusetts, I am currently classified as "permanent part time" being paid for my duties. But the goal of being a full time paid firefighter on a professional department is a major goal.

7. Would you ever consider studying fire protection engineering or services outside of your required trainings for being a firefighter?

Absolutely. If I stop learning, it's time to retire.

8. Is volunteer firefighting sometimes used as a training/mentorship for full time firefighting?

Absolutely. We are lucky to have a department where we have full and part time department members. Several departments have part time training designed to train people 'in-house' to become full time firefighters.

9. What is the most fulfilling part of your job as a volunteer firefighter?

Every day is never the same. It's never like a desk job. I'm most happy having a tangible effect on people- I respond and can change something for the better. I can see a deliberate effect on them from simple (to me) things that I can do.

Thank you for your time and we appreciate your service to the community!

Appendix U: Interview Answers from American Volunteer Firefighter

We are a team of three WPI students investigating in fire safety applications in Morocco. During our investigation process, we came across the idea of suggesting the implementation of a volunteer firefighter program in Morocco, and we would like to learn more about how this system operates in the United States and its benefit to the community.

1. How long have you been a volunteer firefighter? What motivates you to join the volunteer fire department?

44 years. I felt obligated and walked in.

2. Besides being a volunteer firefighter, do you have another occupation or are you pursuing education?

Occupation at the fire dept.: Vice President, interior firefighter, licensed truck driver

At the Torrington Company: mechanical engineer specializing in design of needle & roller bearings, and their field applications. Asst. plant superintendent for pressed metal parts research and development laboratory manager on specific troubleshoot and new product assignments related to rolling element bearing design, innovation, testing, manufacture field application.

3. How many hours do you work every week? How often do you get dispatched to an emergency?

Variable but averaging 2 hours per week. This includes all non-emergency duties practices, equipment and facility maintained. Averaging one to three calls per month. Ours was a small rural department and thankfully most of our residential and commercial establishments were well advised on safety and risk mgmt.

4. Did you have to go through a mentorship program in order to work as a volunteer?

Very informal, if you were new in town and able bodied it was an obligation to offer your services. For approx. the last 30 years we have had a membership committee that does seek out new volunteers. It is not as easy at present to get new members. Initially everything was on the job training and skills acquired at (FIRE) practices. About 15 years from joining the fire dept., a formal everything (TRAINING AND CERTIFICATION) course was established within the

county. I completed this course and stayed current on training upgrades including Red Cross, and CPR courses. Yes, I was allowed to use all of the equipment.

5. Is volunteer firefighting sometimes used as a training/mentorship for full time firefighting?

Currently it is very close, and also difficult to become certified as an interior firefighter, the time commitment to training is severe. (Approx. 1.5 years) most of our volunteers have full time private sector jobs.

6. What is the structure of your fire department (all volunteer or some volunteer)?

Yes, although a small monetary commitment from the town is now afforded the volunteers.

7. What is the most fulfilling part of your job as a volunteer firefighter?

As a retired and honorary firefighter knowing that my small contributions to the dept. and community helped each prosper and offer bright prospects for solid continuance.

Thank you for your time and we appreciate your service to the community!

Appendix V: Original Checklist Data from Morocco Mall

Table of data for calculating R_b in Morocco Mall				
Symbol	Factor	Parking Garage	Ground Floor	Dining Area
Q_m	Mobile fire load factor	1.6	1.1	1.4
μ	Flammability factor of the mobile fire load	2.175	1.75	1.5
Q_i	Immobile fire load factor	0	0	0
F	Fire source factor	1.471	1.458	1.310
S	Building area factor	2.7	2.7	1.8
C	Confinement factor	1.416	1.416	1.416
W	Building fireproof rating factor	1.8	1.8	1.8
R_i	Factor on reduction of fire spreading	1.8	1	1.3
L_0	Factor on firefighting capability of the fire department	2.494	2.494	2.494
L_i	Building firefighting capability factor	2.571	2.496	2.571
R_b	**Risk rating on building structure**	**1.192**	**1.195**	**0.591**

Table of data for calculating R_p in Morocco Mall				
R_p	Factor	Parking	Ground Floor	Dining Area
T	Smoke toxicity factor	1.75	1.35	1.5
f	User characteristic factor	1.5	1.5	1.5
K	Automatic fire alarm factor	1.374	1.374	1.374
E	Evacuation capability factor	1.447	1.547	1.327
H	Ventilation and smoke extraction factor	1.365	1.365	1.365
R_p	**Risk rating on lives and property in the building**	**0.968**	**0.698**	**0.905**

Appendix W: Original Checklist Data from Mondi Group

Table of data for calculating R_b in Mondi Group						
Symbol	Factor	Chemical Storage Room	Production Area	Office Area	Outdoor Storage	Indoor Storage
Q_m	Mobile fire load factor	1.6	1.6	1	4	2.8
μ	Flammability factor of the mobile fire load	2.5	1	1.733	1	1.5
Q_i	Immobile fire load factor	0	0.1	0	0	0
F	Fire source factor	1	1.064	1.000	1.470	1.049
S	Building area factor	1	1	1	1	1
C	Confinement factor	1	1.5	1	1	1
W	Building fireproof rating factor	2	1.5	1.9	1.5	1.9
R_i	Factor on reduction of fire spreading	2	1.6	1.8	1.3	1.15
L_0	Factor on firefighting capability of the fire department	2.78	2.78	2.78	2.78	2.78
L_i	Building firefighting capability factor	2.612	1.227	2.16	1.302	1.87
R_b	**Risk rating on building structure**	**0.185**	**0.282**	**0.103**	**0.739**	**0.434**

Table of data for calculating R_p in Mondi Group						
Symbol	Factor	Chemical Storage Room	Production Area	Office Area	Outdoor Storage	Indoor Storage
T	Smoke toxicity factor	1.25	1.2	1.4	1.35	1.2
f	User characteristic factor	1.8	1.8	1.8	1.8	1.8
K	Automatic fire alarm factor	1.574	1	1.7	1	1.5
E	Evacuation capability factor	1.623	1.562	1.667	1.7	1.658
H	Ventilation and smoke extraction factor	1.668	1.7	1	1.7	1.7
R_p	**Risk rating on lives and property in the building**	**0.528**	**0.813**	**0.889**	**0.841**	**0.511**

Appendix X: Checklist No. 1 on R_b

English version (translation by team member David):

$$R_b = \frac{(Q_m \cdot \mu + Q_i)F \cdot S \cdot C}{W \cdot R_i \ (L_0 + L_i)} \quad (1)$$

$Q_m -$ Mobile fire load factor

Mobile fire load (kg/m^2)	Q_m
0-15	1.0
16-30	1.2
31-60	1.4
61-120	1.6
121-240	2.0
241-480	2.4
481-960	2.8
961-1920	3.4
1921-2340	3.9
>2340	4.0

$\mu -$ Flammability factor of the mobile fire load

Major flammable material type	μ
Wood furniture, flooring, etc.	1.0
Fiber panel, polyester mattress	1.2
Cotton, linen, rubber, polyethylene	1.5
Polystyrene, floor wax, curtain, sofa, butanol, diesel	2.0
Gasoline, alkyl, varnish, pure ethanol, alkali metal	3.0

$Q_i -$ Immobile fire load factor

Scenario	Support material	Ceiling material	Wall material	Q_i
1	Concrete, bricks, steel	Concrete, steel	Concrete, bricks, steel	0
2	Steel	Wood	Concrete, steel	0.2
3	Wood, steel	Wood	Concrete, bricks	0.4
4	Wood	Wood	Wood, tiles, sheet metals	0.6

$F -$ Fire source factor (Numbers in the parenthesis indicate weightings)

I	II	III	Scoring standards			
			1.0	1.5	2.5	3.0
Human fire source (0.333)	People smoking (0.429)		Very rarely	Not often	Normal	More than usual
	Prohibited behavior related to fire (0.571)		Very rarely	Not often	Normal	Often
Electrical fire source (0.333)	Electric Wirings (0.411)	Maintenance Schedule (0.759)	Very often	On schedule	Normal	Rarely
		Installation condition (0.241)	Very good	Good	Normal	Messy
	Lighting Equipment (0.263)	Equipment up to standard (0.133)	All up to standard	Most up to standard	Some up to standard	Not up to standard

		Heat dissipation condition (0.256)	Very good	Relatively good	Normal	Bad
		Flammable materials in proximity (0.369)	None	Few	Normal	A lot
		Spotlight continuous usage time (0.242)	<6h	7-8h	9-10h	>10h
	Electric Appliances (0.216)	Equipment up to standard (0.128)	All up to standard	Most up to standard	Some up to standard	Not up to standard
		Heat dissipation condition (0.288)	Very good	Relatively good	Normal	Bad
		Flammable materials in proximity (0.353)	None	Few	Normal	A lot
		Grounding condition (0.231)	Very good	Relatively good	Normal	Bad
	Power transformation equipment (0.110)	Equipment up to standard (0.360)	All up to standard	Most up to standard	Some up to standard	Not up to standard
		Appearance of electric sparks (0.354)	None	Few	Normal	Often
		Grounding condition (0.286)	All up to standard	Most up to standard	Some up to standard	Not up to standard
Fuel Source (0.333)	Coal	Presence	Describe:			
		Protection of conveyor belt	Very good	Relatively good	Normal	Bad
	Flammable and combustible fuels	Presence	Describe			
		Protection	Very good	Relatively good	Normal	Bad
		Containment	Very good	Relatively good	Normal	Bad

$S-$ Building area factor

Building Area (m^2)	S	Building Area (m^2)	S	Building Area (m^2)	S	Building Area (m^2)	S
5000-8000	1.0	17001-23000	1.8	38001-47000	2.7	68001-80000	3.6
8001-12000	1.2	23001-30000	2.1	47000-57000	3.0	>80000	4.0
12001-17000	1.5	30001-38000	2.4	57001-68000	3.3		

$C-$ Confinement factor (Numbers in the parenthesis indicate weightings)

Items	1.0	1.5	2.5	3.0

Design of ventilation system (0.169)	Reasonable	Relatively reasonable	Partially reasonable	Not reasonable
Usability of ventilation system (0.479)	Complete and usable	Relatively complete and usable	Partially usable	Not usable
Choice of fireproof material (0.352)	Up to standard	Relatively up to standard	Partially up to standard	Not up to standard

$W-$ Building fireproof rating factor

Fireproof rating of the building	Level 1	Level 2	Level 3	Level 4
W	2	1.8	1.2	1

Criteria of fireproof rating of the building

Name of the structure		Fireproof rating and their requirement, numbers indicate time it takes for material failure, in hours.			
		1	2	3	4
Walls	Firewall	Non-flammable, 3.00	Non-flammable, 3.00	Non-flammable, 3.00	Non-flammable, 3.00
	Load-bearing wall	Non-flammable, 3.00	Non-flammable, 2.50	Non-flammable, 2.00	Not-easily-flammable, 0.50
	Non-load-bearing exterior wall	Non-flammable, 1.00	Non-flammable, 1.00	Non-flammable, 0.50	Flammable
	Walls around staircases, elevators	Non-flammable, 2.00	Non-flammable, 2.00	Non-flammable, 1.50	Not-easily-flammable, 0.50
	Walls along escape route	Non-flammable, 1.00	Non-flammable, 1.00	Non-flammable, 0.50	Not-easily-flammable, 0.25
	Room-dividing walls	Non-flammable, 0.75	Non-flammable, 0.50	Not-easily-flammable, 0.50	Not-easily-flammable, 0.25
Columns		Non-flammable, 3.00	Non-flammable, 2.50	Non-flammable, 2.00	Not-easily-flammable, 0.50
Beams of roof		Non-flammable, 2.00	Non-flammable, 1.50	Non-flammable, 1.00	Not-easily-flammable, 0.50
Flooring		Non-flammable, 1.50	Non-flammable, 1.00	Non-flammable, 0.50	Flammable
Roof		Non-flammable, 1.50	Non-flammable, 1.00	Flammable	Flammable
Escape stairs		Non-flammable, 1.50	Non-flammable, 1.00	Non-flammable, 1.00	Flammable
Drop-down ceiling		Non-flammable, 0.25	Not-easily-flammable, 0.25	Not-easily-flammable, 0.15	Flammable

R_i- Factor on reduction of fire spreading

Scenario	R_i
Much flammable goods piled loosely across the room, help spread the fire	1
Moderately flammable goods piled loosely	1.3
25%-50% of the goods not easily flammable, good heat dissipation condition, area smaller than 3000 m^2	1.6
Goods packed in containers, hard to ignite	2.0

$L_0 -$ Factor on firefighting capability of the fire department

$L_i -$ Factor on firefighting equipment in the building (Numbers in the parenthesis indicate weightings)

	Items	3.0	2.5	1.5	1.0
L_0	Fire department equipment (0.276)	Advanced	Relatively advanced	Normal	Not advanced
	Firefighting experience of the fire department (0.176)	Good	Relatively good	Normal	Lack experience
	Fire lane availability (0.144)	Clear	Relatively clear	Partially clear	Blocked
	Outdoor fire hydrant (0.255)	Completely Usable	Relatively usable	Partially usable	Not usable
	Nearest fire station response time (0.151)	0-30min	31-45min	46-55min	>55min
L_i	Fire detection system (0.429)	Completely Usable	Relatively usable	Partially usable	Not usable
	Sprinkler system (0.226)	Completely Usable	Relatively usable	Partially usable	Not usable
	Indoor fire hydrant (0.194)	Completely Usable	Relatively usable	Partially usable	Not usable
	Fire Extinguisher (0.151)	Completely Usable	Relatively usable	Partially usable	Not usable

Original Chinese version:

表 **2**　点火源因子 F

一级指标	二级指标	三级指标	评分标准			
			1.0	1.5	2.5	3.0
人为火源（0.382）	吸烟情况（0.429）		极少	不多	一般	较多
	违章动火情况（0.571）		极少	不常	一般	经常
电气火源（0.618）	电气线路（0.411）	检修情况（0.759）	经常	定期	一般	很少
		敷设情况（0.241）	很好	较好	一般	凌乱外漏
	照明设备（0.263）	产品是否合格（0.133）	合格	大部分合格	小部分合格	全不合格
		散热情况（0.256）	很好	较好	一般	较差
		附近可燃物情况（0.369）	无	较少	一般	较多
		装饰射灯连续使用时间（0.242）	6 h 以下	7～8 h	9～10 h	10 h 以上
	电器设备（0.216）	产品是否合格（0.128）	合格	大部分合格	小部分合格	全不合格
		散热情况（0.288）	很好	较好	一般	较差
		附近可燃物情况（0.353）	无	较少	一般	较多
		接地情况（0.231）	很好	较好	一般	较差
	变配电设备（0.110）	产品是否合格（0.360）	合格	大部分合格	小部分合格	全不合格
		是否有闪烁放电现象（0.354）	无	极少	一般	经常
		接地情况（0.286）	很好	较好	一般	较差

表 **3**　建筑面积因子 S

建筑面积 m^2	S	建筑面积 m^2	S	建筑面积 m^2	S	建筑面积 m^2	S
5 000～8 000	1.0	17 001～23 000	1.8	38 001～47 000	2.7	68 001～80 000	3.6
8 001～12 000	1.2	23 001～30 000	2.1	47 001～57 000	3.0	>80 000	4.0
12 001～17 000	1.5	30 001～38 000	2.4	57 001～68 000	3.3		

表 **4**　密闭性因子 C

目标	一级指标	评分标准			
		1.0	1.5	2.5	3.0
密闭性因子 C	通风系统设计的是否合理（0.169）	合理	较合理	部分合理	全部不合理
	通风系统是否完善可用（0.479）	完善可用	较完善可用	部分完善可用	全部不完善可用
	选择的防火材料是否符合规范（0.352）	符合	较符合	部分符合	完全不符合

表 5　消防队灭火能力因子 L_o 和建筑消防设施设备灭火能力因子 L_i

目标	一级指标	评分标准			
		3.0	2.5	1.5	1.0
消防队灭火能力因子 L_o	消防队装备是否先进（0.274）	先进	较先进	一般	不先进
	消防队实战水平（0.176）	好	较好	一般	不好
	消防车道是否畅通（0.144）	畅通	较畅通	部分畅通	完全不畅通
	室外消火栓是否有效（0.255）	有效	较有效	部分有效	完全无效
	最近消防队到达时间/min（0.151）	0～30	31～45	46～55	>55
建筑消防设施设备灭火能力因子 L_i	火灾探测系统是否有效（0.429）	有效	较有效	部分有效	完全无效
	自动喷淋系统是否有效（0.226）	有效	较有效	部分有效	完全无效
	室内消火栓系统是否有效（0.194）	有效	较有效	部分有效	完全无效
	灭火器是否有效（0.151）	有效	较有效	部分有效	完全无效

表 2　可燃物与易燃性因子的关系

可燃物易燃性因子	可燃物名称	取值
1	实木家具 木质梁柱、天花板、地板等	1
2	纤维板、无棉制品 聚酯床垫等	1.2
3	水平放置的棉、麻、化纤及其纺织品，橡胶、聚乙烯，等	1.5
4	聚苯乙烯、地板腊 窗帘、幕布、沙发 丁醇、柴油等	2.0
5	汽油 烷类 碱金属 纯乙醇 清漆等	3.0

表 4　建筑耐火等级划分

建筑耐火等级	一级耐火建筑	二级耐火建筑	三级耐火建筑	四级耐火建筑
分值	2	1.8	1.2	1

固定火灾负荷因子 Q_i：0

可燃物材料和荷载 1

状况	可燃物量 kg/m^{-2}	支撑材料	天花板材料	墙壁材料	Q_i
1	0～20	混凝土、砖、钢	混凝土、钢	混凝土、砖、钢	0
2	21～45	钢	木材	混凝土、钢	0.2
3	46～70	木材、钢	木材	混凝土、砖	0.4
4	71～100	木材	木材	木材、瓦、铁皮	0.6

火灾减少因子 R_i	1	
考虑火灾危险度下降的因素	3	
等级	主要状态	R_i
1	可燃物多、易着火、堆放松散、面积大，对火灾蔓延有利	1
2	可燃物较多、着火性一般、堆放松散	1.3
3	25%-50%物品难以着火、散热条件好、面积小于 $3000m^2$	1.6
4	货物存放在容器中，包装紧凑、不易着火	2.0

表 5.1.2　不同耐火等级建筑相应构件的燃烧性能和耐火极限（h）

构件名称		耐火等级			
		一级	二级	三级	四级
墙	防火墙	不燃性 3.00	不燃性 3.00	不燃性 3.00	不燃性 3.00
	承重墙	不燃性 3.00	不燃性 2.50	不燃性 2.00	难燃性 0.50
	非承重外墙	不燃性 1.00	不燃性 1.00	不燃性 0.50	可燃性
	楼梯间和前室的墙 电梯井的墙 住宅建筑单元之间的墙和分户墙	不燃性 2.00	不燃性 2.00	不燃性 1.50	难燃性 0.50
	疏散走道两侧的隔墙	不燃性 1.00	不燃性 1.00	不燃性 0.50	难燃性 0.25
	房间隔墙	不燃性 0.75	不燃性 0.50	难燃性 0.50	难燃性 0.25
柱		不燃性 3.00	不燃性 2.50	不燃性 2.00	难燃性 0.50
梁		不燃性 2.00	不燃性 1.50	不燃性 1.00	难燃性 0.50
楼板		不燃性 1.50	不燃性 1.00	不燃性 0.50	可燃性
屋顶承重构件		不燃性 1.50	不燃性 1.00	可燃性 0.50	可燃性
疏散楼梯		不燃性 1.50	不燃性 1.00	不燃性 0.50	可燃性
吊顶（包括吊顶搁栅）		不燃性 0.25	难燃性 0.25	难燃性 0.15	可燃性

注：1　除本规范另有规定外，以木柱承重且墙体采用不燃材料的建筑，其耐火等级应按四级确定。

Appendix Y: Checklist No.2 on R_p

English version (translation by team member David):

$$R_p = \frac{Tf}{KEH} \quad (2)$$

T – Smoke toxicity factor [c]

Flammable materials	Smoke toxicity factor
Ethanol, and natural gas	1
Wood, cotton, paper	1.2
Gasoline, kerosene, diesel, cloths, melamine chipboard	1.5
Polystyrene, polyurethane, PVC, rubber, neoprene	2.0

f – User characteristic factor [c]

Building Types	Office building, station, airport, stadium	Shopping mall, library, theater, museum, restaurant	Apartment, house Industrial setting 1.75	Hotel, bars, clubs	Hospital, kindergarten, and similar
f	1.0	1.5	2.0	2.5	3.0

K – Automatic fire alarm factor [a] (Numbers in the parenthesis indicate weightings)

	1.7	1.5	1.3	1.0
Design of fire detection system (0.333)	Reasonable	Relatively reasonable	Partially reasonable	Not reasonable
Usability of the fire detection system (0.333)	Complete and usable	Relatively complete and usable	Partially usable	Not usable
System Approval or not (0.333)	Yes			No

E – Evacuation capability factor [a] (Numbers in the parenthesis indicate weightings)

Item I	Item II	1.7	1.5	1.3	1.0
Evacuation route (0.381)	Distance to exits (0.052)				
	Clearance of the route (0.336)	Clear	Relatively clear	Partially clear	Blocked
	Design of exits (0.612)	Reasonable	Relatively reasonable	Partially reasonable	Not reasonable
Evacuation equipment (0.619)	Signs to exits (0.203)	Effective	Relatively effective	Partially effective	Ineffective
	Design of the evacuation stairs (0.506)	Reasonable	Relatively reasonable	Partially reasonable	Not reasonable
	Emergency lighting system (0.203)	Complete and usable	Relatively complete and usable	Partially usable	Not usable
	Emergency announcement system (0.098)	Effective	Relatively effective	Partially effective	Ineffective

H – Ventilation and smoke extraction factor [a] (Numbers in the parenthesis indicate weightings)

	1.7	1.5	1.3	1.0
Design of smoke extraction system (0.323)	Reasonable	Relatively reasonable	Partially reasonable	Not reasonable
Functionality of the smoke extraction system (0.677)	Complete and usable	Relatively complete and usable	Partially usable	Not usable

Original Chinese version:

表 8　燃烧物质与烟气因子的关系

烟气因子	燃烧物质	F 取值
1	甲醇/ 乙醇等/ 燃气等	1
2	木材/ 棉花/ 纸张等	1.2
3	汽油/ 煤油/ 柴油/ 三聚氰胺木屑板/ 布料衣物等	1.5
4	聚苯乙烯/ 阻燃聚苯乙烯/ 阻燃聚氨酯/ 钢结构防火涂料/ PVC/ 聚丙烯—066/ 橡胶/ 氯丁橡胶	2.0

表 6　建筑用途与人员特征因子的关系

建筑物用途	建筑物及人员特性	分值
办公楼、车站、码头、机场和学校、体育场馆	建筑内的人员处于清醒状态，熟悉建筑物及报警系统和疏散措施	1
商场、图书馆、影剧院、展览馆、饭店博物馆、休闲中心等	建筑内的人员处于清醒状态，不熟悉建筑物、报警系统和疏散措施	1.5
住宅或公寓	建筑内的人员可能处于睡眠状态，熟悉建筑物、报警系统和疏散通道	2.0
旅馆或歌舞厅迪厅 酒吧	建筑内的人员可能处于睡眠状态，或者由于过量饮酒处于半清醒状态。不熟悉建筑物、报警系统和疏散通道	2.5
医院、疗养院、幼儿园及其他社会公共福利设施	有相当数量的人员需要帮助	3.0

表 6　火灾自动报警系统因子 K

目标	一级指标	评分标准			
		1.7	1.5	1.3	1.0
火灾自动报警系统因子 K	火灾自动报警系统设计是否合理(0.371)	合理	较合理	较不合理	不合理
	火灾自动报警设施完好情况(0.629)	完好	大部分完好	小部分完好	全部不完好

表 7　安全疏散能力因子 E

目标	一级指标	二级指标	评分标准			
			1.7	1.5	1.3	1.0
安全疏散能力因子 E	疏散通道(0.381)	安全疏散距离是否符合规范(0.052)	符合	较符合	不符合	完全不符
		疏散通道是否畅通(0.336)	畅通	较畅通	不畅通	完全不畅通
		安全出口设计是否合理(0.612)	合理	较合理	不合理	完全不合理
	疏散设施(0.619)	安全疏散指示标识有效性(0.203)	有效	较有效	无效	完全无效
		疏散楼梯是否合理(0.506)	合理	较合理	不合理	完全不合理
		应急照明是否完善可用(0.203)	完善可用	较完善可用	部分不完善可用	全部不完善可用
		应急广播系统是否有效(0.098)	有效	较有效	部分无效	全部无效

表 8　防排烟能力因子 H

目标	一级指标	评分标准			
		1.7	1.5	1.3	1.0
防排烟能力因子 H	防排烟系统设计是否合理(0.323)	合理	较合理	部分不合理	完全不合理
	防排烟设施是否好用(0.677)	好用	较好用	部分好用	完全不好用

Appendix Z: Excel Checklist Model Template

The Excel checklist template mentioned in section 4.6 is submitted as a separate file named:
Final Checklist Template for FirePRO.xlsm

Appendix AA: FirePRO Checklist

PROJET : Fire mitigation Analysis in Aviation, Commercial, and Industrial Sectors in Morocco.

CHECKLIST : ACTIVE FIRE PROTECTION

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DATE :

Project/Site name	type	floor	local	AREA	APPLICATIO	Classification of Occupancies and fire	Item	SPECIFICATIONS		MATERIELS		QUANTITY	UL Certificate	FM Approved	NF/EN Listed/Approved	Observations & Comments
							FIRE DETECTION SYSTEMS	COVERED SURFACE/HORNE STROBE		1	FIRE CONTROL PANEL					
								COVERED SURFACE /DETECTOR		3	BRISE GLASS					
								TYPE OF DETECTORS		4	DETECTORS					
								threshold of the detection temperature		2	HORNE STROBE					
								DISTANCE BETWEEN DETECTORS		5	CABLE FOR FIRE ALARM SYSTEM					
								DISTANCE BETWEEN DETECTOR / WALL								
								number of points per detection loop								
							FIRE EXTINGUISHING SYSTEMS	density		1	PIPE & fittings					
								Sprinkler demand area		2	CONTROL VALVES					
								COVERED SURFACE /Sprinkler		3	VATERFLOW ALARME DEVICES					
								TYPE OF Sprinkler (K, T)		4	GAUGES					
								Sprinklers spacing		5	SPRINKLERS					
								DISTANCE BETWEEN Sprinkler / WALL		6	VALVE SUPERVISORY SIGNAL DEVICES					
								Clearance to ceiling		7	FLOV SVITCH					
								HOSE STREAM		8	TEST & DRAIN VALVE					
										9	HANGER/SEISMIC BRACING					
										10	FIRE DEPARTMENT CONNECTIONS					
							PRIVATE FIRE SERVICE MAINS	Hydrants spacing		1	HOSE HOUSES					
								flow rate/hydrants		2	HYDRANTS					
								nomber of operating hydrants		3	MONITOR NOZZLES					
								hose houses spacing		4	MAINLINE STRAINERS					
								flow rate/hose house		5	PIPING (exposed)					
								nomber of operating hose house		6	PIPING (underground)					
								monitor nozzles spacing								
								flow rate/monitor nozzles								
								nomber of operating monitor nozzles								
							FIRE EXTINGUISHER	EXTINGUISHER spacing		1	EXTINGUISHER DRY POVDER					
								TYPE OF EXTINGUISHER		2	EXTINGUISHER CO2					
								EXTINGUISHER CAPACITY		3	EXTINGUISHER VATER					
										4	EXTINGUISHER FOAM					
										5	EXTINGUISHER VET CHEMICAL					