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DMAIC Approach to Improve on Safety Performance Using Safety Management System in Kuwait International Airport

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Abstract

For aviation industry and facilities, safety is the most sensitive issue to consider at each processes. This is because a minor mistake can result huge problems and can significantly affect industry and corresponding facilities. In this paper, a DMAIC approach to improve on safety performance using Safety Management System (SMS) is illustrated at the Kuwait International Airport (KIA). The paper shows an implementation of such a system reduces the rate of accidents along with their costs, increases the productivity of the place, and meets the legal specifications needed to insure safety at airports. Several hazards with the suggested preventions to control these hazards were illustrated. The DMAIC methodology is used to describe the hazards and how they should be improved and controlled. A Fault Tree Analysis (FTA) technique is applied to investigate the hazards. At the end, SMS was proved to be an effective system to apply at KIA.

Keywords
Safety, Safety Management System, Hazard Analysis, Risk Analysis, DMAIC

1. Introduction

Air transportation is expected to nearly double in the next two decades and the forecasted traffic is also expected to double by then (ICAO 2013). This traffic will result in over two commercial air transport accidents per week if the same accident rate of 2016 prevails in 2030 (ICAO 2017). This strongly suggests that growth in air traffic requires a parallel effort in aviation safety to reduce accident rates (Batuwangala et al. 2018). Occupational safety and health issue is a serious action that is considered by many countries and is taken into account (Abrey and Smallwood 2014). Kuwait is one of the countries that consider the occupational safety and health issues as one of the fundamental issues that needs to be upgraded, improved, and developed every now and then. In this paper, we chose Kuwait international airport (KIA) as a real case facility related to occupational safety and health issues. The most common types of hazard problems at KIA are musculoskeletal disorders, temperature extremes, noise, and being affected due to chemical materials. Therefore, proper occupational safety and health assessments, preventions, controls, and methodologies are necessary to be followed in order to avoid these hazards (Müller et al. 2014). Occupational Safety and Health Administration (OSHA) and the New York Committee for Occupational Safety and Health (NYCOSH) focused on the dangers associated with airline and airport environment. They emphasized the need of private contractors operating at airports to enhance the safety and efficiency of airports. Unsafe hazardous working conditions may put workers, airport visitors, and passengers at huge risk of injuries or death. Contractors and airport management play an important role in reducing and preventing these risks. This is done by committing and applying OSHA's and NYCOSH's recommendations such as conducting workplace hazard assessments, providing health and safety training, providing personal protective equipment (PPE), and notifying employees of any hazardous substances and chemicals (Newman et al. 2015). Many tools, techniques, and approaches such as Failure Tree Analysis (FTA), risk analysis, and safety management system (SMS) helped occupational safety and health managers to make further judgment of hazards (Baig et al. 2013). SMS is an approach that is applied in (KIA) to manage safety risks that are associated with operational organization and activities performed by employees. One reason behind SMS implementation in KIA is that the International Civil Aviation Organization (ICAO) has mandated SMS to be implemented in all sides of all

airports in order to increase safety awareness and safety communication (Yuling and Guldenmund 2018). In this paper, a DMAIC approach to improve on safety performance using SMS is proposed in KIA. The paper shows the step of the DMAIC methodology to reduce the rate of accidents and meet the legal specifications needed to insure safety in KIA. DMAIC approach is used to describe the hazards and how safety should be improved and hazards controlled. Additionally, policies, guidelines, and supervision were conducted to make sure that the workers are working under safe conditions.

2. Safety Management System (SMS)

International Civil Aviation Organization (ICAO) has defined safety management systems as "systematic approach to managing safety, including the necessary organizational structures, accountabilities, policies and procedures" (ICAO 2009). ICAO requires all international airports to implement a SMS to ensure safety practices in the airports, and to reduce the occurrence of accidents and incidents. A successful implementation of SMS resulted in a significant reduction of risks and the severity of the accidents, as well as their cost; thus, reducing the injuries and the lost days away from work resulting from the accidents. (Liou et al. 2008, Stolzer and Goglia 2008, Thompson 2016). An SMS has been successfully implemented in Al- Sharjah International Airport, UAE, in a way that improved the attitudes, behaviors, culture, and the practices of employees in the airport, and enhanced safety and health (Remawi et al. 2013). A Safety Culture Survey was conducted in Al-Sharjah airport to measure the impact of the power of SMS on the employees' attitudes. The results showed that the implementation of SMS enhanced and improved workers' attitudes, communication between workers, committing to safety rules and regulations, and work environment. In addition, the results showed that committing SMS must be done in all the international airports in the world to ensure a safe and efficient environment for workers and passengers.

3. Methodology

We applied DMAIC methodology to improve on safety performance in KIA. DMAIC is a general engineering design approach that can be applied for many production or service problems that need practical solutions. It is an acronym stands for Define, Measure, Analyze, Improve, and Control (George et al. 2005, Mahesh et al. 2010). DMAIC provides a comprehensive improvement method in order to enhance the selected system or process.

3.1 Define:

In this phase, the hazard categories at KIA that creates danger should be addressed and defined clearly. Fig. 1 illustrates the flowchart of KIA SMS reporting process for hazards.

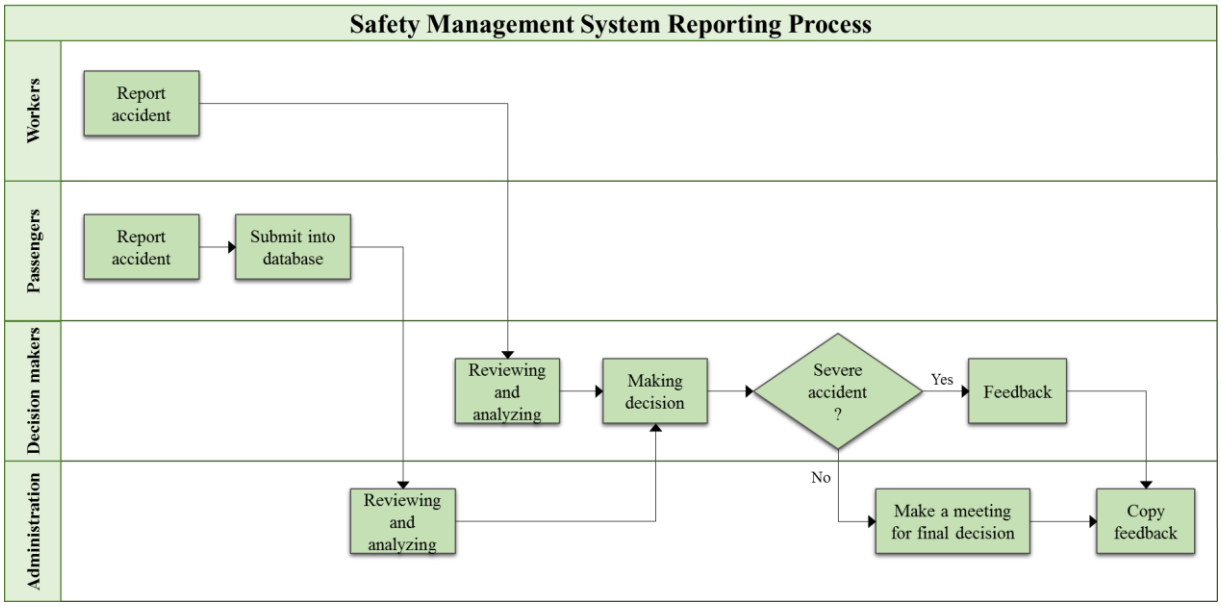

Figure 1: KIA SMS Reporting Process Swim Lane Flowchart

After understanding KIA SMS reporting process, we conducted brainstorming sessions to identify the hazards categories of each safety activity type, as shown in fig. 2. Moreover, we used cause and effect diagram to categorize and analyze the main causes of the hazards and their roots that were generated from the brainstorming sessions, as shown in fig. 3.

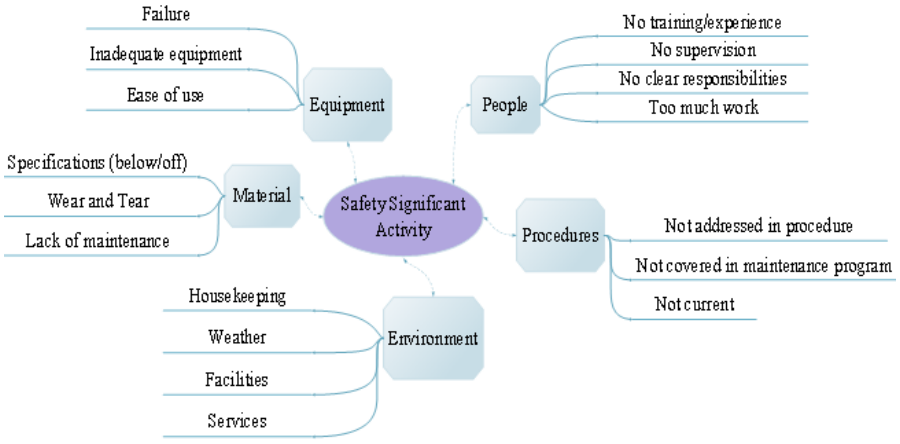

Figure 2: Brainstorming for KIA Hazard Identification

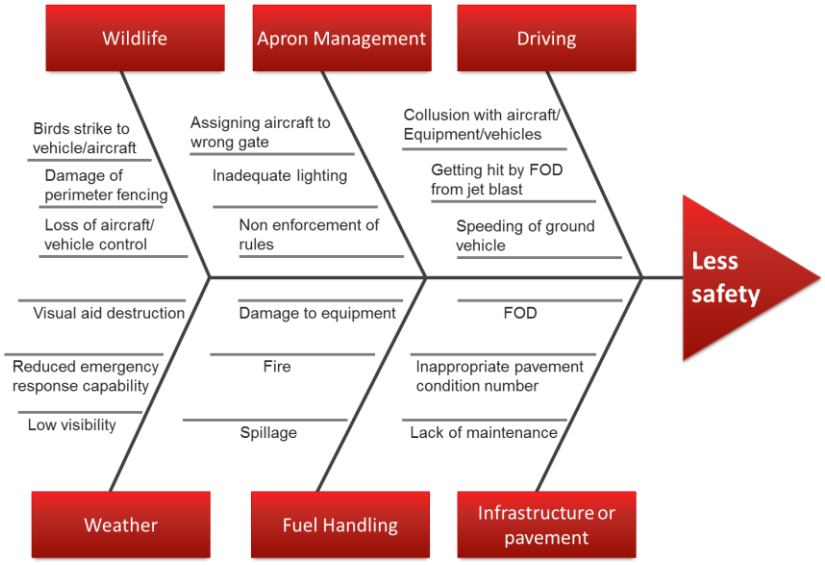

Figure 3: Cause and Effect Diagram

After all of these processes, KIA is divided into four main sections and for each section categories of hazard are illustrated in table 1.

Table 1: KIA Sections and Hazards Categories

Section	Section Name	Section Description	Hazards categories
1	**Airside**	The section in which aircraft stands on	➢ Chemical ➢ Physical
2	**Airstrip**	The section in which the aircraft lands or leaves	➢ Temperature of extreme
3	**Arrivals**	The section for arrived passengers	➢ Radiation ➢ Ergonomic
4	**Departures**	The section for leaving passengers	

In the first section, chemical hazards are the chemicals used to clean the leakage of the airplanes diesel, clean any foreign material, and other usages like cleaning the airplanes tires if necessary (Kirwan et al. 1997). Moreover, physical hazards, which are the present of Foreign Object Damage-FOD, are the objects that increase the risk level as they are dangerous obstacles against the airplanes and workers movements (Al-Humaidi and Tan 2010). In the second section, the category of the hazard is related to the Kuwait climate that usually provides extreme high temperature and dusty weather. The last two sections are combined together due to the similarity of their hazard categories. The first category of the hazard is the radiation from screening machines. These machines allow increase in safety but decrease in health conditions (Xianfeng and Shengguo 2012). The second category of the hazard is the ergonomic hazard. This category is mostly related to the lifting that is exposure by the KIA workers. Although the movement of passengers' items is fully automated, but in reality, that most of times KIA uses its workers to move the passengers and other needed stuff in order to accelerate its service, help people, and financially benefit from it. Thus, the risk will increase by the frequent lifting (Kirschenbaumab 2013).

3.2 Measure:

In the measure phase, the required baseline of the system's current performance should be drawn. This is a very beneficial step in which we can determine the significance of the problem, especially reflected in loss of money, time, and effort. In this paper, we considered the assessment of hazards from the riskiest to the least risky. Table 2 shows the hazards with their probabilities and assessments that are organized and explained for later improvements.

Table 2: Summarizes the Hazard Assessments at KIA

Hazard Assessments					
Type of Hazards	**Symptoms**	**Causes**	**Diseases**	**Probability (Risk Matrix)**	**Control**
1. Cleaning Materials Hazard	a. Cough b. Rash c. Nails broken d. Asthma	a. Improper training b. Lack of awareness c. Managers orders to use chemicals for cleaning	a. Respiratory system diseases b. Eyes and skin allergy c. Hardness in breath d. skin burns	High	a. Ventilation b. Regular wash c. Proper training d. Offer PPE
2. Temperature Extremes	a. Collapsing b. Inability to think c. Confusion d. Dizziness e. Vomiting f. Headache	a. Exposure to extremely high temperatures b. Lack of ventilation c. Excessive exposure to coldness	a. Heats strokes b. Heat exhaustion c. Hypothermia d. Mental illnesses	Medium	a. Offering gloves b. Proper AC systems c. Heat systems d. Proper clothing
3. Noise	a. Hypertension b. Unable to hear	a. Engines of the airplane b. Alarms	a. Psychological stress b. Hearing loss	Low	a. Earplugs b. Noise limit exposure
4. Transportation (speed)	a. No symptoms	a. No enough seats and belts b. Supervisor orders to reach quickly c. Assigning planes to wrong gates d. Careless Workers	a. Partial disability due to accidents. B. Total disability c. Mental disorder	High	a. Speed limit signs b. Penalties c. Cameras and radars
5. Musculoskeletal Disorders	a. Back pain b. Body discoloration	a. Fall b. Handling c. Office environment	a. Moving disability	Medium	a. Maximum weight= 30 Kg b. Provide conveyers c. Use robots for handling and automobiles d. Record keeping
6. Infection	a. coughing b. Eyes and skin discoloration c. Vomit	a. Using restrooms b. Breathing polluted air c. Coughing of sick person d. Vomiting e. Cleaning and touching dirty areas	a. AIDS b. Flu c. Tuberculosis d. Cholera e. Hepatitis	Medium	a. Use PPE b. Hygiene c. Regular wash d. Record keeping

3.3 Analyze:

Analyzing the root causes is essential for the system improvements. Thus, the impact of analyzing the hazards on passengers and workers helped us in determining the failures. Therefore, we constructed Fault Tree Analysis (FTA) and used risk matrix to analyze hazards and measure their levels (Naji and HusseinAli 2017). FTA is a tool for accidents' investigations (Ericson 2011, Yi-nan 2016). Fig. 4 shows the one example of the problem, which is burned skin that is caused by the chemical hazard.

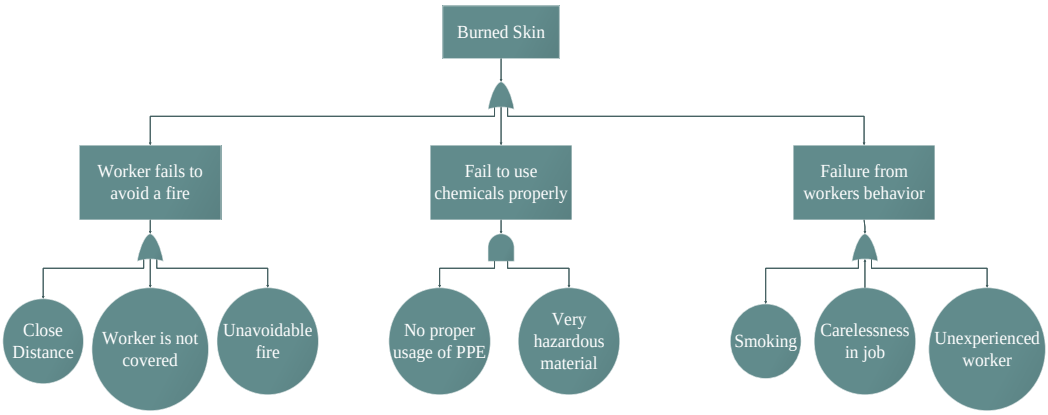

Figure 4: Sample FTA for burned skin caused by chemical hazards

In addition, fig. 5 shows the second categories of hazards, which is the physical hazard in which it causes aircraft collapse due to flat tires.

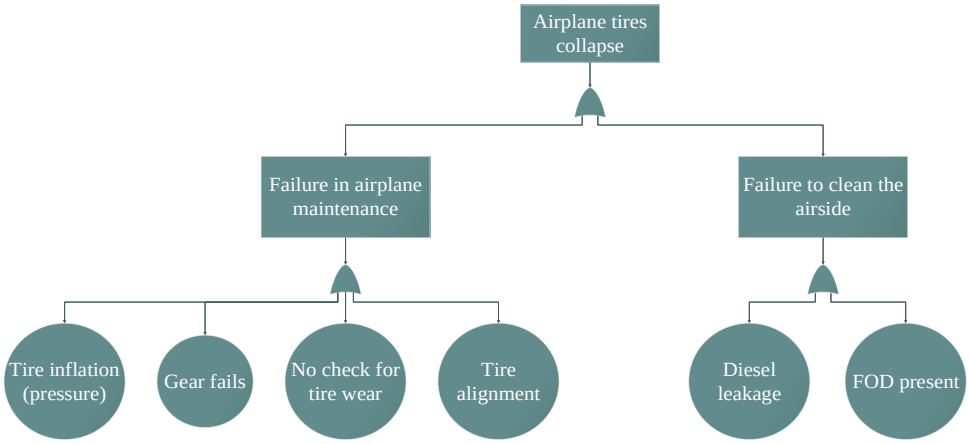

Figure 5: Sample FTA for airplane collapse due to flat tires caused by physical hazards

Moreover, fig. 6 shows the third hazard category, which is the temperature extreme hazard. High temperature causes heat syncope or fainting, especially for female workers.

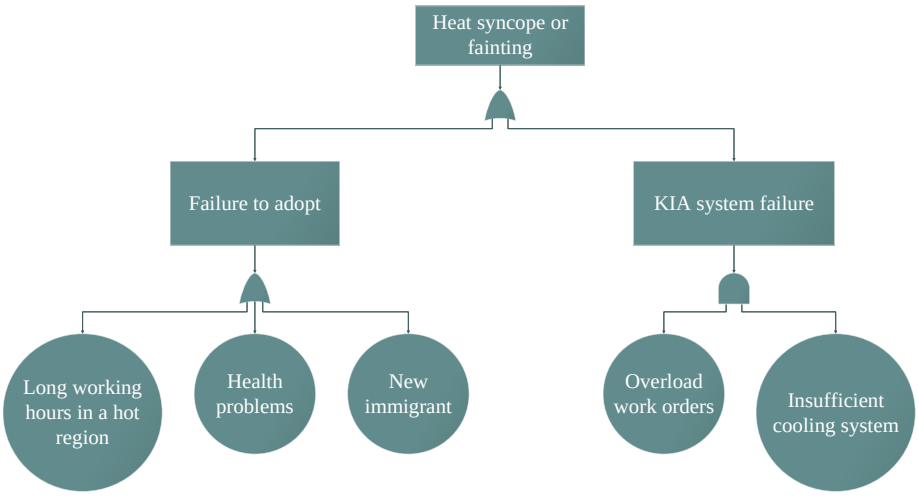

Figure 6: High Weather Temperature of Extreme Hazard FTA

Furthermore, fig. 7 explains the fourth type of hazards, which is the radiation hazard. The effects of these hazards are very dangerous in which they cause health diseases such as cancer.

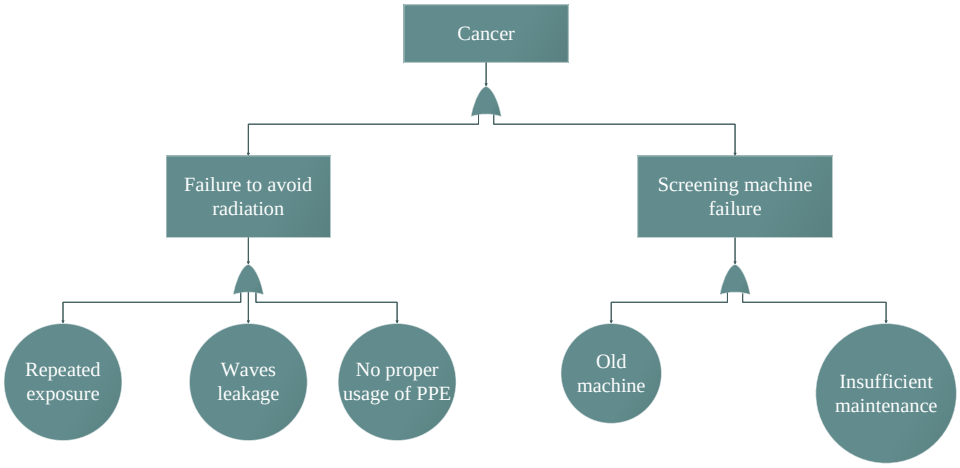

Figure 7: Radiation Hazard FTA

The last category of hazards is the ergonomic hazards. Fig. 8 shows the main accident of this hazard which is back problems. This type of health problems is very common in most of the airports, especially for old workers and pregnant women.

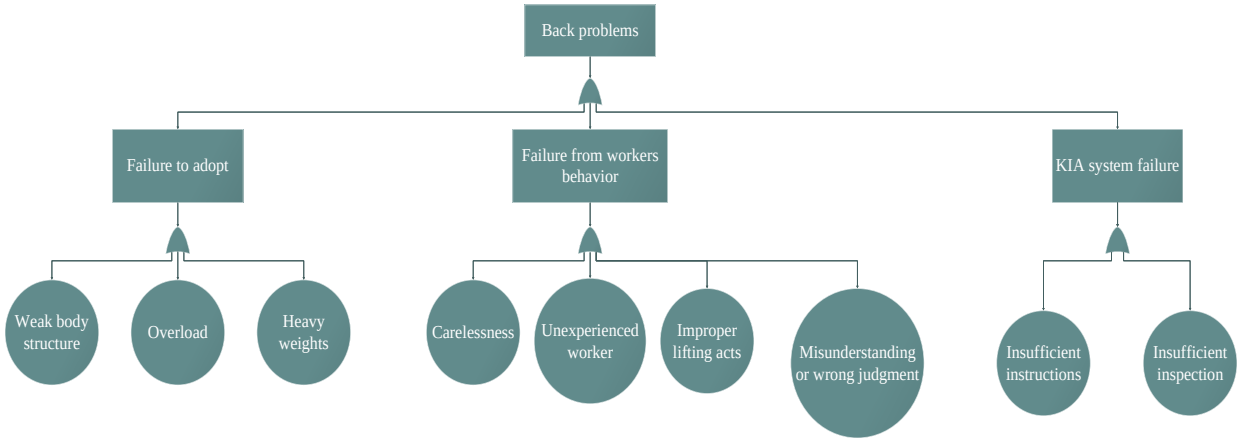

Figure 8: Ergonomic Hazards FTA

After better understanding of the causes and the sub-causes of each problem, we analyzed the risk of each hazard in terms of its severity, probability of occurrence, and level of risk. Table 3 shows KIA risk levels that help KIA management, employers, and employees to analyze the risk of different hazards and therefore control them.

Table 3: Accidents Risk Level

Problem	Probability	Severity	Risk level
Burned skin	medium	medium	3
Airplane tires collapse	Low	High	3
Heat syncope or fainting	medium	medium	3
Cancer	medium	High	4
Back	high	medium	4

3.4 Improve Phase:

In the improve phase, potential solutions could be recommended in order to achieve the main goal of enhancing safety and health level and commitment among workers. Thus, KIA has prevention actions could be taken whenever the worker works inside hazardous environments, as illustrated in table 4 by using hazards prevention checklist. However, reporting hazards and their accidents have an impact on prevention effectiveness. Consequently, the improvements are reflected in the decreasing of hazards exposure and hazardous acts comparing to the baseline of the system performance (Chang et al. 2015). Therefore, one can be state that, the safety and health service quality are significantly increased.

Table 4: KIA Hazards Prevention Checklist

Room:		**Kuwait International Airport Hazard Prevention Checklist** Department of Civil Aviation		
Building:				
Date:				
Hazard Name	Hazard Prevention Description Section Name:	Yes	No	Inspection Notes
	PPE is provided			
	Automatic controls are used (if possible)			
	Train KIA employees from exposure (if possible)			
	Periodic health check is enforced and reinforced			
	Safety polices are clearly understood and applied while handling with or performing any hazard tasks			
	Workplace cleanness and self-cleanness			

3.5 Control Phase:

In this phase, the improvements should be sustained and developed periodically, if possible. As a result, we recommended an action plan based on several KIA policies and rules. Fig. 9 shows some basic controls as a periodic checklist for KIA hazards. In addition, fig. 10 shows the Corrective Action Plan (CAP) that is used in KIA for supervision and reporting. As a result, KIA is reducing risk levels as much as possible.

Name of individual:		Individual position:		Name of supervisor:	
Responsible Department:		Section being supervised:		Date & time:	

Instruction Number	Instruction	Yes	No
1	Do workers have **legal impact** on the workplace safety and health?		
2	Do employers have authority to **assess the hazards**?		
3	Are **employers and employees trained** very well before they assigned for this type of jobs?		
4	Do employers **provide PPE** to reduce hazards exposure?		
5	Do employers aware of the **hazard type and information** related to the material composition, task height, or weight effects?		
6	Do employers have a **control plan** against hazards exposure?		
7	Are employers aware of **Kuwait weather changes**, ventilation, and protective clothes in both summer and winter?		
8	Are employers aware of the acceptable **level of noise**?		
9	Do employers control **fall hazard**?		
10	Do employers have a control plan on the **transportation method and its condition**?		
11	Does KIA provide **good working environment** inside and outside offices?		
12	Does KIA provide **treatment** in the nearest hospital (Farwaniya hospital)?		
13	Do employers **keep recording** the trend of hazards?		
TOTAL:			

Comments:				
Signatures:	Supervisor:		Individual being supervised	

Figure 9: KIA Policies and Rules Checklist for Controlling Hazards

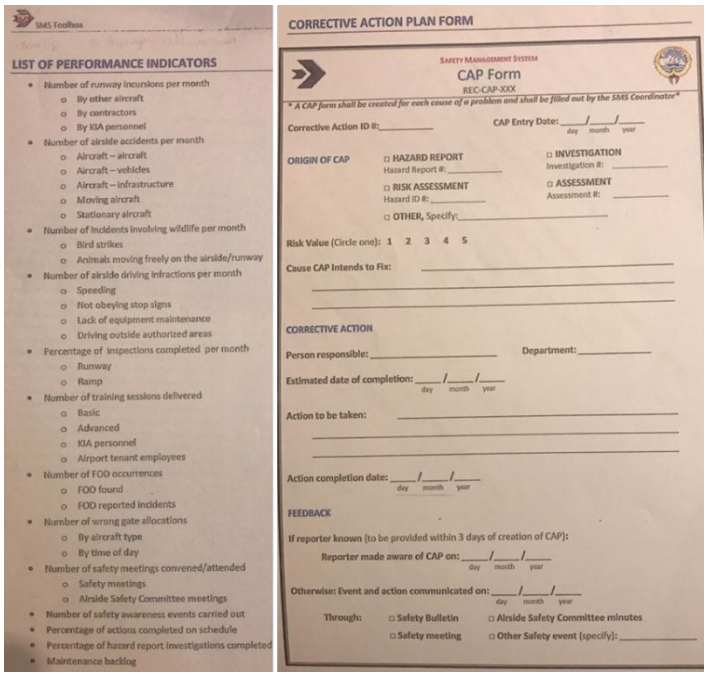

Figure 10: CAP used for Hazards Reporting and Supervision

4. Results and Discussions

A DMAIC methodology has been illustrated the sequence of defining the problem, finding the causes, planning for a correction plan, applying this plan and ensuring that the corrections are perfectly done at the end. As mentioned above section, we have reached improvements for each hazard at KIA. Polices were set to eliminate the problems and improve safety at the place. The results were successfully completed and each department at KIA was given a certain procedures to reduce the hazards probability. Fig. 11 shows the management part for how to control safety for people who are working inside the airport as well as workers who drives vehicles.

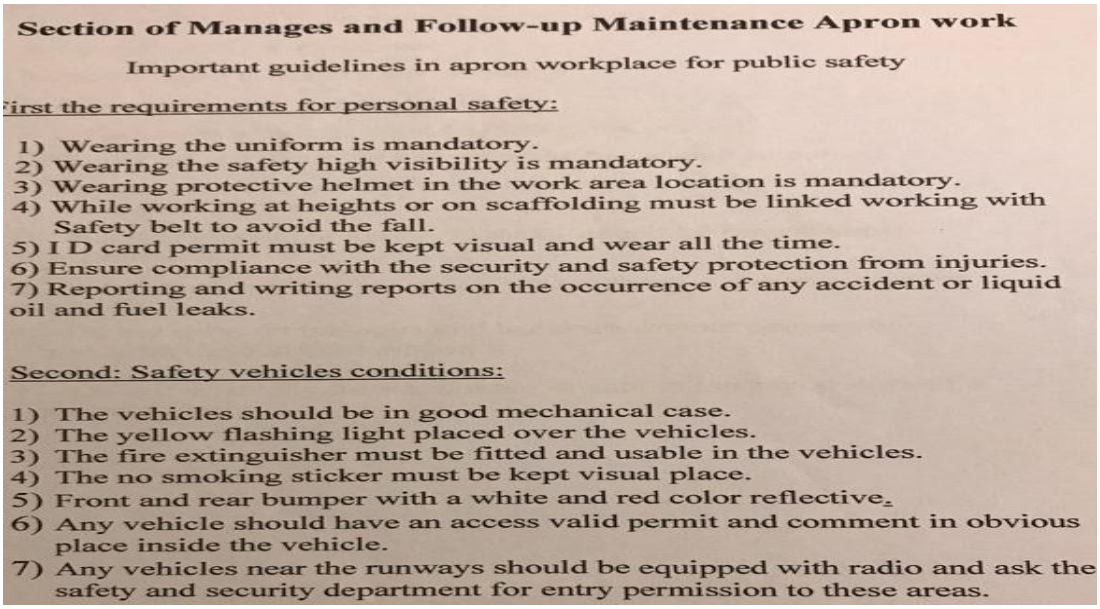

Figure 9: Management Section for Personal and Vehicles Safety

5. Conclusion

To sum up, in this paper a real life problems from KIA were studied by using DMAIC methods and materials related to occupational safety and health. Many work places often suffer from lack of safety requirements which would cause hazards and would sometimes lead to series health problems or even death (Charles 2003). KIA is one of the important facilities in Kuwait where not only local people work in it but it is also visited by global people from all around the world. Therefore, KIA needs to insure a safer environment which guarantees a better working place. This paper showed different hazard types that may happen at KIA. It also described the main causes of these hazards. At the end, a methodology was constructed to show the steps of finding the problems and how they were eliminated and controlled. A fault tree analysis technique was applied. The results showed that SMS application guaranteed a better and safer environment to work at.

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Biographies

Alaa Alshammari is an industrial engineer graduated from the American University of the Middle East, Kuwait. She was an honor student along all academic years. Ms. Alaa and her teammates had a senior project in "Quality Improvements in Plastic Injection Molding Using Six Sigma" that was the best senior project for the spring semester of academic year 2016-2017 and their findings are implemented by the host company. Their work is also awarded as first place winner for the undergraduate research competition at the 8th International Conference on Industrial Engineering and Operations Management held in Bandung, Indonesia during March 6-8, 2018. She did another qualified six sigma project in a service sector. Ms. Alaa achieved certificates in many fields such as Robotics club, financial management training, site engineer training, during her academic years. Furthermore, she has completed projects such as dual axis solar tracker, distances optimization, analyzing power plant system, analyzing a local facility layout and location, analyzing economically a production of a local company.

Nadine Awadah is an industrial engineer graduated the American University of the Middle East, Kuwait, in 2018. She had continuous AUM honor scholarship 2014-2018. She and her teammates had a senior project in "Smart Grid Optimization" that was the best senior project for the fall semester of academic year 2017-2018. Their work titled as "Dynamic Programming Approach to Unit Commitment Problem for Kuwait Power Generations" is also awarded as first place winner for the undergraduate research competition at the 2nd European Conference on Industrial Engineering and Operations Management held in Paris, France during July 26-27, 2018. She joined as an official candidate for AUM's elections-2016. She won the 3rd place in International Day Expo Competition at AUM-2017. She won the 2nd place for both Calculus 2 and CS-programming Competitions. Her main interest areas are researching in topics related to renewable energy resources, optimization, and safety. She had worked with many software during her study period such as Minitab, MATLAB, SCILAB, AutoCAD, Arena, Jack, Visual Studio, and MS office.

Sahar Redha is an industrial engineer graduated from the America University of the Middle East, Kuwait. Ms. Sahar and her teammates had a senior project in "Quality Improvements in Plastic Injection Molding Using Six Sigma" that was the best senior project for the spring semester of academic year 2016-2017 and their findings are implemented by the host company. Their work is also awarded as first place winner for the undergraduate research competition at the 8th International Conference on Industrial Engineering and Operations Management held in Bandung, Indonesia during March 6-8, 2018. She did another qualified lean six sigma project in Al-Farwaniya Hospital, Kuwait.

Zahraa Kamal is an industrial engineer graduated from the America University of the Middle East, Kuwait. Zahraa and her teammates had a senior project in "Quality Improvements in Plastic Injection Molding Using Six Sigma" that was the best senior project for the spring semester of academic year 2016-2017 and their findings are implemented by the host company. Their work is also awarded as first place winner for the undergraduate research competition at the 8th International Conference on Industrial Engineering and Operations Management held in Bandung, Indonesia during March 6-8, 2018. She did another qualified lean six sigma project in Al-Farwaniya Hospital, Kuwait. She achieved certificates in AutoCAD 2D Professional Training program. She completed a project of Thermal Analysis of a Steam Power Plant using cyclepad software and Improving Emergency Department Services in Al-Addan Hospital Using Simulation.

Suat Kasap has degrees in electrical-electronics engineering and industrial engineering. He received his Ph.D. in Industrial Engineering from the University of Oklahoma. His research interests are in human factors and ergonomics, occupational safety and health, work and process analysis, technology and innovation management, multi-criteria decision making, financial engineering, data mining, and modeling, analysis, and optimization of complex engineering problems. He worked in different Industrial Engineering Departments of the American University of Middle East, University of Turkish Aeronautics Association, Hacettepe University, and Çankaya University. He has taught courses on Work Analysis and Design, Ergonomic Work Analysis, Cognitive Ergonomics Work Analysis, Safety Engineering, Technology and Innovation Management, Management of Information Systems, Introduction to Optimization and Modeling, Deterministic Models of Operation Research, Project Management, Multi-criteria Decision Making.