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

Suat Kasap, Alaa Al-Shammari, Nadine Awadah, Zahra’a Kamal, and Sahar Redha
Industrial Engineering Department
College of Engineering and Technology
American University of the Middle East, Kuwait
suat.kasap@aum.edu.kw, AlaaAlshammari@hotmail.com, nadiine-awadah@hotmail.com, Z.kamal94@gmail.com, engsahar94@gmail.com

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.

<table>
<thead>
<tr>
<th>Safety Management System Reporting Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workers</td>
</tr>
<tr>
<td>Report accident</td>
</tr>
<tr>
<td>Passengers</td>
</tr>
<tr>
<td>Report accident</td>
</tr>
<tr>
<td>Submit into database</td>
</tr>
<tr>
<td>Decision makers</td>
</tr>
<tr>
<td>Reviewing and analyzing</td>
</tr>
<tr>
<td>Making decision</td>
</tr>
<tr>
<td>Severe accident ?</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>Feedback</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Make a meeting for final decision</td>
</tr>
<tr>
<td>Copy feedback</td>
</tr>
<tr>
<td>Administration</td>
</tr>
<tr>
<td>Reviewing and analyzing</td>
</tr>
</tbody>
</table>

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](image)

![Figure 3: Cause and Effect Diagram](image)

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>
<thead>
<tr>
<th>Section</th>
<th>Section Name</th>
<th>Section Description</th>
<th>Hazards categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Airside</td>
<td>The section in which aircraft stands on</td>
<td>⊆ Chemical, ⊆ Physical</td>
</tr>
<tr>
<td>2</td>
<td>Airstrip</td>
<td>The section in which the aircraft lands or leaves</td>
<td>⊆ Temperature of extreme</td>
</tr>
<tr>
<td>3</td>
<td>Arrivals</td>
<td>The section for arrived passengers</td>
<td>⊆ Radiation</td>
</tr>
<tr>
<td>4</td>
<td>Departures</td>
<td>The section for leaving passengers</td>
<td>⊆ Ergonomic</td>
</tr>
</tbody>
</table>

Table 1: KIA Sections and Hazards Categories
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

<table>
<thead>
<tr>
<th>Type of Hazards</th>
<th>Symptoms</th>
<th>Causes</th>
<th>Diseases</th>
<th>Probability (Risk Matrix)</th>
<th>Control</th>
</tr>
</thead>
</table>

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.
Burned Skin

Worker fails to avoid a fire

Fail to use chemicals properly

Failure from workers behavior

Close Distance
Worker is not covered
Unavoidable fire

No proper usage of PPE
Very hazardous material

Smoking
Carelessness in job
Unexperienced worker

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.

Airplane tires collapse

Failure in airplane maintenance

Failure to clean the airside

Tire inflation (pressure)
Gear fails
No check for tire wear
Tire alignment

Diesel leakage
FOD present

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.

Heat syncope or fainting

Failure to adopt
KIA system failure

Long working hours in a hot region
Health problems
New immigrant

Overload work orders
Insufficient cooling system

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.

![Radiation Hazard FTA](image)

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.

![Ergonomic Hazards FTA](image)

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>
<thead>
<tr>
<th>Problem</th>
<th>Probability</th>
<th>Severity</th>
<th>Risk level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burned skin</td>
<td>medium</td>
<td>medium</td>
<td>3</td>
</tr>
<tr>
<td>Airplane tires collapse</td>
<td>Low</td>
<td>High</td>
<td>3</td>
</tr>
<tr>
<td>Heat syncope or fainting</td>
<td>medium</td>
<td>medium</td>
<td>3</td>
</tr>
<tr>
<td>Cancer</td>
<td>medium</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td>Back</td>
<td>high</td>
<td>medium</td>
<td>4</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Room:</th>
<th>Kuwait International Airport Hazard Prevention Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building:</td>
<td>Department of Civil Aviation</td>
</tr>
<tr>
<td>Date:</td>
<td></td>
</tr>
<tr>
<td>Hazard Name</td>
<td>Hazard Prevention Description</td>
</tr>
<tr>
<td>Section Name:</td>
<td></td>
</tr>
<tr>
<td>PPE is provided</td>
<td></td>
</tr>
<tr>
<td>Automatic controls are used (if possible)</td>
<td></td>
</tr>
<tr>
<td>Train KIA employees from exposure (if possible)</td>
<td></td>
</tr>
<tr>
<td>Periodic health check is enforced and reinforced</td>
<td></td>
</tr>
<tr>
<td>Safety polices are clearly understood and applied while handling with or performing any hazard tasks</td>
<td></td>
</tr>
<tr>
<td>Workplace cleanliness and self-cleanness</td>
<td></td>
</tr>
</tbody>
</table>

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.

Figure 9: KIA Policies and Rules Checklist for Controlling Hazards
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

Figure 10: CAP used for Hazards Reporting and Supervision

Section of Manages and Follow-up Maintenance Apron work

Important guidelines in apron workplace for public safety

First the requirements for personal safety:
1) Wearing the uniform is mandatory.
2) Wearing the safety high visibility is mandatory.
3) Wearing protective helmet in the work area location is mandatory.
4) While working at heights or on scaffolding must be linked working with Safety belt to avoid the fall.
5) ID card permit must be kept visual and wear all the time.
6) Ensure compliance with the security and safety protection from injuries.
7) Reporting and writing reports on the occurrence of any accident or liquid oil and fuel leaks.

Second: Safety vehicles conditions:
1) The vehicles should be in good mechanical case.
2) The yellow flashing light placed over the vehicles.
3) The fire extinguisher must be fitted and usable in the vehicles.
4) The no smoking sticker must be kept visual place.
5) Front and rear bumper with a white and red color reflective.
6) Any vehicle should have an access valid permit and comment in obvious place inside the vehicle.
7) Any vehicles near the runways should be equipped with radio and ask the safety and security department for entry permission to these areas.
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.

References
ICAO, Global Air Transport Outlook to 2030 and Trends to 2040, ICAO Montreal, QC, Canada, 2013.
ICAO, Safety Report, ICAO, Montreal, QC, Canada, 2017.


**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.