Risk Assessment and Decision Support

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ABSTRACT

Typically, oil production activities contain many hazardous scenarios which could cause catastrophic disasters such as loss of asset, human fatalities or injuries and environmental pollutions. Essence of designing a safe process plant and delivering sustainable performance makes an efficient risk management plan necessary for promoting safety in hazardous industries such as oil production. Risk management activities including hazard identification and risk assessment support decision makers to manage the relevant risks and take appropriate actions to reduce the critical risks levels and contribute sustainable development.

In spite of abundant number of tools, techniques and methodologies to apply risk management, there are still some difficulties to address uncertainties associated with decision making during different phases of a project life cycle. Furthermore, in most decision making models, there isn't a clear distinguish between the key components of risk management process e.g. risk, uncertainty, hazard, and feeling threat. The aim of this paper is an attempt to present an efficient model to provide an appropriate decision making approach under the uncertain situation.

An oil field development plant is selected as a case study to apply the presented model and assess related risks and uncertainties during the basic design phase of the project in order to demonstrate the efficiency of the model. Three main categories are identified as the major causes of hazard situations in the oil field development plant which are technical causes, organizational causes, and political issues. The required considerations and appropriate actions to reduce the level of risks levels as a result of identified variables have been analyzed for the selected possible hazardous scenarios.

Key words: risk assessment, decision making, uncertainty; process industry

1. INTRODUCTION

Decisions made during the design phase can greatly influence the safety of the plant during the operation phase. Every decision making situation involves some degree of uncertainty and managers face with judgment regarding uncertainties. Uncertainty exists where the all possible consequences of an event are unknown, the probability of either the hazards and/or their associated consequences are uncertain, or both the consequences and the probabilities are unknown (Holton, 2004; Kaliprasad, 2006; Cleden, 2009). To move from an uncertain situation, there is a need to improve the level of knowledge about the hazard situations, their probabilities and possible impacts; this process is referred as risk assessment. The result of risk assessment is used to provide information to aid decision making on the need to introduce risk reduction measures.

The overall aims of this paper are how to address uncertainties in decision making process, and clear distinguish between the key components of risk. To fulfill the research purpose and achieve the aim of the study the researcher identified following objectives:

- Reviewing the relevant literatures including basic concepts of risk and uncertainty, risk management processes, hazard identification and risk assessment techniques, including academic journals, articles and books.
- Presenting an uncertainty decision making model to provide an appropriate decision making approach and establish an effective risk management process
- Applying the presented decision making model to risk and uncertainties associated with an Oil Field Development Project and evaluating its effectiveness

These steps enable the researcher to evaluate the effectiveness of the presented uncertainty decision making model in the real case study and find out its weaknesses and strengths.

2. RESEARCH METHODOLOGY

The research started with a general review of relevant literatures including basic concepts of risk and uncertainty, risk management processes, hazard identification and risk assessment techniques, including academic journals, articles and books. The uncertainty decision making model is presented to provide an appropriate decision making approach to support decision makers under uncertain situations. That is followed by applying the presented model to risks and uncertainties associated with an oil field development plant’s case study. This enables the researcher to evaluate the effectiveness of the presented uncertainty decision making model in the real case study and find out its weaknesses and strengths.

3. THE THEORETICAL BACKGROUND

3.1. The Concept of Risk

In general, the concept of risk is defined as a combination of the probability and the consequence of an undesirable situation (Sherif, 1989; Renn, 1998; WHO, 2004; Kristensen, et. al, 2006; Aven et al., 2007; Aven, 2010).

3.2. Hazard

It is important to remember hazard is different to risk. A hazard is a situation that has the potential to cause harm, including human injury, damage to property, damage to the environment, or some combination of these (ISO 17776, 2000; AS/NZS: 4360, 2004; IEC, 2008; Sutton, 2010; Filipsson, 2011). Risk, on the other hand, is the chance that such effects will occur.

3.3. Uncertainty

Uncertainty indicates the level and quality of our knowledge about probability and consequence of an event (Willows et al., 2003).

3.4. Risk Vs Uncertainty

It is important to distinction between risk and uncertainty. *Uncertainty* exists where you don't know the all possible consequences, the possibility of subsequences are completely unknown or you don't know what the underlying distribution look like, or both consequences and probabilities are unknown (Rodger *et al.*, 1999; Kaliprasad, 2006; Sackmann, 2007; Migilinskas *et al.,* 2008). While, *risk* exits where we know the all possible consequences but we don't know which consequences will occur for sure; in addition the probability of outcomes or the underlying outcome distribution is known by decision makers (Sackmann, 2007; Migilinskas *et al.,* 2008). Figure 1 shows the relation between the level of knowledge about probability and consequence and distinction between risk and uncertainty.

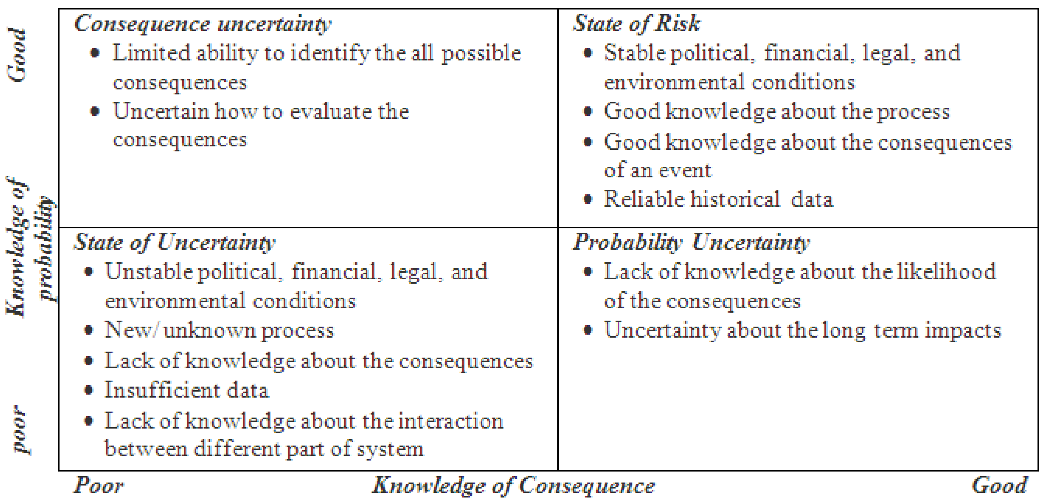

Figure 1-The relation between the level of knowledge about probability and consequence and distinction between risk and uncertainty (Adopted from Willows *et al.,* 2003)

3.5. Risk Management Processes

There are wide ranges of literatures which are illustrated a framework for risk management process. The steps which are discussed in all of them are almost same and differences are because they are established based on different views in different industries and problem areas such as engineering, human health, and environment. According to Australian and New Zealand standard (2004), risk management process includes establishing the context, risk assessment (includes hazard identification, risk analysis, and risk evaluation), managing the risks, communication and consultation, and monitoring.

4. THE UNCERTAINTY DECISION MAKING MODEL

Figure 2 shows the decision making model under uncertain situations. Generally, there could be two different situations where one has to make a decision, either in a normal planning or in an emergency situation.

In a normal planning, decision makers set a goal to achieve the desirable outcome, for example an investment to establish a plant, or to develop a product to launch into the market. After setting the goals, all related variables which affect the defined goals should be taken into account e.g. technical, environmental, political and economical variables. It must be noted that decision maker face with variables along the project life cycle from the beginning up to the end. However, the type of variables might be changed, or new variables add to the decision making process through the project life cycle. These variables in general could cause potentials for failures (hazard situations) such as loss of capital investment, reputation, productivity, assets, human life, environmental pollution, etc. The hazard situation could in turn results in a feeling of threat and an urgency to act against an uncontrollable and uncertain situation by finding some alternatives and try to make proper decisions. Once decision makers feel threat they have to make decision and choose the best options to prevent the hazard situation. Decision makers by using their mental models analyze the received information and variables in order to identify, analyze and evaluate the alternatives. Based on the mental model the information/variables are processed in two ways, either the mental models will filter the information based on the perceptual filters or the information will change the mental models (Isenberg, 1984 in Shahriari et al. 2008). Perceptual filters are ways decision makers look at things based on expectation, assumption, and experiences. The lack of knowledge about the alternatives causes the decision makers to face an uncertain situation. To move from an uncertain situation, there is a need to improve the level of knowledge about the alternatives by quantification of uncertainties. In order to quantify the uncertainties, each alternative should be evaluated by estimating the relevant risk probabilities and consequences, calculating risk and comparing weakness and strengths of different alternatives, this process is referred as risk assessment. The result of risk assessment is feed back to the decision maker as a decision support to choose the best option among the all alternatives.

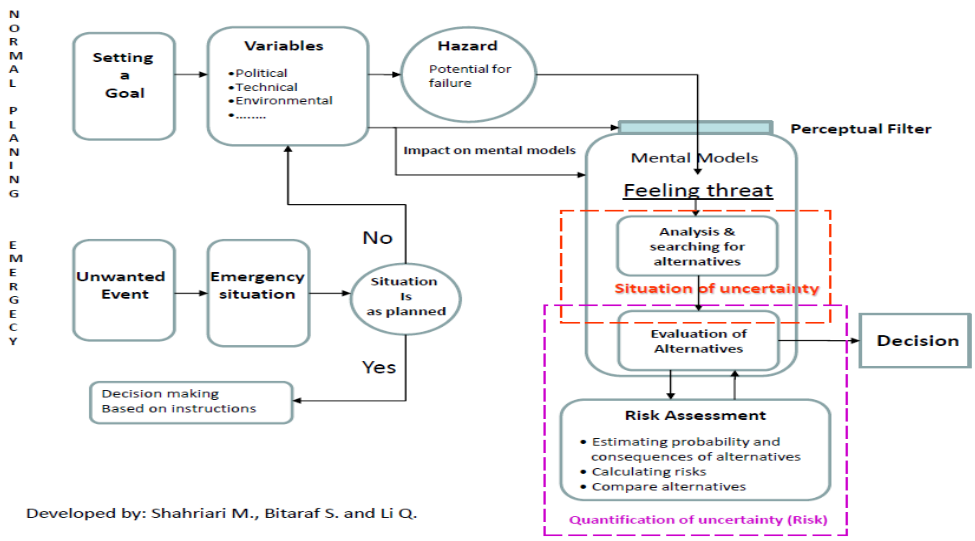

Figure 2- The Uncertainty Decision Making Model

Decision making under an emergency situation has its special characteristics which makes it different from the normal planning situation. During the emergency situation, decision makers face with an unwanted event, and they need to process large amount of data and information which are sometimes unavailable or unreliable, under time pressure. The decisions that are made in the first minutes, and hours are critical to damage control, prevention of human life and assets loss, environmental pollution, and financial costs (Kowalski-Trakofler, et al, 2001). One who is faced with an emergency situation may know what to do as it has been planned before or has no idea which action to take. Therefore, if the emergency situation is as planned, decision maker should follow the instructions e.g. evacuation instructions in the event of fire in a building. In case, there is no instruction and plan for emergency situation or the situation has turned to an unexpected state instead of being match with what has been planned, the decision will be made based on the individual experience and perceptions.

5. CASE STUDY DESCRIPTION

An oil field development plant is selected as a case study to apply the presented model and assess related risks and uncertainties during the basic design phase of the project in order to demonstrate the efficiency of the model. This case study was selected due to importance of oil field development plants after oil and gas extraction from the reservoir.

Extracted fluids from wells are normally a mixture of oil, gas and water. An oilfield development plant is a unit which is constructed to apply preliminary process treatment to producing fluids from wells in order to separate major compounds and prepare them for export to the refineries.

The production hydrocarbon mixture from each well is passed through the choke valve, which reduces the flow rate and piped to a manifold via flow lines. The next facilities are 3 phase separators where separate three phases of oil, gas and water by gravity forces and density differential of compounds. Separated oil is pumped by transfer pumps to downstream facilities for producing other petroleum products afterwards. The produced water is normally piped to water testing package to separate residual oil, gas and solids prior to injection to the well for advanced oil recovery or safety releasing to the environment. The produced gas shall be dehydrated by dehydration package to reduce the water content to less than 5ppm to meet gas quality for refineries. However, gas could be transported or injected to reservoir for gas lift or used as a fuel for prime movers and power generators. The Figure 3 Shows the Block Flow Diagram of the plant.

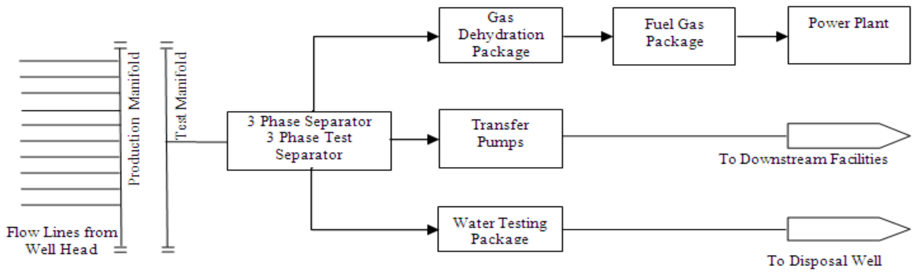

Figure 3- Block Flow Diagram of the Oil Field Development Plant

6. RESULTS AND DISCUSSION

The presented decision making model is applied in the case study to evaluate the effectiveness of the model. The main goal is to design an oil field development plant in a safe and environmental friendly manner that can be safely operated and minimize the costs of failure as well as maintenance. Therefore safety consideration shall be coupled with any decision made over the period of plant design.

6.1. The Variables

The cause and effect diagram is developed to identify all key variables which may cause hazardous scenario of fire, explosion, and toxic material release. Three major categories are identified as the major causes of hazard situation in the oilfield development plant which are technical causes, organizational causes, and political issues (see figure 4).

The historical data related to the accidents in process industry is used to identify the main causes of each defined category. There are several literatures and historical reviews and analysis about technical and organizational causes of accidents in process industry, whereas it is rare to find historical reviews and literatures about effects of political matters on safety of process industries. Therefore, for the first couple of groups, organizational and technical causes, the historical analysis of accidents in process industry is used as a source to identify the key variables which are effective on the safety of the project; and the effects of political issues on the safety of the project are identified based on the experts' judgment and experience.

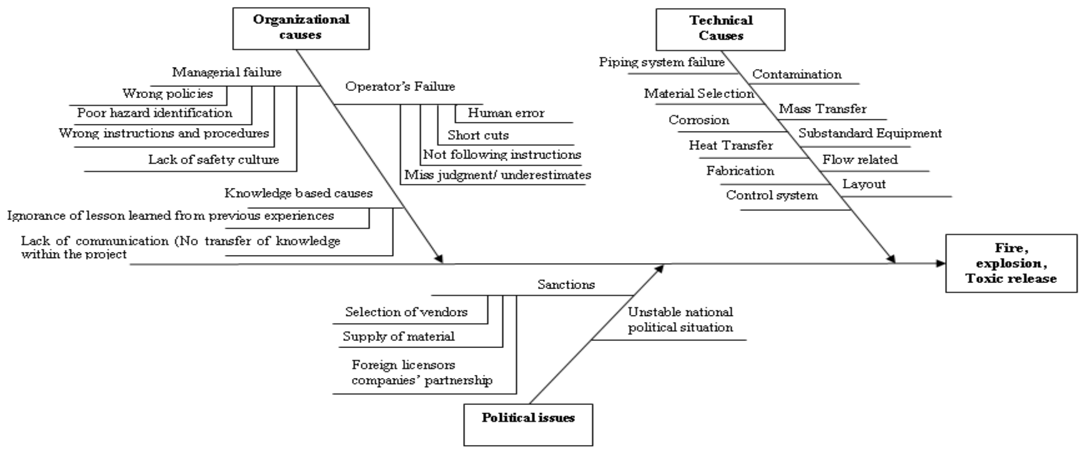

Figure 4- The cause and effect diagram of key variables which may cause hazard events

There are several historical analyses to categorize the causes of accidents in process industry. Kidam, et al, (2009) analyzed the historical data of 364 accident cases related to process industry based on the Failure Knowledge Database (Japan & Science Technology Agency). The causes of accidents are categorized into two main groups; technical and human/organizational (Figure 5). Figure 5 shows that 73% of accidents in process industry are caused by technical failures, 23% by organizational matters and 4% by unknown reasons.

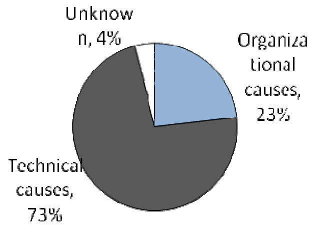

Figure 5- The general causes of accidents in process industry (adopted from Kidam, et al, 2009)

The main reasons for technical causes based on reviewing the accidents in process industry are, piping system failure, contaminations, material selection, corrosion, and heat transfer. The organizational failures are happened by poor human performance in managerial level or operator's level and also poor knowledge sharing. Moreover, main oilfields are located in unstable political areas like Middle East, Africa, and Latin America. So, this industry is very sensitive to geo-political events in hydrocarbon producing areas. Unstable political situation and sanctions affects the safety of process plants by imposing limitations on supply of required materials and facilities, selection of vendors, and avoiding foreign licensor's to be companies' joint ventures.

6.3. Hazard Identification

This hazard situation in turn results in feeling of threat to act against an uncontrollable and uncertain situation. Consequently, identification of hazards is essential at the early stage of design for assessing the safety level. Not all hazard identification methods are suitable for all phases of project life cycle. The appropriate method for each stage of project will differ in respect to the available information as well as the level of detail that decision makers need. In respect to the available information and documents at the basic design stage of the investigated case study, HAZOP study had been carried out at final stage of basic design phase to identify hazardous scenarios.

6.4. HAZOP

The purpose of HAZOP study is to review every part of process and operation to discover the deviations from the normal operation and provide the recommendations for design improvements and operating procedures. The HAZOP team review the process based on the P&IDs or equivalent, and systematically questions every part to discover the deviation which can give rise to hazards. The HAZOP procedure is described in the following paragraphs:

6.5. The Hazard Scenarios

The following hazard scenarios had been identified based on the HAZOP study results in Process Area of the plant:

Scenario 1: Fire/Explosion due to leakage of gas and crude oil as a result of damage to 1st stage separator

Scenario 2: Loss of hydrocarbon due to rupture of flow line

Scenario 3: Rupture of production tube due to High pressure on upstream of well

Scenario 4: Reduce the plant load due to less supply of gas to dehydration package

Scenario 5: Damage to export pumps due to low NPSH (Net Positive Suction Head) and as a result possible cavitations

Between the identified scenarios, the first three scenarios are chosen for further analysis and risk assessment. These scenarios are chosen between other identified scenarios due to their high likelihood or their major consequences. The first two scenarios are chosen, since their consequences are so sever once the incident happen. The consequence of the scenario 3 is pretty low, but the probability of this scenario is high.

6.6. Probability and Consequence Estimation

Once the hazard scenarios are identified based on the HAZOP study; the fault tree analysis is developed for each hazard scenario in order to estimate the probability of undesirable scenarios. The consequence analysis for each investigated scenario should be developed to estimate the impact of the hazards on health, safety, environmental, and economical consequences. In this study the qualitative consequence analysis is developed to estimate the impact of hazard scenarios. According to the estimated number in probability estimation and consequence estimation, the risk level is developed based on the semi-quantitative risk ranking matrix.

The result of risk evaluation shows risk level of scenario I & III are at unacceptable risk level, and Scenario II is acceptable but is required more investigation to reduce the level of risk to the tolerable level. The management team should develop required modification to reduce the risk level either by decreasing the probability or consequences. Furthermore, there are some uncertainties due to different variables (technical, organizational, and political) which may affect the risk level considerably. The required considerations and appropriate actions to reduce or mitigate the associated uncertainties due to the key variables are explained in the next section in detail for each hazard scenario.

6.7. Required Considerations to Reduce the Effect of Variables

There are some uncertainties due to different variables (technical, organizational, and political) which may affect the risk level considerably. The required considerations and appropriate actions to reduce or mitigate the associated uncertainties due to the key variables are explained in the following Sections:

Technical Causes

To prevent the hazard scenarios due to technical causes, the following considerations should be taken into account during the design phase:

- Following codes and standards by designers apart from limitations arisen from sanctions and economical crises;
- Appropriate design and material selection to meet technical requirements in spite of imposed sanctions and consequent cost impacts;
- Regular audit plans and inspection schedules during the operation phase to obtain sustainable safety;
- Appropriate control and safety systems implementation to detect the possible deviations from safe operation conditions;

In addition to the general aspects which are mentioned above, the following considerations should be taken into account in design of 1st stage separator to reduce the risk level of scenario 1:

- Studying the necessity of demulsifiers and corrosion inhibitors to increase separation efficiency and corrosion attack risk mitigation respectively;
- Considering mercaptans (components with sulfur contents exists in crude oil which are extremely corrosive) effect on material selection in separator as well as other equipment in process area;
- Installation of level controllers to prevent operational problems such as carry over and blow-by;
- Antifoam injection in separators to prevent mixing gas and water in their surface contacts;

The main reasons of piping system failure (Scenario II) are corrosion, poor bounding between pipe joints, sever cycling condition and over pressure, inappropriate method of fabrication, and wrong material. To prevent these failure causes, the following considerations should be paid attention during the design of a flow line:

- Injection of corrosion inhibitors to prevent different types of corrosion attacks such as H_2S and CO_2 corrosion.
- Special design requirements like stress analysis and very strict inspection level to avoid possible damages of the system due to over pressure and sever cycling conditions in flow line
- Appropriate welding mechanism and method of fabrication for pipes shall be utilized to prevent piping leakage at operation.
- Proper material selection for equipment, instruments and piping considering fluid nature and process parameters to assure proper functioning of facilities over design life of the plant.

Tubing as a mean of crude oil and gas transportation from subsurface to the ground level is exposed to corrosion attack, high temperature loads as well as elevated temperature. Therefore to prevent the undesirable event of production tube rupture in Scenario 3, the following design considerations should be applied by engineers during the design stage:

- Using corrosion and temperature resistant Alloy like Nickel Alloys to satisfy technical requirements;
- To calculate adequate wall thickness to withstand high pressure of fluid extracted from reservoir.

Organizational Causes

In addition to the design considerations other operational safeguards and procedures should be considered to prevent or decrease the consequences of hazards due to organizational causes. The most important procedures are as follow:

- Identifying escape routes from process area;
- Considering medical assistance equipments, ambulance and proper training for personnel;
- Providing environmental/waste management plan to protect the environment after any fire accident;
- Periodic operating inspection;
- Operational personnel shall be trained for toxic gases and specially H2S hazards.
- Develop emergency response procedure.
- The risk assessment and evaluation should be conducted from the earlier stage of the project
- Operators should have work permit and follow the instructions

Political Issues

Unstable political situation in oil producer countries and sanctions against countries like Libya, affect the safety of process plants in these countries by imposing limitations on supply of required materials and facilities, selection of vendors, and avoiding foreign licensor's to be companies' joint ventures. The effects of political issues on investigated hazard scenarios are described in the following paragraphs:

Scenario 1: Fire/ explosion due to leakage of gas and crude oil from 3 phase separator

Separators are generally made of carbon Steel and can withstand the fluid corrosion considering the fact that the injected corrosion inhibitor is effective in the separator. Additionally, since supplying carbon steel is not an issue even because of sanction, separator leakage as a result of material failure is not a risky scenario.

On the other hand, less qualified vendors cannot achieve welding, casting, forging and inspection qualities as high standard as reputable experienced vendor can which definitely increase the risk of vessel failure.

Scenario 2: Loss of Hydrocarbon due to rupture of flow line

Flow lines are generally made of carbon steel since it is not economical to use expensive alloys for relatively long distance. However, corrosion inhibitor is injected in the flow line to avoid any possible corrosion attack. Since supplying carbon steel is not an issue even because of sanction, flow line rupture due to material failure is not a risky scenario.

However, like the first scenario as a result of sanction, many qualified vendors from Western European countries and Japan do not show any intention to deal with some countries so that the choice of selection becomes very limited for these companies. This in turn leads to risky situations when potential vendors cannot meet some supplementary requirements to avoid sour corrosion risk in flow lines as follows:

- The quality of material in term of chemical composition maybe less than specified request.
- Some required tests such as HIC test and SSC test which affect the sour corrosion in pipe cannot be performed with less qualified vendors.

Scenario 3: Rupture of production tube due to High pressure on upstream of well

Tubing as a mean of crude oil and gas transportation from subsurface to the ground level is exposed to corrosion attack, high pressure loads as well as elevated temperature. Therefore, very costly CRA (Corrosion Resistant Alloy) like Nickel Alloys shall be selected to satisfy technical requirements.

Sanction against countries like Libya makes it nearly impossible for companies to purchase Nickel alloys so that they sometimes ought to shift to lower grades material such as duplex which could not offer adequate corrosion resistance. Additionally, designing a plant requires licensor technical support as well as its guarantee to end users. But unstable political situations in oil producer countries make licensors to stop their cooperation. So, designing plants without any licensor which fully aware of Know-How, increases the risk of plant failures in terms of material selection, process condition, etc.

4. CONCLUSIONS

The implementation of this model in the selected case study proves that the model has the ability to support decision makers and managers to take an appropriate action by addressing the key variables which may cause potential for failures (hazard situation). The success of this model is associated with addressing all key variables related to the defined goals or unwanted event. The process of variable identification should be performed by expert's backgrounds and knowledge along with developing a systematic method. Some methods such as, checklists, fishbone diagrams, brainstorming sessions can be applied to identify all key variables properly. On the other side, the management intention and openness to the expert's judgments and analysis is vital to consider all related variables during the decision making process.

The novel aspect of this model is that, all key components of risk management process are addressed clearly. Typically, in most decision making models, there isn't a clear distinguish between risk and hazard. But this model define the hazard and risk clearly and shows the relation between hazard, feeling of threat, and risk assessment process trough the decision making situation. Additionally, the presented model is general and could be applied to all types of decision making processes under uncertainty situation.

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