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Emergency response management native model to reduce environmental impacts using by analytic hierarchy process (AHP)

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Oil&petrochemical industry normally uses the large storage tanks, which contain considerable volumes of flammable and hazardous chemicals. Thus, the occurrence of a tank accident is possible and usually leads to fire and explosions. Major industrial accidents can have very dangerous environmental and health consequences. One of the mitigation accident effects implication of Emergency Response Management in the Industries.

Emergency Response Management (ERM) enables and supports emergency response operations across organizational, jurisdictional, and geographical boundaries. Emergency response management guidelines which mostly consist of four parts include prevention, preparedness, response, and recovery.

The paper reviews the existing emergency management patterns (ISO 15544, CCPS, NFPA 1600, DEP, and OSHA 3022) to find an emphasis on identifying and reducing environmental impacts was examined based on five international guidelines.

The common elements of these five international guidelines were determined. A questionnaire containing the information was designed and distributed between experts to give their answers as the best native model. The information gathered through questionnaires was analyzed by Expert choose software and the results was priorities with Analytical Hierarchy Process Method (AHP), in four phases of prevention, preparedness, response, and recovery. The results shows that the CCPS guideline is a best models and suitable for Emergency management in Iran Oil & Petrochemical Plants with an approach to environment priorities

Key words: Native model, Emergency response management, Analytic Hierarchy Process (AHP), Environment Effect

INTRODUCTION

The petrochemical industry normally uses large storage tanks, which contain considerable volumes of flammable and hazardous chemicals. Thus, the occurrence of a tank accident is possible and usually leads to fire and explosions. A thorough analysis of tank accidents with a classification of causes and contributing failures is presented by Chang and Lin [1]. The most common consequence of a tank accident is fire.

Although large-scale tank fires are very rare, they pose a severe challenge to employs & stockholders, oil companies and the environment, due to the multiplicity of the physical processes involved. According to the study of Persson and Lonnermark [2] , there are two ways of dealing with a tank fire, either to let it burn-out fully and thereby self-extinguish or, alternatively, to extinguish the fire actively, using firefighting foams. One of the mitigation accident effects implication of emergency response management in the industries.

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Tank fires produce large quantities of combustion products, such as Sulphur dioxide (SO2), carbon monoxide (CO), hydrogen sulfide (H2S), and lead to soot and particulates formation. More specifically, the transport of combustion products by a wind-blown smoke plume can distribute potentially hazardous materials over a large area and may lead to serious consequences for the health of people and for the environment

Cascading disruptions and failures product of natural, industrial and man-made disasters can be avoided or minimized if the concept of Crisis Lifecycle is included and understood into emergency management. Research studies by Turner and also by Vaughan have shown that crisis often have long incubation times. There are numerous precursors or warnings that are ignored or not detected.

Strategic aspects of emergency management have to include the whole lifecycle of crises [3] to minimize cascading disruptions and failures due to the dynamism of crises as a consequence of variable's evolution over time. To achieve this lifecycle perspective, a bird's eye view in temporal, spatial and configuration space is necessary.

Therefore, it can be argued that effective crisis management starts well in advance of the actual physical manifestation of the crisis. Ideally, crises could be avoided if perfect early warning systems were in place, if managers understand how to solve them and if the evolution of crises is perceived beforehand.

EMERGENCY MANAGEMENT LIFE CYCLE

A life-cycle approach provides a broad and systematic view of the activities relating to emergency response management [4]. Therefore, the framework we suggest is adapted to each of the stages in the life cycle. The management of emergency response can be visualized in terms of three distinct sets of activities on the time line continuum [5]. These include actions taken (a) prior to an incident (typically deals with preparedness issues such as planning and training), (b) during the incident (mitigation), and (c) after the incident (a.k.a. the response and recovery stage).

Disaster operations life cycle and disaster types Tufekci and Wallace [6] suggest that emergency response efforts consist of two stages; prevent and post-event response. Pre-event tasks include predicting and analyzing potential dangers and developing necessary action plans for mitigation. Post-event response starts while the disaster is still in progress. At this stage the challenge is locating, allocating, coordinating, and managing available resources. Tufekci and Wallace also suggest that an effective emergency response plan should integrate both of these stages within its objective. They add that separating pre- and post-loss objectives may lead to suboptimal solutions to the overall problem. In the United States comprehensive emergency

Management is commonly described in terms of four programmatic phases: mitigation, prepared preparedness, response, and recovery [7,8.9] . The four-phase approach covers all of the actions described in Tufekci and Wallace’s classification while providing a more focused view of emergency management actions. Moreover, the four-phase classification is based on the Comprehensive Emergency Management concept introduced in the 1978 report of the National Governors Association Emergency Preparedness Project [10].

These terms have been widely used by policy makers, practitioners, trainers, educators, and researchers. As illustrated in Figure 1 the four phases are often described as part of a continuous process.

Mitigation is the application of measures that will either prevent the onset of a disaster or reduce the impacts should one occur. Preparedness activities prepare the community to respond when a disaster

Fig. 1. Four Phases of Emergency Management [11].

occurs. Response is the employment of resources and emergency procedures as guided by plans to preserve life, property, the environment, and the social, economic, and political structure of the community. Recovery involves the actions taken in the long term after the immediate impact of the disaster has passed to stabilize the community and to restore some semblance of normalcy

Industrial and commercial installations which have the potential for causing accidental pollution of air, land or water, or the endangerment of public health and safety are required to develop and implement Prevention/Mitigation, Preparedness, Response and Recovery which encompass the other Departmental program requirements.

ANALYTIC HIERARCHY PROCESS (AHP)

AHP is a decision-making tool that can help describe the general decision operation by decomposing a complex problem into amulti- level hierarchical structure of objectives, criteria, sub criteria and alternatives [12]. Applications of AHP have been reported in numerous fields such as conflict resolution, project selection, budget allocation, transportation, health care, and manufacturing, Environment challenges (Harker, 1989). More and more researchers are realizing that AHP is an important generic method and are applying it to various manufacturing areas [14], [15], [16], [17], [18]. In addition to the wide application of AHP in manufacturing areas, recent research and industrial activities of applying AHP on other selection problems are also quite active [19],[20],[21],[22].

AHP’s hierarchic structures reflect the natural tendency of human mind to sort elements of a system into different levels and to group like elements in each level [12]. From a human factor point of view, AHP can be a very effective tool to assist human decision making. A study conducted by [23] show that when a human being and an intelligent machine cooperate to solve problems, but where each employs different problem-solving procedures, the user must have an accurate model of how that machine operates. This is because when people deal with complex, interactive systems, they usually build up their own conceptual mental model of the system. The model guides their actions and helps them interpret the system's behavior. Such a model, when appropriate, can be very helpful or even necessary for dealing successfully with the system. However, if inappropriate or inadequate, it can lead to serious misconceptions or errors [24]. Therefore, it is very important for decision makers to be able to understand the decision-making model structure, while AHP just provides such a simple, easily understood, and flexible model structure.

Dagdeviren and colleagues [25] have expressed first by AHP method, complex multi-criteria decision making problem turns into a hierarchy of decision elements means purpose, criteria and decision options related to that problem. The method of AHP makes objectives, criteria or options to the hierarchical structure like a family tree. Hierarchy has at least three levels: the total purpose of the first level is, placing multiple criteria that evaluate options in the middle and decision options under this part. View of decision-making hierarchy that has four levels has been drawn in the Figure 2

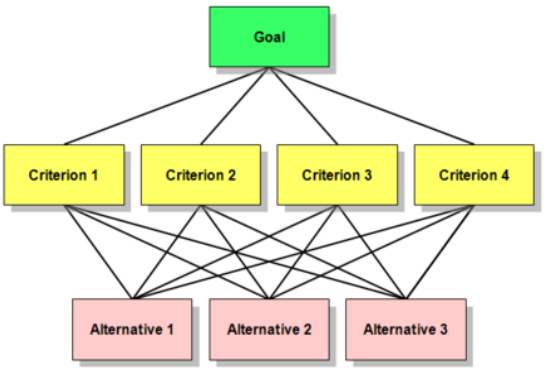

Fig. 2. Grossly Simplified Structure Of an Exemplary AHP Hierarchy.

The next step is the comparison of options and criteria. When the problem breaks down and its hierarchy is made, prioritization procedures start for determining the relative importance of criteria for each level. Pair judgments start from the second level (criteria) and in the last level end. In each level, criteria as pair and according to their effect levels and based on specified criteria are compared at a higher level.

Bogdanovic and colleagues [26] asserted paired comparing should be conducted by the question from decision maker. For example, be asked, according to the purpose of decision which scale of 1 to 9, as shown in Table1 should be allocated as the importance level of criteria to each other. Also Vidal and colleagues [27] concluded 8, 6, 4, 2 middle numbers should be used for comparison correction.

Table 1. Scale of paired comparison in AHP method.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or Slight	
3	Moderate Importance	Experience and judgment slightly favor one activity over another
4	Moderate Plus	
5	Strong Importance	Experience and judgment strongly favor one activity over another
6	Strong Plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another, its dominance demonstrated in practice.
8	Very very Strong	
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation

GUIDELINES STRUCTURE

The Center for Chemical Process Safety (CCPS)

Technical planning for on-site emergencies

The Center for Chemical Process Safety (CCPS) was established in 1985 by the American Institute of Chemical Engineers (AIChE) for the express purpose of assisting industry in avoiding or mitigating catastrophic chemical accidents. To achieve this goal, CCPS has focused its work on four areas [28], [29]:

• Establishing and publishing the latest scientific, engineering, and management practices for prevention and mitigation of incidents involving toxic, flammable, and/or reactive material.

• Encouraging the use of such information by dissemination through publications, seminars, symposia, and continuing education programs for engineers.

• Advancing the state-of-the-art in engineering practices and technical management through research in prevention and mitigation of catastrophic events.

• Developing and encouraging the use of undergraduate engineering curricula that will improve the safety knowledge, and consciousness of engineers.

This Guideline is a Technical Planning for On-Site Emergencies and Include of four phases Prevention, Preparedness, response and Recovery. Table 2 shows the important elements.

Table 2. Elements of CCPS pattern about Emergency Management.

CCPS
1. Principles of Prevention
2. Principles of Mitigation
3. Identification of Credible Incidents
4. Conceptual Approach to Emergency Response
5. Developing Response Tactics
6. Physical Facilities and Systems
7. Response Equipment and Supplies
8. Developing a Workable Plan
9. Training
10. Response Functions
11. Support Functions, Systems, and Facilities
12. Recovery Functions
13. Cleanup of Facilities

ISO 15544 (Petroleum and natural gas industries

Offshore production installations — Requirements and guidelines for emergency response)

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies [30]. The work of preparing International Standards is normally carried out through ISO technical committees.

The successful development of the arrangements required promoting safety and environmental protection during the recovery of hydrocarbon resources requires a structured approach to be applied to the identification and assessment of the hazards which may be present during the various phases in the lifecycle of an offshore installation. These principles also apply to the development of the strategy, arrangements and procedures required to respond to emergencies.

The content in this International Standard is consistent in table 3.

Table 3. Elements of ISO pattern about Emergency Management.

ISO 15544
1. Emergency response strategy (ERS)
2. Emergency response plan (ERP)
3. Command and control
4. Detection of the need for emergency response
5. Competence
6. Maintenance of emergency response equipment
7. Communications
8. Escape, refuge, evacuation and rescue
9. Environmental emergency response
10. Medical emergency response

This International Standard is based on an approach where the selection of measures for emergency response is determined by an evaluation of hazards on the shore installation. The methodologies employed in this assessment and the resultant recommendations will differ depending on the complexity of the production process and facilities, type of facility (i.e. open or enclosed), manning levels, and the environmental conditions associated with the area of operation.

DEP (Guidelines for the development and implementation of environmental emergency response plans)

Department of Environmental Protection (DEP) has developed and implemented of environmental emergency response plans with this guideline. The policy of this to plan and provide effective and efficient response to emergencies and accidents for any situation dealing with the public health, safety and the environment [31]. A wide variety of industrial activities, both manufacturing and commercial, exist in the world. Many of these activities have the potential for causing environmental degradation or endangerment of public health and safety through accidental releases of toxic, hazardous, or other pollution materials.

In recognition of this fact, several State and Federal regulatory programs have been developed to encourage the use of preventive approaches to deal with unwarranted releases of toxic, hazardous, or other pollutants to the environment.

The Department's objective is to consolidate the similarities of the State and Federal pollution incident prevention and emergency response programs into one overall program. Industrial and commercial installations which have the potential for causing accidental pollution of air, land or water, or the endangerment of public health and safety are required to develop and implement Preparedness, Prevention and Contingency (PPC) Plans which encompass the other Departmental program requirements. Key elements of this guideline show in table 4.

Table 4. Elements of DEP pattern about Emergency Management.

DEP
Description of Facility
Organization Structure & Duties and Responsibilities
Chain of Command
Emergency Response Plans
Spill Leak Prevention
Housekeeping
Security
Employee Training
Countermeasures
Communications and Alarms
Evacuation Plan
Emergency Response Equipment
Emergency Spill Control Network

National Fire Protection Association (NFPA 1600)

Standard on Disaster/Emergency management and business continuity programs

NFPA® codes, standards, recommended practices, and guides ("NFPA Documents"), of which the document contained herein is one, are developed through a consensus standards development process approved by the American National Standards Institute. This process brings together volunteers representing varied viewpoints and interests to achieve consensus on fire and other safety issues. While the NFPA administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in NFPA Documents. [32]
The NFPA disclaims liability for any personal injury, property or other damages of any nature whatsoever, whether special, indirect, consequential or compensatory, directly or indirectly resulting from the publication, use of, or reliance on NFPA Documents. . Key elements of this guideline show in table 5.

Table 5. Elements of NFPA pattern about Emergency Management.

NFPA 1600
1. Laws and Authorities
2. Risk Assessment
3. Incident Prevention
4. Mitigation
5. Resource Management and Logistics
6. Mutual Aid/Assistance
7. Incident Management
8. Planning
9. Communications and Warning
10. Operational Procedures
11. Facilities
12. Training
13. Exercises, Evaluations, and Corrective Actions
14. Crisis Communication and Public Information
15. Finance and Administration

OSHA 3022

(Principal emergency response and preparedness requirements and guidance)

The importance of an effective workplace safety and health program cannot be overemphasized. There are many benefits from such a program, including increased productivity, improved Employee morale, reduced absenteeism and illness, and reduced workers' compensation rates.

Unfortunately, workplace accidents and illnesses still occur in spite of efforts to prevent them, and proper planning is necessary to effectively respond to emergencies. Several Occupational Safety and Health Administration (OSHA) standards explicitly require Employers to have emergency action plans for their workplaces [33]. Emergency preparedness is a Well-known concept in protecting workers' safety and health. To help employers, safety and Health professionals, training directors, and others, the OSHA requirements for emergencies are compiled and summarized in this booklet.

This publication provides a generic, non-exhaustive overview of OSHA standards for emergencies. It is not intended to alter or determine compliance responsibilities in OSHA standards or the Occupational Safety and Health Act of 1970. Please review the current OSHA standards applicable to your work operations to ensure your compliance. Key elements of this guideline show in table 6.

RESEARCH-METHOD

As previously stated, the aim of this study is the ranking of current international pattern and providing local pattern of Emergency Management. The ranking of crisis management pattern is done

Table 6. Elements of OSHA pattern about Emergency Management.

OSHA 3022
1. Medical services and first aid
2. Prevention through Process Safety Management (PSM)
3. Design, construction requirements and Maintenance, safeguards and operational features for exit routes
4. Emergency and fire action plans
5. emergency response equipment
6. Additional Requirements for Specific Workplaces / Operations
7. Personal Protective Equipment
8. communication

using Analytical Hierarchy Process (AHP) and data analysis is performed by using Expert Choice software.

To ranking is required to define the main criteria and sub-criteria and patterns are rated based on it. Given the importance of the life cycle of any system, phases of the cycle (prevention, preparedness, response and recovery) are considered as the main criteria and the requirements of studied patterns were classified into four groups. In table7, the way of categorizing requirements of studied patterns is shown in four categories: prevention, preparedness, response, and recovery.

By placing each of the criteria, sub-criteria and options to get her and drawing the connection between them, hierarchy pattern is defined as figuer3.

According to the created hierarchical model, a questionnaire to gather experts' opinions in this field were developed and provided them. At the end completed questionnaire in formation was analyzed and investigated using the software.

Among the four main criteria for prevention, readiness, response and recovery prevention phase with a score of 0.662 achieved the higher starting, after it phases of preparation, recovery and response respectively ranked in second to four the respectively. (Figure 4).

Among the studied sub criteria in the prevention group of requirements Principles & method of Prevention, in the preparedness set of sub criteria Emergency response strategy & plan (ERS & ERP), sub-criteria of Communications in Response group and sub-criteria of Cleanup of Facilities in the recovery group achieved the highest score.

Among the studied crisis management patterns that were defined as investigated options in the analysis of hierarchical, models CCPS, NFPA, DEP, OSHA and ISO respectively placed in the first to fifth positions. (Figure 5).

Table 7. How to categorize the requirements of studied patterns

		ISO	CCPS	NFPA	DEP	OSHA
Prevention	1. Principles & method of Prevention		■	■	■	■
	2. Principles & method of Mitigation		■	■		
Preparedness	1. Emergency response strategy & plan (ERS & ERP)	■	■	■	■	■
	2. Emergency response equipment	■	■	■	■	■
	3. Physical Facilities and Systems		■	■		
	4. Competence & Training		■	■	■	
	5. Identification of Credible Incidents		■	■		
	6. Exercises, Evaluations, and Corrective Actions			■		
	7. Laws, Requirements and Authorities			■		■
	8. Mutual Aid/Assistance & Countermeasures			■	■	
Response	1. Finance and Administration		■	■	■	
	2. Command and control	■	■	■	■	
	3. Communications	■	■	■	■	■
	4. Medical emergency response	■				■
	5. Environmental emergency response	■	■		■	
	6. Security				■	
	7. Detection of the need for emergency response	■				
Recovery	1. Recovery Functions		■			
	2. Cleanup of Facilities		■			

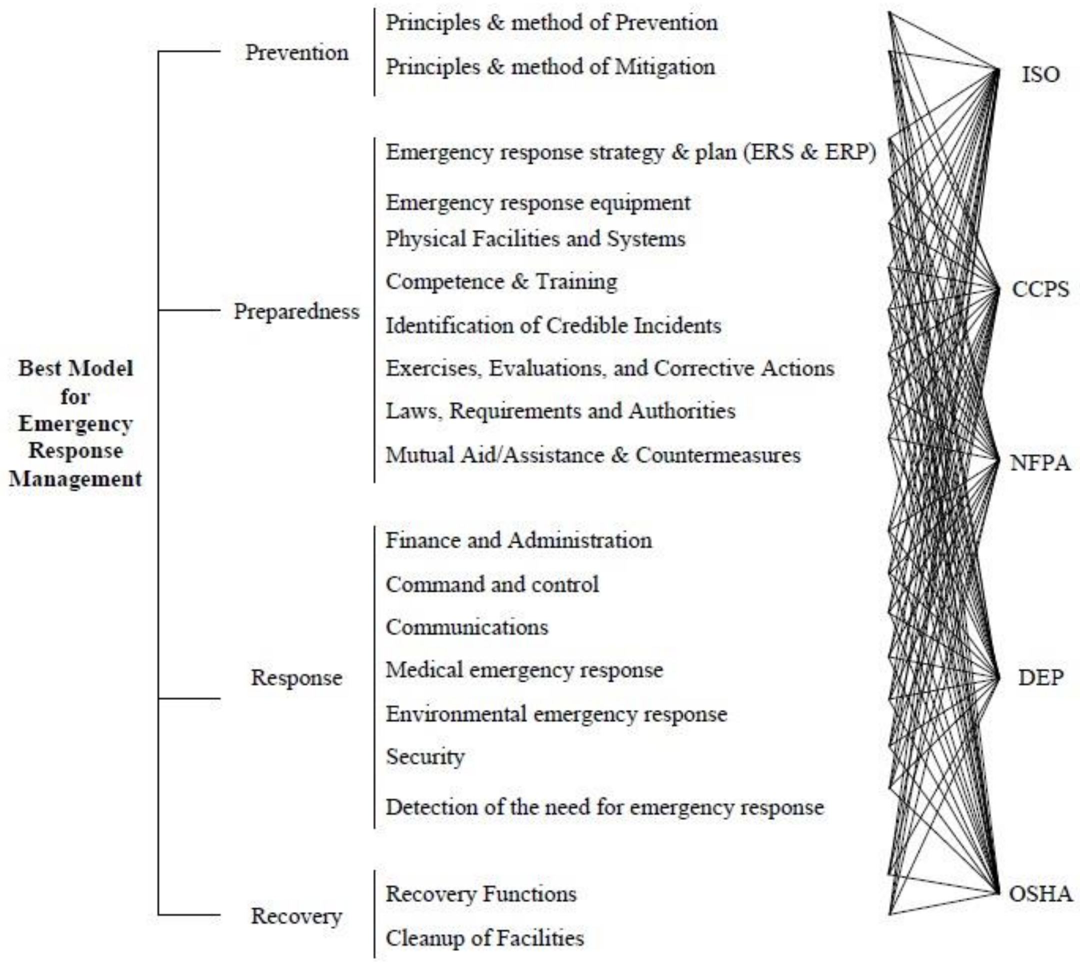

Fig. 3 Pattern of hierarchy.

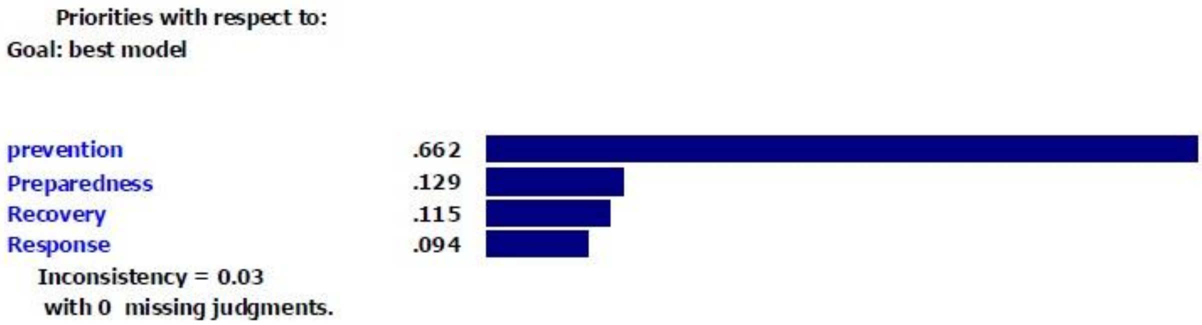

Fig. 4. The results of rankingthe main criteria

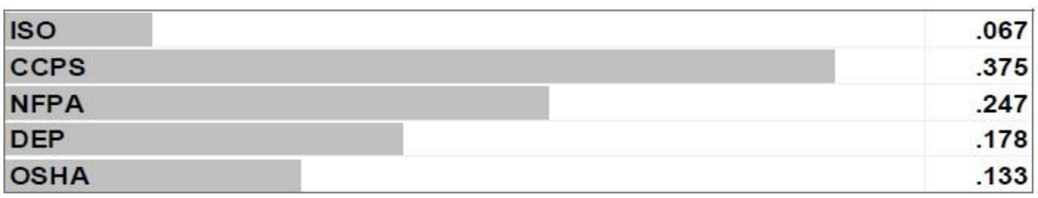

Fig. 5. The results of ranking the main criteria

Table 8. Native model of emergency management.

	Elements		Requirements according with
Prevention	1.	Principles & method of Prevention	CCPS ERP Model
	2.	Principles & method of Mitigation	CCPS ERP Model
Preparedness	1.	Emergency response strategy & plan (ERS & ERP)	DEP ERP Model
	2.	Emergency response equipment	NFPA ERP Model
	3.	Physical Facilities and Systems	CCPS ERP Model
	4.	Competence & Training	CCPS ERP Model
	5.	Identification of Credible Incidents	CCPS ERP Model
	6.	Exercises, Evaluations, and Corrective Actions	NFPA ERP Model
	7.	Laws, Requirements and Authorities	OSHA ERP Model
	8.	Mutual Aid/Assistance & Countermeasures	DEP ERP Model
Response	1.	Finance and Administration	CCPS ERP Model
	2.	Command and control	DEP ERP Model
	3.	Communications	NFPA ERP Model
	4.	Medical emergency response	CCPS ERP Model
	5.	Environmental emergency response	DEP ERP Model
	6.	Security	DEP ERP Model
	7.	Detection of the need for emergency response	ISO ERP Model
Recovery	1.	Recovery Functions	CCPS ERP Model
	2.	Cleanup of Facilities	CCPS ERP Model

CONCLUSION

To develop indigamous pattern of crisis management in the petrochemical industry to reduce the environmental consequences of accidents, five international model CCPS, NFPA, DEP, OSHA and ISO are analyzed and ranked, that the presented model by the Center for Chemical Process Safety America (CCPS) with a score of 0.375 achieved the highest rating. But by studying the achieved scores about all the requirements of the 5 models, dealing with the requirements that despite achieving high points in their group, not placed in the pattern CCPS (as Laws, Requirements and Authorities in the defined pattern by OSHA) and or have higher score than the same pattern in CCPS model. For example, it can be pointed to the elements of Emergency response strategy in the presented model of ISO that has achieved a higher rating from the same pattern in the CCPS, namely developing a Workable Plan. Thus, to define the indigenous pattern, these requirements were investigated and placed in the native model. So, indigenous pattern of crisis management with approach of reducing environmental consequences of accidents were defined as follow.

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