

# Integrated Coastal Zone Management in Kuwait: A Knowledge-Based System Model

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## ABSTRACT

A coastal environment is intrinsically multifaceted and active, making its management challenging. Development and natural processes could affect a coastal environment, and so reliable efforts need to be implemented to preserve this environment and ensure coastal integrity. Inadequate control of stakeholders' activities worldwide and developmental projects are degrading coastal areas. Integrated Coastal Zone Management (ICZM) is a holistic management approach used to sustainably plan human activity within coastal zones. ICZM is being implemented in several countries to maintain a balance between social-economic development and environmental preservation. This research aims to develop a knowledge-based system that facilitates the implementation of an ICZM framework in Kuwait. The proposed system is an "Integrated Coastal Zone Management: Knowledge-Based System" (ICZM-KBS), which is a tool created using C# programming language. The tool supports the application of ICZM strategies to safeguard coastal areas. The system is designed to provide comprehensive means to raise awareness about the misuse of coastal zones, provide, identify, and collate critical environmental data, assess risks to be faced, and anticipate the development capacity of the coastal zone. An ICZM-KBS allows stakeholders involved in coastal zones to manage and mitigate risks associated with development projects to achieve sustainable development. The system was tested using a case study provided by Kuwait Environment Public Authority (EPA) experts, and it was found to be reliable and important to facilitate the ICZM implementation in Kuwait. Overall, this research focused on developing an ICZM-KBS, encouraging more sustainable marine space use safeguarding the coastal environment.

**Keywords:** Coastal environment; Integrated coastal zone management; Knowledge-based system; Risk management.

## INTRODUCTION

Coastal areas are considered the most dynamic and productive areas since the beginning of time. A coastal area has diverse ecosystems and is abundant with different marine resources. They are a site for transition, business practices, touristic attractions, and settlement areas. The seas and oceans are the main engine of the world economy, and their share in the global economy is equivalent to \$ 2.5 trillion (Hoegh-Guldberg, 2015). According to Sahin (2011), by 2030, 50% of the world population will be living within the coastal zone. Because of these various features that prompt growth, coastal areas are characterized as sites of urbanization (Mafwila, 2008).

It can be argued that rapid urbanization and economic development that are driven by social demands are the main sources of the diverse problems occurring in coastal areas. Current coastal area capacities are unable to meet all demands preventing their efficient development. Moreover, demands for a coastal area to provide and deliver diverse

services are increasing pressure on the environment subsequently leading to different coastal hazards (Mafwila, 2008). Negative impacts imposed on the coastal area such as pollution, erosion, salination of groundwater, and soil are deteriorating marine life and despoiling the coastal environment in the long run. These problems have been widespread internationally, and so proper management strategies were developed to minimize such issues and their effects (Mafwila, 2008).

The development of the integrated coastal zone management (ICZM) concept is imperative because it is an effective method that would help protect the coastal environment against rising pressures exerted on it. According to Mafwila (2008), ICZM is identified as a “dynamic continuous, interactive and multidisciplinary process to promote sustainable management of the coast”. It is a broad system joining the government, public, science as well as planning, divisional, and community interests to promote and employ a plan to safeguard and improve coastal systems and natural resources (Mafwila, 2008). In addition, it looks at the triangular relationship between the environment, the economy, and the society (Chua and Scura, 1992; Xue *et al.*, 2004).

The ICZM coordinating mechanism aims to achieve different objectives that would allow for a more sustainable use of the coastal environment. One of the main objectives is to illustrate the capacity of the coastal area by identifying allowable activities. Recognizing the capabilities of the coastal area would provide insight on the potential of what could be achieved at the coastal area. The inter-relationships of the different uses of coastal areas would be organized and coordinated to avoid, or reduce, conflicting activities (Celliers *et al.*, 2013). This promotes divisional cooperation and coordination to pinpoint key issues and formulate strategies that encourage more sustainable development. On the other hand, environmental guidelines must be enforced to minimize coastal area degradation to preserve the natural environment. There would be an efficient use of the marine resources available to provide different services. These are the main outcomes to be achieved through the implementation of an ICZM plan.

To close with, positive changes would be induced to optimize the benefits of coastal marine resources without comprising the environment and minimization of environmental degradation to maintain biodiversity (Ehler and Douvere, 2009).

## **THE ICZM FRAMEWORK**

The ICZM is a comprehensive notion being implemented in several coastal countries nowadays as a framework for the management of coastal areas to achieve sustainable development and to maintain the quality and the productivity of the coastal zone (Post and Lundin, 1996). This concept is extremely important since rising daily pressures on the coastal areas are threatening the integrity of the coastal environment. There is a limit for the magnitude of stress a coastal environment could withstand. The strain exerted on a coastal environment could be from natural coastal processes or by human activities (Beatley *et al.*, 2002). It is believed that both events are inter-related, and the anthropogenic activity can interfere with the physical processes of the environment. This obstruction prevents the ecosystem from maintaining a balance that is crucial for its vitality (Beatley *et al.*, 2002). Implementing more sustainable development measures is necessary because the impacts of current actions are too severe for current coastal area capabilities to maintain equilibrium. To achieve sustainability, development efforts should meet current needs without limiting the capability of future generations to satisfy their own needs (Beatley *et al.*, 2002). Broad knowledge of the uses of the coastal resource systems and their properties is crucial to a solid recognition and the use of ICZM (Thia-Eng, 1993). The ICZM was proposed as an innovative approach that would address coastal management issues to achieve ecological sustainable development through an organized system.

Sustainable coastal management requires the adequate identification of all stakeholders to understand the interrelationship between the parties and the role of each stakeholder in maintaining sustainable development. Niavis *et al.* (2019) considered that stakeholder engagement is essential in ICZM. Niavis *et al.* (2019) further explained that detailed stakeholder analysis would support decision-making particularly, where the coast capacity is limited. Coastal areas management and development may encounter conflict of interests of stakeholders that are usually participating in decision-making. Implementing ICZM process would help in coordination efforts with all stakeholders and

minimizing conflicts. Stakeholder analysis is performed to identify and assess the importance of individual, groups, or institutions that may have significant impact on the success of the ICZM process (Niavis *et al.*, 2019).

The ICZM framework has been implemented in many coastal areas and has been proposed for diverse objectives. O'Mahony *et al.* (2020) proposed the ICZM as a framework for climate change adaptation action using the example of ICZM implementation in Cork Harbor. In their study, O'Mahony *et al.* (2020) analyzed how the ICZM can facilitate the implementation of climate adaptation through the coastal management activity at the local level by reviewing national policy for climate adaptation. O'Mahony *et al.* (2020) argued that climate adaptation may be considered synonymous with ICZM in making transition from a primarily theoretical focus to comprehensive body of good practice. Another study by Van Dijk *et al.* (2016) discussed the options for socioeconomic developments in ICZM for the trinational Wadden area. The Wadden Sea Forum has implemented the ICZM as a process to achieve the sustainable development of the Wadden Sea in an environmentally, economically, and socially feasible approach (Van Dijk *et al.*, 2016). In their research, Van Dijk *et al.* (2016) stated that if broad ICZM is to be achieved, insights are needed into the combined ecological and socioeconomic system of the whole Wadden Sea area.

On the other hand, the implementation of ICZM process involves handling vast amount of information and data that need to be adequately processed and collated. This can be achieved by developing software applications or knowledge-based systems that would facilitate data collection and analysis while utilizing the collective knowledge and experience of associated stakeholders. A study by Gvilava *et al.* (2015) outlined the experience of the Black Sea countries with the application of European Union (EU) ICZM progress indicators. Gvilava *et al.* (2015) developed a software tool to simplify data entry and modification processes. The study recommended the considerations in building an interface between ICZM progress reporting and aggregated mapping of coastal sustainability indicators.

## THE ICZM IMPLEMENTATION CHALLENGES

There are various setbacks that could be encountered while implementing ICZM strategies. The challenges that could be faced may be caused by insufficiencies of different capacities including legal and administrative capacity, financial capacity, technical capacity, and human capacity. To face the challenges related to the legal and administrative capacity, it is inevitable to have an agency the has a legal jurisdiction that is expected to fulfill multiple roles and responsibilities such as defining and categorizing the coastal zones, developing and implementing coastal plans, and regulating the development activities in congested zones. Ngoran *et al.* (2016) concluded that, to achieve a beneficial employment of the integrated coastal management, the sectoral lines must be minimized. With respect to the financial capacity, adequate financial resources need to be available for the appropriate planning and application of coastal management strategies. On the other hand, to increase the technical capacity, the limited knowledge about the coastal dynamic processes needs to be reinforced with collecting the critical information about the coastal zone through continuous monitoring of the coastal and marine ecosystems and processes. Additionally, several efforts need to be established to identify the human activity pattern, to overcome the barriers of limited data and experience in implementing ICZM strategies, to assess the current government coastal management programs, and to establish and maintain a coastal database and information system. Finally, implementing the ICZM framework requires the availability of reliable human resources that can implement the process effectively. The anticipated barriers for the availability of such resources include the absence of manpower with interdisciplinary training in the different sciences including social, natural, and physical sciences as well as engineering disciplines that is necessary for understanding and enforcing the ICZM approach. More to this point, the lack of public awareness about coastal hazards, the developmental potential coastal areas could offer, and sustainable management of marine resources is another expected ICZM implementation challenge (Mafwila, 2008).

Until all these challenges are dealt with, optimum outcomes of ICZM would not be achieved. There needs to be raised awareness about ICZM to overcome the various challenges that may arise. Furthermore, the implementation tool and process must be simple and acceptable with appealing rewards to facilitate the implementation process. Therefore, initiating a coastal management knowledge-based system would assist in mitigating anticipated risks of improper management to protect the coastal environment.

Essentially, the unavailability of information about coastal area capacities has been a major constraint for having sustainable development in coastal zones in Kuwait. As a result, a conceptual framework for proper management of anthropogenic activity within the coastal environment needs to be established. In Kuwait, coastal development projects are improperly managed, and such inadequate control is posing a threat on the marine environment. Having access to the latest data and information about the various coastal areas is necessary to achieve effective management of a coastal zone and evaluation of anticipated project risk. In this research, an attempt to collect the essential information about the status of the coastal zone in Kuwait was undertaken, and then this information was implemented to develop an ICZM knowledge-based system. The developed ICZM can be considered as a pilot software to follow up coastal zone management under one controlled reference.

The unavailability of such an integrated framework for planning and managing a coastal area is the driving factor for this research. This research proposed an ICZM knowledge-based system that can provide an information database for marine development sectors, reduce potential losses to the different stakeholders, and minimize adverse environmental effects. The ICZM combines up-to-date principles of planning and resources management, and an intensive information basis for multidisciplinary projects of different stakeholders. It is a highly applicable framework for dealing with potential risks associated with a project through a risk management plan. This research aimed to reveal how an ICZM knowledge-based system would guide coastal zone development in an ecologically sustainable mode through incorporating a risk assessment tool that implements a standardized risk assessment model.

## **METHOD AND APPROACH**

The goal of this research is to facilitate adequate implementation of ICZM in Kuwait. The aim is to provide an effective management framework to minimize the impact of increased strain placed on the coastal environment. It was planned to achieve this goal by providing a tool to implement ICZM for managing coastal areas that may be used by Kuwait Environment Public Authority (EPA), which is the environmental regulatory agency in Kuwait. To accomplish this outcome, the following objectives were established:

1. Facilitate the development of a database that provides up-to-date data and statistics for coastal zones.
2. Identify all relevant stakeholders and their level of impact.
3. Identify and assess risk of current and ongoing projects.
4. Anticipate opportunities of future development for adequate utilization of coastal areas.
5. Offer plans to develop response strategies for different levels of impact.
6. Raise public awareness about risks of improper management.

Overall, to achieve these objectives, a knowledge-based system was created using Microsoft Visual Studio. It can be argued that launching an ICZM knowledge-based system would allow for better control and categorization of the coastal zones, which would assist in adopting more effective management strategies for coastal areas.

## **RISK MANAGEMENT PLAN**

Risk may be defined as the uncertainty of being exposed to opportunities or losses (Jaafari, 2001). The dynamic nature of a coastal environment increases a coastal area's exposure to risk. As a result, it is essential to predict its effect on the community or the environment by assessing the service or project to be developed at the coastal area. This would allow for appropriate anticipation of its risk to formulate other options or response strategies. Therefore, the evaluation of the risk impact requires the investigation of the anticipated threats and the assessment of the available alternatives to facilitate the selection of the most appropriate response. To manage risks, there are various risk response strategies including (Bu-Qammaz, 2015)

1. Risk elimination: to eliminate the sources of risk.
2. Risk reduction: to limit the consequences of risk.

- 3. Risk transfer: to transfer the risk to another party.
- 4. Risk acceptance: to accept the consequences of risk.

To adequately manage risks that are associated with a project, a risk management plan needs to be established (Bu-Qammaz, 2015). The risk management plan is developed to outline the process of responding to the anticipated risk. This plan is used to identify, analyze, evaluate, and respond to the anticipated risk as illustrated in Figure 1, and to achieve the rewards from the plan, the process must be dynamic. It is important to communicate, consult, review, and monitor the different stages of the risk management plan continuously to effectively mitigate the potential risk.

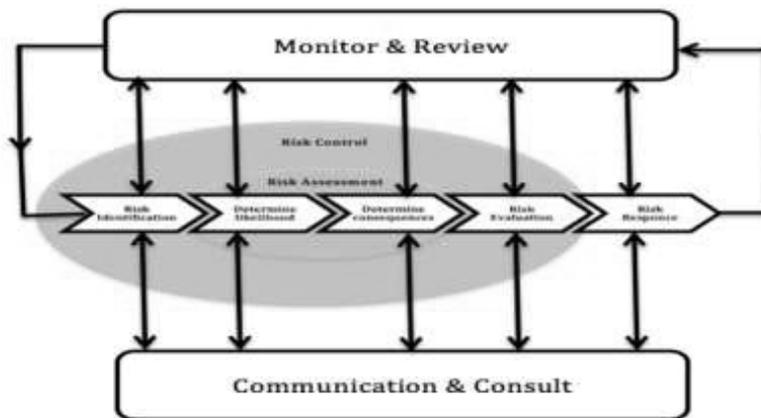


Figure 1. Proposed risk management plan.

The risk management plan combines different steps that lead to the stakeholder’s response to the risk. The first step is identifying the risk, which could be concluded with recognizing the different risk clusters associated with a project. These clusters represent the first level of the risk and may include the different risk factors of the project in another level. Such clusters and factors may be expanded or reduced depending on the nature of the project and the objectives of the risk management plan.

The second step of the risk management plan is to analyze and assess the risk (Hillson and Hulett, 2004). Anticipated risk may be assessed qualitatively or quantitatively as shown below in Figure 2. The qualitative assessment deals with assigning a relative ranking to each risk, whereas the quantitative assessment assigns a numerical rating to the prioritize the identified risks. The level of risk of the factor identified for a project may be scored using a traffic light assessment while assigning a numerical value to each linguistic risk level as shown below in Table 1.

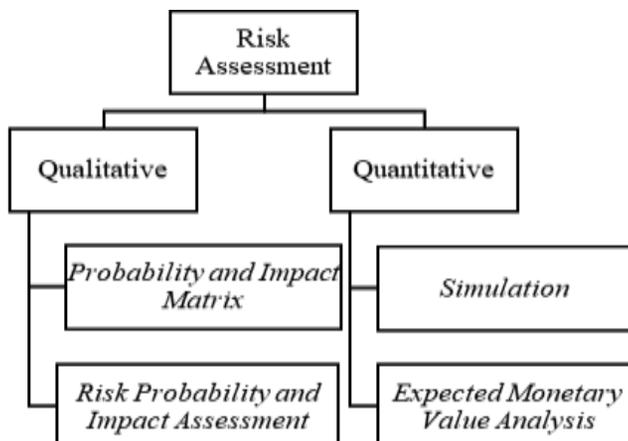


Figure 2. Types of risk assessment.

**Table 1.** Level of risk categories.

Numeric Value	Linguistic Value
1	Low
2	Medium
3	High

In this research, and to establish proper analysis of the anticipated risk, three different criteria will be assessed. The first criterion is the likelihood of the risk occurring, which describes the level of confidence that a certain risk will occur. The second criterion is the consequence of a risk, which describes the severity of the risk impact. The third criterion is the project risk level, and it depends on the project, where each project has its own scenario based on the coastal zone of the project. Assessing these criteria assists in the outline of the anticipated impacts of these risks on the asset being evaluated. Once the likelihood and consequence have been determined, a risk prioritization level could be established.

Each factor has its own probability (likelihood) and level of impact (consequence). These factors may be presented in the risk prioritization level matrix using the same traffic assessment values, as a high, medium, or low risk, which scored 3, 2, and 1, respectively. The risk rating of the risk factors may then be calculated as shown in Tables 2 and 3, respectively. In Table 2, the matrix provides linguistic and numeric risk value for each risk combination of likelihood and impact by multiplying their level (low (1), medium (2), and high (3)), and the total of all values for cases presented is 36. To achieve the normalized values, each combination was assigned its normalized value from the total (e.g., High-High case normalized value = 9/36 = 0.25). Accordingly, individual risk rating for each risk factor can be established, and then to calculate the total risk rating, the following formula can be used:

$$\text{Total Risk Rating (TRR)} = \sum (\text{weight} * \text{Risk Rating (RR)})$$

**Table 2.** Risk rating matrix.

		Consequences		
		Low 1	Medium 2	High 3
Likelihood	Low 1	Low 1	Medium 2	Medium 3
	Medium 2		Medium 4	High 6
	High 3			High 9

**Table 3.** Normalized risk rating matrix.

		Consequences		
		Low 1	Medium 2	High 3
Likelihood	Low 1	0.03	0.06	0.08
	Medium 2	0.06	0.11	0.17
	High 3	0.08	0.17	0.25

where the weight in the proposed formula represents the importance weight of the cluster normalized with respect to the other clusters. The total rating for each risk factor is calculated by multiplying 1<sup>st</sup> level and 2<sup>nd</sup> level weights of the cluster and risk factor, respectively. Importance weight is dependent on the number of clusters and risk factors identified. The summation of the product of the total weight and risk rating of all risk factors gives the value of the total risk rating for the project. Risk assessment is followed by the third step of the risk management plan, which is the evaluation of the risk. Project risks are evaluated to prioritize the assessed risks and to suggest the most appropriate response for the defined risks. The evaluation can suggest eliminating, controlling, transferring, or accepting the given risk.

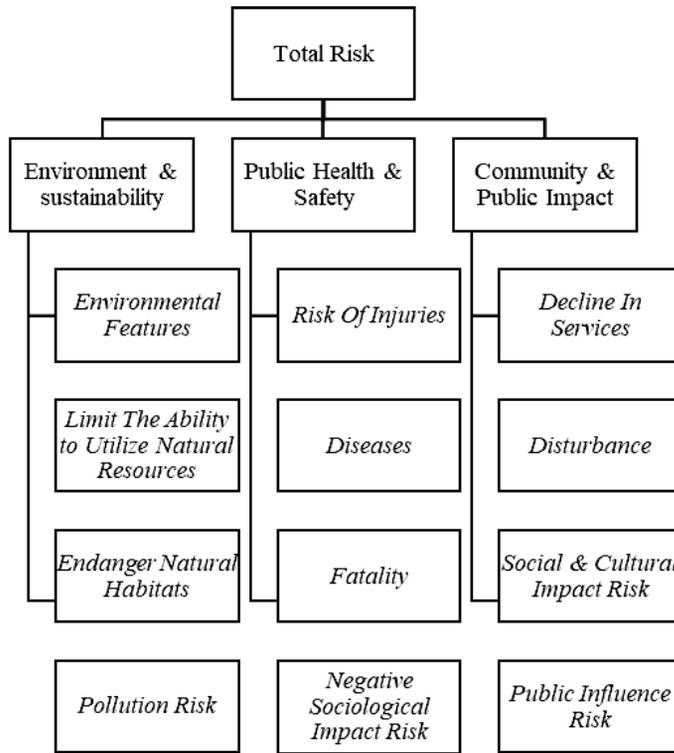
Based on the described evaluation above, a decision can be made to either reduce the likelihood of a risk event or reduce the impact arising from that risk. The action strategy (response) describes the stages needed to implement the approach. The response strategies could be implemented through the following approaches:

1. Government: facilitating the cooperation and integration between sectors and different stakeholders.
2. Improving regulations and enforcement of environmental laws; identification and protection of endangered habitats; prohibition of environmentally harmful activities in threatened areas; and strict application of Environmental Impact Assessment (EIA) and Strategic Environmental Assessment procedures on all projects.
3. Knowledge: training people about the value of environmental management; training programs such as training management staff in understanding coastal nature; and raising environmental awareness among the public.
4. Public & community: protecting critical infrastructure and services (i.e., water supply and electricity supply; telecommunications; sanitation; and roads) and protecting existing community structures.

## HIERARCHICAL RISK BREAKDOWN STRUCTURE

The defined risk values are used for measuring the amount of risk for a certain project. To calculate the total risk rating, risk clusters and risk factors had to be identified to express the importance weight of each cluster and factor. To identify these clusters, the nature of the development environment must be understood.

The risk clusters were defined as 3 different categories including Environment & sustainability, Public Health & Safety, and Community & Public Impact. The factors identified under each cluster represent the first step of the risk management plan, which is identifying the risk. The identified risks were clustered in a breakdown structure known as hierarchical risk breakdown structure (HRBS) as shown in Figure 3 (Hillson, 2003). The depicted HRBS accumulates all the risk sources that may define the total risk related to the project. It would ultimately help in understanding the predicted risks that may be encountered by a project in a coastal zone. Overall, this breakdown structure can be used to guide the risk management plan.



**Figure 3.** Coastal zone projects hierarchical risk breakdown structure.

It was assumed that all the defined clusters are equally important; thus, each cluster has an equal importance weight of 33.33% (i.e., 0.33). On the other hand, the project risk level is expected to be similar in all projects at the same coastal zone. However, the individual risk factor risk rating is independent and different for each project. This assumption was discussed with the former deputy EPA director in Kuwait (referred to as the “expert”) who confirmed it and agreed that the defined clusters are comprehensive and included all the types of risks that may be encountered. To evaluate the reliability of the proposed risk model, it was applied to a case study provided from the expert, and the results will be discussed in the following section.

**VALIDATION OF THE RELIABILITY OF THE RISK MODEL**

The expert was requested to provide his own assessment to the defined risk factors for a current project. First, the project to be used as a case study was defined, then the risk factors were placed in Table 3 to be rated to provide the risk rating. Then, the total project risk rating is calculated and compared to the Total Risk Rating Equivalents in Table 4 to define the level of project’s risk. Finally, Table 5 illustrates the model’s proposed risk response based on the assessment results, where each project and its risk level have their own scenario.

**Table 4.** Total project risk rating equivalents.

Numerical Risk Assessment	Linguistic Risk Equivalent
$\leq 1$	Low
$1 < Rate \leq 2$	Medium
$2 < Rate \leq 3$	High

**Table 5.** Proposed risk response plans.

Risk level	Action required	Risk Evaluation	Risk Response
<b>High</b>	Immediate action required eliminating or reducing risk to acceptable levels.	Unacceptable /Intolerable	Effective (i.e. effective response plan to be developed to response to the high-risk areas)
<b>Medium</b>	Immediate to short-term action required eliminating or reducing risk to acceptable levels.	Tolerable	Adequate (i.e. adequate response plan is needed to monitor and response to the risk)
<b>Medium</b>	Short to medium term action to reduce risk to acceptable levels or accept risk.	Tolerable /Acceptable	Needs Improvement (i.e. the available approaches may be accepted or improved depending on the acceptance level of the assessed risk)
<b>Low</b>	Accept risk.	Acceptable	None (i.e. the project imposes no concerns and the associated risk may be accepted)

The information about the project that was provided as a case study and was assessed by the expert as listed in Table 6. The project stakeholder is a governmental stakeholder, which is the Ministry of Public Works (MPW). According to the expert, this project was used as a case study because it is a current operating project that has an impact on the sea front in Kuwait Bay.

**Table 6.** Case study general information.

<b>Project Description</b>	Sewage treatment plant / Sulaibia
<b>Location</b>	Kuwait - Sulaibia
<b>Description</b>	Treatment plant (600,000 m <sup>3</sup> )
<b>Stakeholder</b>	MPW

The expert was requested to provide project level risk for the coastal zone, the likelihood of each risk factor, and the level of the anticipated consequence with respect to the project under assessment. Based on the provided ratings, the cluster local risk ratings and the total project risk ratings were calculated. As can be seen from Table 7, the total risk rating was calculated as 1.45, i.e., Medium Risk as listed in Table 4. The results were discussed with the expert who confirmed that it was acceptable and aligned with the anticipated risk level of the given project. Thus, the assessment was reliable. On the other hand, the proposed risk strategies based on the level of risk were also discussed and found logical. The development of the general and specific risk response plans is dependent on the involved stakeholders and their objectives in addition to risk controllability and ownership.

Table 7. Project risk assessment results.

Cluster	Cluster Weight	Risk Factor	Project Risk Level	Value of Project Risk	Likelihood	Consequence	Risk rating	Total Rating by Cluster	Total Rating	
Environment & Sustainability	0.33	Environmental Features	High	3	Medium	Medium	0.11	0.33	0.11	
		Limit the Ability to Utilize Natural Resources	Medium	2	Medium	Medium	0.11	0.22	0.07	
		Endanger Habitat	High	3	Medium	Medium	0.11	0.33	0.11	
		Pollution Risk	High	3	High	High	0.25	0.75	0.25	
<b>Cluster Local Risk Rating</b>							<b>1.63</b>	<b>Medium</b>	<b>0.54</b>	
Public Health & Safety	0.33	Risk of Injuries	Low	1	Low	Medium	0.06			0.06
		Diseases	High	3	High	High	0.25	0.75	0.25	
		Fatality	Low	1	Low	Low	0.03	0.03	0.03	0.01
		Negative Sociological Impact Risk	High	3	High	High	0.25	0.75	0.75	0.25
<b>Cluster Local Risk Rating</b>							<b>1.59</b>	<b>Medium</b>	<b>0.53</b>	
Community & Public Impact	0.33	Decline in service	Medium	2	Low	Medium	0.06			0.12
		Disturbance	Medium	2	Low	Low	0.03	0.06	0.02	
		Social & Cultural Impact Risk	Medium	2	Medium	Medium	0.11	0.22	0.07	
		Public Influence Risk	High	3	High	High	0.25	0.75	0.75	0.25
<b>Cluster Local Risk Rating</b>							<b>1.15</b>	<b>Medium</b>	<b>0.38</b>	
<b>Total Project Risk Rating</b>							<b>1.45</b>			<b>Medium</b>

## THE ICZM KNOWLEDGE-BASED SYSTEM

It is believed that a knowledge-based system (KBS) would provide a viable tool for capturing and utilizing the essential information and knowledge related to the coastal zones in Kuwait and would facilitate the proper management of the coastal zones. Thus, the KBS allows for the effective implementation of the ICZM concept. The KBS system offers a holistic framework that would assist in following a systematic procedure to manage Kuwait's coastal environment. The developed ICZM-KBS has a simple user interface design that can utilize the latest attained knowledge to evaluate and control the use of different coastal zones. As a result, it is a user-friendly tool that provides a beneficial assessment of the coastal area for the target user. It is designed to present the risks associated with the use of the coastal area and anticipate future capacity for development. Most importantly, it is an environmentally friendly solution because it is developed into an interactive user application. This ICZM-KBS aims to systematically evaluate and control coastal areas under one controlled reference to minimize potential errors.

The objective of creating this application is to have a design that is compatible with the common computer operating systems to facilitate the implementation process. Additionally, the design is consistent with common computer applications so that users will be able to utilize their own knowledge, and no further training for using the ICZM-KBS would be required. The application was developed using Microsoft Visual Studio (C#) programming language, since it could create applications to be used on computers, mobiles, tablets, and the web. The ICZM-KBS software provides a systematic procedure to insert inputs into the system to collect the desired outputs. This can help save time by reducing steps usually taken by the regular paperwork procedure. It is simple and capable of providing effective, valuable, and clear outputs. The software allows for storing and utilizing the stored information in the system for future use, which is very essential for effectively managing a dynamic environment such as the coastal zones.

ICZM-KBS consists of many windows that serve diverse functions. Initially, the user will be introduced to the "WELCOME" window as shown in Figure 4, which offers three options to the user: start and proceed to the software, read how to use ICZM-KBS, or quit. There is also a "HELP" button that opens another window to provide step-by-step guide on how to use the ICZM-KBS. Once the user chooses to start using the software, login options will be displayed.

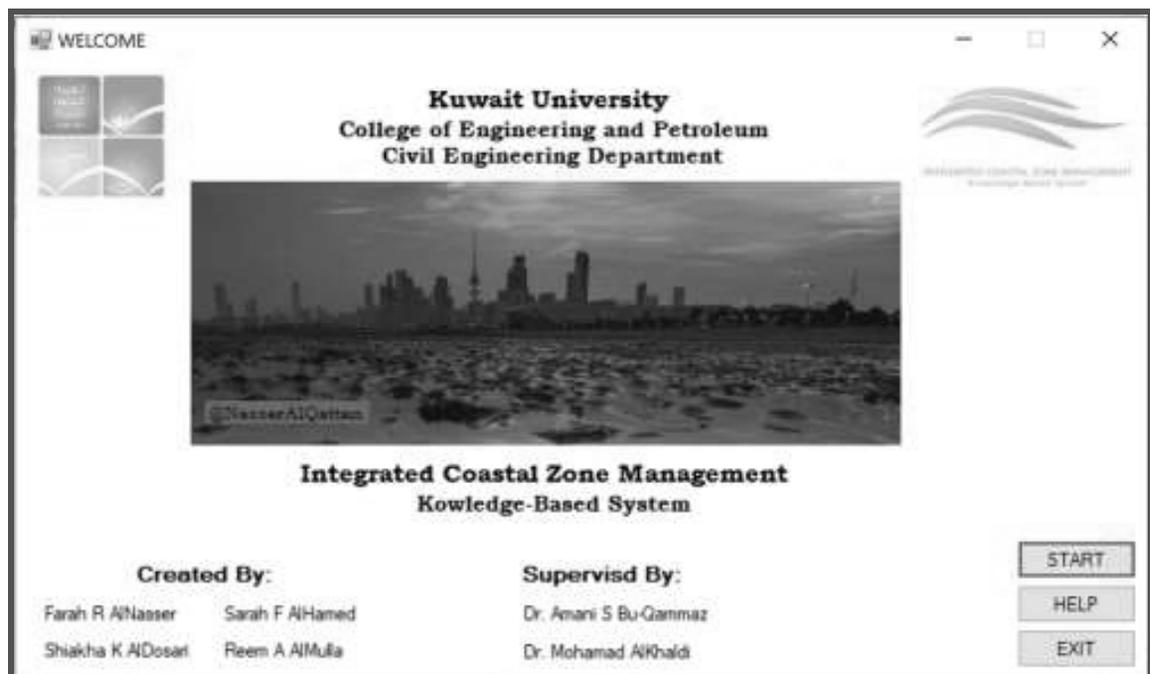


Figure 4. The ICZM-KBS welcome screen.

To use the ICZM-KBS to assess current projects, the user needs to click on the “Form” button in the menu strip. To evaluate the projects, the user may click on the evaluation form depicted in Figure 5, which allows entering information about the employee who is evaluating and the project under evaluation; the form also includes the assessment of the current projects owned by the same stakeholder to reveal if there are any violations recorded on the same stakeholder. Finally, the user may choose to save the assessment to complete the evaluation. The ICZM-KBS offers another important function, which is the risk assessment, and its form is shown in Figures 6(a) and 6(b). Figure 6(a) depicts the same risk clusters and factors of the HRBS with their normalized risk rating, while Figure 6(b) shows the individual and total local risk rating for each risk factor by clusters together with the project total risk rating. This assessment implements the exact risk assessment process and HRBS that was defined and validated in the Risk Model. The risk assessment form helps the user identify the projects risk rating based on the entered project assessment. If the assessment results imply applying penalties on the project, a violation form under the same strip may be issued for the project. Before exiting the assessment, the user can save the form at the desired location.

The screenshot shows a window titled "Evaluation Form" with the following fields and sections:

- Employee:** ID, EXT., E-Mail, Mobile No., Date (Day, Month).
- General Information about Stakeholder:** Civil ID, E-Mail, Mobile No., Name, Nationality.
- Current Projects:** Number of Current Projects (Excluding this Project), Category, Type, Project, No. of Violations, Location, Name of The Project, Description.
- Buttons:** CLEAR, SAVE and FINISH.

Figure 5. The project evaluation form.

The screenshot shows the 'Risk\_Assessment' application window. On the left, there is a 'General Information' section with the following fields: Identified Asset (Sewage treatment plant/Sulbi), Location (Kuwait/ Sulabia), Asset Description (Treatment plant 600,000 m3), Stakeholder (MPW), Topography (-), Geomorphology (-), and Date (Monday, September 14, 2020). Below this, the 'Risk Rating' is displayed as 1.452, and there is a 'Start Assessment' button. On the right, there are several risk categories with their respective ratings: Environment and Sustainability (0.543), Public Health & Safety (0.529), Community & Public Impact (0.383), and Project Total Risk (1.452). A 'Rating Scale' is shown with Low (0,1), Medium (1,2), and High (2,3). On the far right, there are buttons for various risk categories: Environmental Features, Limit the Ability to Utilize Natural Resources, Ecological Features, Pollution Risk, Risk of Injuries, Diseases, Fatality, Negative Sociological Impact Risk, Decline in Services, Disturbance, Social & Cultural Impact Risk, and Public Influence Risk.

Figure 6(a). Risk assessment form general information and total risk rating screen.

The screenshot shows the 'Risk\_Assessment' application window with the 'Assessment Criteria' section. It is divided into three columns: Environment and Sustainability, Community and Public Impact, and Public Health and Safety. Each column contains several sub-sections with Likelihood, Consequence, and Proj. Risk Level dropdown menus, and a Rating field. The ratings are: Environment and Sustainability (0.35), Natural Resources (0.22), Habitat (0.33), Pollution Risk (0.75), Community and Public Impact (0.12), Disturbance (0.06), Social and Cultural Impact (0.22), Public Influence (0.75), and Public Health and Safety (0.06), Diseases (0.75), Fatality (0.03), Negative Sociological Impact (0.75). On the right, there are navigation buttons: '<<', 'Calculate', '1.452', and 'Clear'.

Figure 6(b). Risk assessment form assessment criteria.

On the other hand, the software provides a map function, which is revealed in Figure 7. This function can be found under the maps menu to visualize the projects locations in Kuwait using Google maps by inserting the name of the project. Finally, valid environmental laws and regulations that are particularly applied in Kuwait are collected under the policies button in the menu strip; this would support public awareness of the laws and regulations related to coastal areas and environment in general.



**Figure 7.** The map screen.

The ICZM-KBS was also introduced to the expert, and the available functions of the developed software were discussed. The expert describes it as an important tool that would facilitate the implementation of the ICZM in Kuwait. The expert also indicated that implementing the risk assessment model into the software would create a common ground for assessment and fairness between all potential projects, as the same defined factors would be assessed for all projects under assessment, which would eliminate the variability of the assessment reports by using standardized assessment criteria. Then, and based on the risk level, the adequate response strategy can be implemented as shown in Table 5. It must be emphasized that response strategies may be categorized into two main categories, namely, general and specific, where general response actions shall be defined based on the risk that may be encountered by the environmental zone and the specific risk responses shall be defined based on the project specific characteristics. The expert added that the possibility of having a web-based version of the software and different levels of access would create a great opportunity of expansion and thus integration between all stakeholders, including EPA, MPW, Ministry of Finance, Ministry of Interior- General Department of Coast Guard, Kuwait Municipality, Kuwait Ports Authority, the current and potential investors, the public, and others.

## CONCLUSION

In this research, an Integrated Coastal Zone Management Knowledge-Based system was created. The ICZM-KBS was designed to be implemented as a reliable tool in effectively managing and controlling coastal areas. Different stakeholders who are involved in coastal environment activities may use this framework to mitigate and manage

anticipated risks of developing a project. This system could also be used to raise public awareness about coastal management problems through revealing the risk impact of abusing the coastal zones. The software design reveals how it was as a user-friendly one. Thus, it is an appropriate approach for dealing with the improper management of coastal areas to hopefully enhance the future capacity of the coastal environment for future generations. The incorporated risk assessment model into the ICZM-KBS was tested using a case study, and it was found to be reliable.

On the other hand, although it can be argued that the developed software helped in achieving the objectives detailed in this research, some improvements could increase its performance and effectiveness. These improvements would be the subject of future work to expand the application and ensure its implementation as recommended. The software could use symbolism to introduce and identify the status of each project and coastal area; for example, the map may use color coding to indicate congested or problematic areas. Moreover, the map could be more interactive showing a brief description of each project at the coastal area. Allowable coastal activities should be identified and communicated to the users to avoid misconduct and misuse of the coastal area. Providing a live chat box for users to upload comments or photos instantly to identify any violations occurring at the coastal area. This could help the community to react to negative human activity to raise awareness about wrongful use of marine space. Such recommendations could be implemented to further expand the capabilities of the ICZM-KBS software. Applying these improvements merely enhances the performance and effectiveness of the system and would result in a tool that can be implemented by the environmental authorities for better control of the coastal environment.

To close with, most of the information collected during this research was obtained from available literature and through meetings with EPA experts. For such research to be tailored for the coastal environment in Kuwait, there is a need for up-to-date quantitative data to be implemented in the research, but access to documents from different organizations was not an easy task. This limited the scope of the information that was presented in the research and the developed software. Therefore, further exploration of this research to implement reliable quantitative data expanding the effectiveness of the knowledge-based system created will be the subject of future work.

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