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Resilient Maintenance System to Avoid System Disruptions Due to External Shock: Application to Drainage System in Qatar

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Abstract: Many negative occurrences in any system cannot be linked to a single failure cause or system malfunction. They usually occur as a result of unforeseen combinations of typical performance variability. Disasters that human civilization has had to deal with in the past have highlighted the need of being ready and having the ability to quickly recover from a sudden and unexpected change in technological, organizational, social, and economic status of the community. Continuous emergences of business continuity disruptions lead to the global orientation towards resilience management application replacing the conventional risk assessment. The research studies risk assessment data prior to and after the emergence of resilience affecting shocks, and conducts a set of questions that will formulate resilience evaluation. The study proposed an evaluation framework of the current drainage system that will subsequently institutes a framework for a resilient system complimenting the main resilience attributes into three main models, and continuously improve its vulnerability status. The originality of this study lies on the unique demographical, geographical status of Qatar, the relative newness of drainage authority in Qatar and recent formation of its risk team.

Keywords: Qatar, Resilience management, Risk assessment, System shocks

Introduction

Background

Drainage System

Since the early Mesopotamian Empire in Iraq - ca. 4000–2500 BC- , drains were recognized in the streets. Since then, the need for efficient sewer systems began to be mandated by specific legislation in all industrialized countries. One of the most significant aspects was the provision and distribution of water, as well as the hydraulic transfer of sewage into drains. Rapid technical advancement since the 20th century generated a dismissal for old water technologies that were regarded to be far behind the modern ones. Until now, drainage systems are thriving with knowledge. There are numerous issues relating to sewerage and drainage systems that keep emerging with the advance of maintenance and data recordings. Infrastructure systems are increasingly needed by modern civilizations to deliver basic services that enable economic growth and quality of life [1].

In Qatar, ASHGHAL Assets Affairs (AA) is in charge of the operation and maintenance of drainage infrastructure. This includes – but not limited to- the following:

- Wastewater Network:
    - Sewage treatment works (STW): A sewage treatment plant works by circulating air in order to stimulate bacteria to reproduce and break down sewage. The idea is to produce effluent that is

cleaner and more environmentally friendly. It works in a similar way to a traditional septic tank, but with important modifications. Sewage treatment plants can treat the waste of commercial buildings or a large number of household residences, depending on their size.

  - Package treatment plants (PTP): Similar to STW, PTP is a package that will execute similar role of STW but with compact size, simpler design and serve smaller residential areas.
  - Sewage tankers: Tankers that will move the sewage to Sewage treatment works and Package treatment plants from the sewage sources that are not connected to drainage networks.

- Treated water network: Treated water network or treated sewage effluent is the processed water residual from Sewage treatment works and Package treatment plants process that can be used for something other than human consumption.
- Surface ground water network: networks that carry surface and ground water for disposal or usage. Any freshwater that is founded in wetlands or lakes is considered surface water. Groundwater, on the other hand, is found in water sources located underground. The majority of groundwater comes from snowmelt and rainfall that seeps into the bedrock through the soil. This water will settle between cavities and fissures in the rocks.
- Pumping stations: Stations that will transfer the water in all network types if the gravity force is not enough. They can differ in size and type depending on the size of the city and the type of the pumped effluent.

COVID-19 in Qatar

At 26th of February 2020, Qatar has recorded its first COVID case. Since then, more than 350,000 cases have been recorded over two years after first case, with most of them coming mainly over three waves.

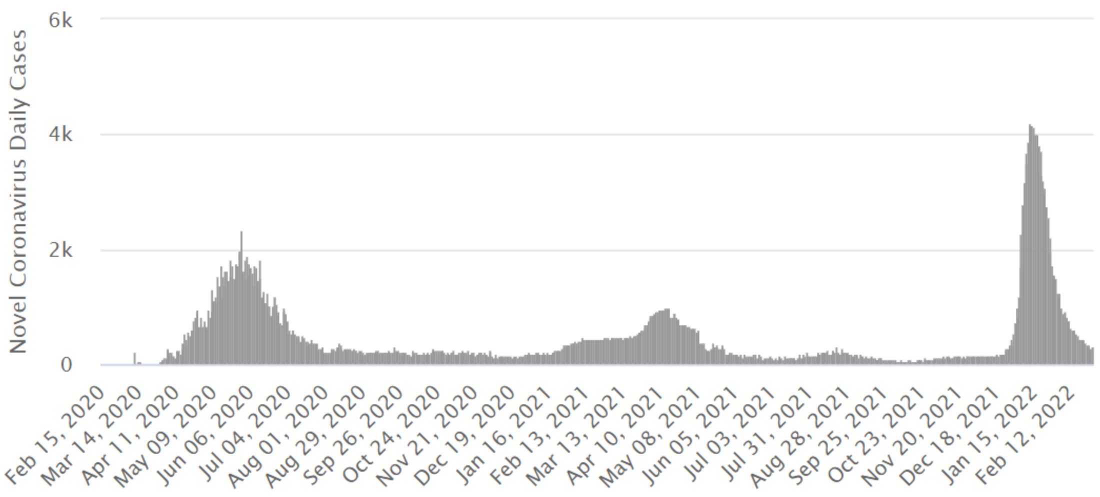

Figure 1. Coronavirus Daily Cases in Qatar

By February 2022, the death rate of COVID-19 in Qatar was among the lowest in the world (670 deaths or 0.1% of cases) and the percentage of vaccines taken by civilians is around 215 doses per 100 people. The medical resources alongside the awareness of the danger lead to a relative success dealing with COVID-19 in Qatar. On the other hand, because of Precautionary regulations or constraints, the adaptability of work atmosphere after

COVID was mandatory to assure safety and abide with regulations issued by the supreme committee for crisis management in Qatar. Depending on the cases in Qatar, the supreme committee for crisis management will modify the constraints for home quarantine period, percentage of workers on site, meetings capacity and even importing strategies. Thus, companies and systems must react with the regulation to maximize productivity and minimize risk.

The way that all industries are now conducting business has been significantly impacted by the restrictions that have been placed in place. The effects of lockdown on infrastructure projects might vary from nation to nation and project to project depending on the type, activities, scale, and location [2].

Problem Statement

The evolution of wastewater collection and treatment has been growing health and environmental concerns, particularly as cities grew in size. Drainage systems are becoming more sophisticated and disposals that are dumped to the systems are becoming different and more hazardous. That lead to continuous improvement of it maintenance system to assure the healthy condition of drainage assets. Determining the right steps required to maintain the performance of a rapidly integrating and degrading drainage system over a lengthy service life is a significant problem for asset managers. To accomplish this goal, infrastructure repair activities must be properly budgeted for and planned [3].

Many negative occurrences cannot be linked to a component failure or system malfunction. The best explanation for them is that they arise from unforeseen combinations of typical performance variability. Thus, hindsight analysis, error tabulation, and failure probability calculations cannot be the basis of an effective management [4]. Current operational conditions do not comply with the original operating procedures. It is typically caused by limited capacity to forecast future events and their features, as well as a lack of knowledge regarding the kind and scope of uncertainties, the nature of linkages and the amount of complexity [5].

Disasters that human civilization has had to deal with in the past have highlighted the need of being ready and having the ability to quickly recover from a sudden and unexpected change in technological, organizational, social, and economic status of the community [6]. An effective management needs to be proactive as well as reactive [4]. A resilient system with resilience engineering fundamentals will assure these traits. A system is considered resilient if it reduced failure probability, reduced failure consequences -including decreased loss of life, property damage, and adverse economic and societal effects-, and reduced time of recovery to be back to normal condition [7]. Although system resilience has gained more attention in several areas of systems engineering over the past few years, there is still a lot of variation in how resilience is defined [8]. According to resilience engineering, variability should be controlled rather than repressed because some of it is unavoidable and desirable [9]. Various studies in the field of safety have paid close attention to resilience engineering, as a different perspective on safety and continuity.

While traditional approaches to risk management rely on knowledge gained after the fact, failure reporting and risk assessments compute probabilities based on previous data, resilience engineering seeks to improve an organization's capacity for recognizing, absorbing, and adapting to variations, changes, disturbances, interruptions, and surprises [10]. The difficulty is in creating thorough procedures for providing a system with the skills it needs to adapt to changing conditions and recover fast and effectively from a shock event [8].

Dissertation Objectives

Due to the reoccurrence of extremely rare events on local and global levels, an effective system must be proactive as well as reactive. Risk assessment that is built based on previous data only will be vulnerable to against sudden disruptions. This study aims to:

- Define resilience affecting hazards that might occur to drainage system & measure risk assessment vulnerability.
- Apply an evaluation criteria for resilience capability of the current drainage maintenance system
- Develop resilience management framework for drainage maintenance system against sudden system disruptions

Dissertation Scope

The study will focus on

- Study validity of resilience management applicability for drainage system
- Retrieve data from past maintenance risk assessments
- Study the ability of risk assessment alone to mitigate hazardous situations that will affect drainage system in Qatar
- Apply the proposed methodology evaluate the current resilience state, and suggested resilience management framework for drainage system.

Overview of the Dissertation

The study is organized as follows. Firstly, the introduction of this study is stated background for drainage system and COVID-19 stats in Qatar, then proceed to problem statement that subsequently identify objective and scope of the study. Then, literature review is presented to obtain the technical backbone to produce an adequate Gap analysis. Chapter 3 highlights the methodologies used and sources of the analyzed data. The results will be discussed simultaneously to propose the model and resilience evaluation criteria. Finally, recommendations, limitation and future work is will conclude the study.

Literature Review

Drainage System

Flooding in urban drainage systems is mistakenly assumed to be a result of only overloading in systems such as excessive rainfall and growing urbanization. Internal system risks such as equipment failure, sewer collapse, blockages and other imperfections in maintenance system could lead to the same outcome [11]. A similar case can be seen in most of researches on urban drainage systems. Researches tend to concentrate on examining hydraulic dependability, which only takes functional failures like the occurrence of excessive rainfall or rising dry weather flows into account [12]. Thus urban drainage systems must thus be made more resilient in order to improve their operation and maintenance capability for adequate flood protection service levels in the cities they serve and to reduce the flooding implications under unforeseen or unusual loading situations that cause system failure [11].

Current hydraulic reliability-based design and rehabilitation techniques for urban drainage frequently concentrate on preventing hydraulic functional failures driven on by a certain design flood occurring at a specific frequency. The systematic level of flood protection is determined by the design flood return period. Some strategies will be based on hydraulic dependability, places a lot of attention on recognizing and measuring the likelihood of excessive rains and reducing the likelihood of the ensuing hydraulic failures. However, such methods exclude additional reasons of failure, such as structural or component problems [11].
It is believed that the direct use of reliability-based methodologies for the assessment of structural failures in may not be adequate, primarily due to the fact that the causes and processes of failure are mostly unknown and tricky to quantify. To guarantee that drainage systems are built to be robust to exceptional situations as well as dependable under normal operating conditions, it is crucial to create resilient strategy [11].

Maintenance System

Every process that is conducted over a period of time will require maintenance. Maintenance has become increasingly a subject of numerous researches because of its increasing cost with time. Many studies have been conducted to assess the frequency of maintenance, stage when to conduct maintenance and categorization of maintenance depending on its role [13].
Maintenance is a set of actions that occurs during equipment or a process lifecycle to fix it, restore it or retain it. The maintenance will be conducted based on:

- Time interval: classified as Preventive
- Current condition of the system: classified as corrective or condition-based
- Predicted conditional upset: Predictive

Maintenance system existence will enhance reliability of the system which is defined as the ability of the system to reduce its own frequency of failure when subjected to operation loads over normal operating conditions [11].
Maintenance has developed throughout history starting as mainly corrective, before researchers start to study the financial advantages of applying preventive maintenance and its huge impact on the lifecycle of the maintained system. Moreover, technology advancement leads to have a set of predictable techniques that monitor the condition of the system continuously and detect an upcoming process disturbance that is not within the preventive period to maintain it [13].
This development of maintenance required an integration management system to balance between the various maintenance jobs based on their duration, criticality and predictability. Any predictive or corrective maintenance might modify the preventive maintenance frequency. Thus, availability of the maintenance data in a system will

ease decision making, and act as a reference for futuristic similar processes [14]. Availability of resources needed to conduct a maintenance job is a challenge, especially for unplanned jobs. So, the development of a management system will assure the availability of resources based of strong and reliable maintenance data [15]. Asset managers and maintenance teams must weigh a variety of decision-making horizons, including short, mid, and long-term perspectives, as well as the anticipated effects of their choices on the performance of the asset over the desired time period, in order to allocate the limited resources [16].

The importance of having a maintenance system and objectives is to increase the efficiency of the system, increase availability over its lifecycle and improve the overall reliability of it. The current competition put the pressure of management and stakeholders to assure that the system runs with the least maintenance cost, highest performance, highest quality and most overall control [13]. The commercial and operational environment that modern businesses work in is complicated. Their entire management and operations are subject to a number of severe risks connected to natural, technical, technological, market, organizational, economic, financial, political, and other frequently intangible important elements [5].

Risk Assessment

Risk is identified as an uncertainty on an objective of a firm, project or an operation. The definitions of risk are many and every researcher has its own interpretation of the definition that is similar to the main identification of risk. Some of the qualitative definitions of risk are:

- The possibility for an unfortunate to occur
- The potential of unwanted consequence to be realized
- Exposure of uncertain proposition
- Uncertainty of the severity of a consequence, and many other definitions [17].

The management and monitoring of risk throughout a lifetime of a system is referred to as the risk assessment. Risk assessment will keep a balance between safety and operation by identifying risks of the operation and the plans to avoid it [18].

Risk is determined by three factors: hazard, exposure and vulnerability. A hazard is an incident that disturbs system owners, managers, operators, or stakeholders because it has the potential to compromise the identity and functionality of the system. The characteristics of the process producing the event and the characteristics or behaviors of the system exposing it to the event are considered to represent the exposure to this hazard. Vulnerability is defined as the degree to which an incident compromises the regular system dependability [2]. Risk analysis is ultimately impossible in situations when risks are unknown [19]. Risk analysis is a main part of risk assessment. Analyzing risk could be reached by different techniques, but all should cover:

- Planning:
    - Identification of risk and gathering operational and organizational data
    - Selection of analysis method
- Risk assessment:

  - Cause and effect analysis
  - Root cause analysis of previous similar operations
- Risk treatment:
  - Risk avoidance, transference or reduction
  - Identifying and evaluating alternatives
  - Decision making and management review [20].

Resilience Management

It is becoming increasingly clear that, in the context of rising threats, risk analysis alone is insufficient for protecting critical infrastructure systems. Recent catastrophes like Hurricane Katrina, the Deep-water Horizon, and the Fukushima nuclear reactors serve to support the idea that ignorance in complex systems exists to some extent and cannot be eliminated. Therefore, risk assessment alone will never be completely justified, and ignoring resilience would make failures inevitable and their effects worse .Subsequently, resilience engineering was introduced [19] [21]. Despite being a more recent notion, resilience has a wealth of literature from many different fields. The idea of resilience is often employed in study across a variety of fields, including psychology, sociology, economics, and engineering. Resilience is a term that frequently refers to both flexibility and strength [7]. Engineering and ecological perspectives on resilience are fundamentally dissimilar. While ecological resilience is primarily concerned with retaining function, engineering resilience primarily concentrates on guaranteeing function efficiency post failure. The more specific definition of the first meaning is of an importance to drainage systems [22].

Resilience is the ability for a system to sustain itself during or following any disturbance by adjusting its operation to serve the required function of its original operation during expected or unexpected conditions. Resilience is a proactive defense tools that can be developed if the firm strategy assist its presence. Resilience will attempt to control the systematic situation proactively and predictively by reducing the probability of failure and the recovery time to go back to non-disturbingly run system [23].

As mentioned earlier, Reliability is a trait that guarantees that the system effectively fulfills its purpose during normal operating condition. Normally, reliability is judged based on anticipated or required service levels. Resilience is a quality and performance measure, but is particularly important when faced with unforeseen or unusual interruptions. Reliability and resilience are correlated with the probability and magnitude of a disturbance, as seen in the figure below. Subsequently, the two elements are linked, with reliability serving as a foundation for resilience in a probability-magnitude measure [24].

To improve resilience application, resilience engineering was introduce to develop engineering measures, decision making techniques, safety tradeoff over performance and feedback obtaining to enhance ability of any firm to predict process disturbance and provide a set of instructions to damp its effect. A complex system design and management method based on resilience take into account unknown hazards that have any chance of happening. Such unidentified hazards may manifest as low chance stochastic events or as dangers that develop from integrated, complex systems. Resilience engineering is a mutational evolution of reliability principles, business continuity tools and understanding of system disturbance and risk [18] [21].

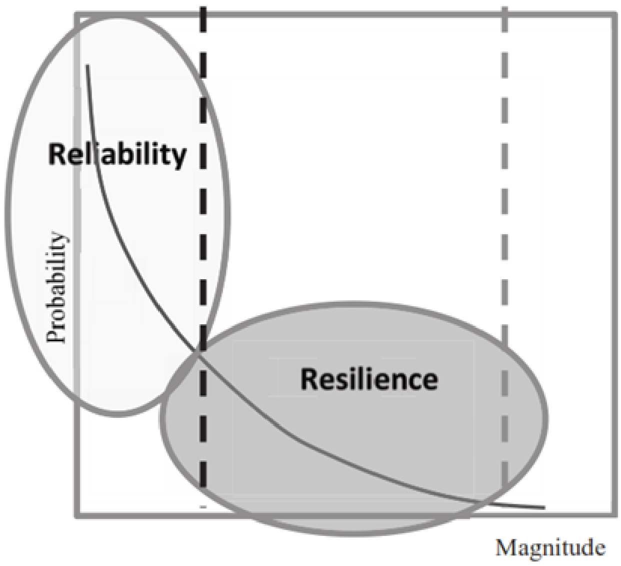

Figure 2. Relationship between Reliability and Resilience

Vital part of resilience engineering is to assess the tradeoff between safety and processes. Resilience engineering will introduce indicators to measure the concern over an upcoming alert that would lead to a conflict between deliver the process and safety of it [18].

Resilience engineering has been the center of many studies and researches due to its promises of process continuity assurances. Numerous efforts have been made to come up with conceptual principles to provide the ground base of a resilient system. In order for a system to be resilient, the firm organization should:

- Respond to expected or unexpected system disturbances and threats
- To monitor and quantify performance
- To have an adequate risk assessment that sets up preventive and protective barriers.
- To learn from experience and develop prevention capabilities to observe, identify, and comprehend weak signals and alarms. [14] [25].

However, the resilience of the system will not only depend on the incorporation of resilience engineering tools. The system and the organization running it will also contribute to the application of resilience. Some of the factors that affect resilience are:

- Contextual factor: lack of detection potential or sense of abnormality. Knowing what is to be detected or how normal is current situation will require experts view in absence of proper resilience context
- Design factor: the system design and its flexibility to integrate resilience engineering on
- Lack of communication means/ signals
- Emergency response availability in the system or organization
- Safety management system: managing tradeoffs

These factors contribute to resilience of the system from technical initiation, technical running and organizational awareness and margins of safety [23] [25].
After understanding what is needed and the factors contributing to the best resilience engineering practice, the resilience engineering will have to acquire the abilities to execute its premise efficiently. Those abilities are:

- Ability to monitor what is happening
- Ability to respond to what happened
- Ability to learn from what happened
- Ability to anticipate what will happen

Any system that has these abilities and have the organizational assistance to apply them will be resilient [20].
A main objective of resilience engineering is continuity. Continuity need to be measured to rate the overall resilience of the system, identify gaps and support the development of operational plans. Also, resilience engineering must be integrated within the assent management activities including maintenance systems from strategic planning prospective [15]. If the continuity of the system disrupted, the resilient system will pass through a period of restoration to be back to its status, this is called recovery time. The recovery time ended once the operation or system goes back to a desirable operating level.

In addition to continuity, performance variability is viewed as both natural and necessary in resilience engineering. It is the origin of both favorable and unfavorable results. Constraining performance variability would compromise the capability to achieve desired results, which is not enough for a system to be called healthy or safe. Instead, the best course of action is to reduce variability that can result in undesirable consequences while simultaneously enhancing variability that might result in desirable ones.

Risk vs Resilience

Although there is now much more need for resilience to be included into system design and management, there are still very few concrete ways to do so in an engineering environment. Quantitative metrics or models would make it easier to evaluate complex designed systems and determine if structural or functional changes are needed to reach the desired degree of resilience, which would allow the engineered systems to withstand dangers that are not yet known to exist [21].

Resilience engineering practices have recently replaced the conventional risk management approach. Resilience engineering is an alternative that evolve the risk knowledge, risk assessment, failure reporting and historical data to a proactive continuous response technique defending any shocks or abnormalities. The basic risk assessment will be part that supports a resilience system [10] [26].
There are main principal ways differentiating resilience management from risk management. Risk analysis starts with the assumption that risks are known, whereas resilience techniques call for planning for the unexpected [22]. Conventional risk assessment used its methods for defining undesired uncertainties, allocate their negativity and mitigate any exposure of the system to these uncertainties. In comparison, resilience management

is a trait or a property of the system within the system that gave it the capability to avoid discontinuities during any disruptive exposure [27].

Resilience engineering provides systems engineering techniques to proactively manage risks by utilizing insights from research on failures in complex systems, including organizational drivers to risk and the factors that impact human performance [28]. Resilience must also have the anticipation capability which goes beyond standard risk assessments. The standard approach to risk and safety makes the assumption that systems are manageable once that the principles of functioning are known, that descriptions are simple and with few details, and that a system does not change while it is being described. The analysis of socio-technical systems is not seen to be suitable for only conventional usual risk assessments [10].

Simply, Risk assessment and resilience analysis are distinct from one another in a various ways. The main purposes of traditional risk assessment techniques are to quantify the negative effects of potentially unwanted events and to reduce the exposure of the business to such undesirable outcomes. Risk is a measurement of possible loss of any kind and is connected to the intensity of the effects of a disruptive action as well as the degree of uncertainty around those effects. Contrarily, resilience is an inherent or facilitated characteristic of a system that can successfully resist against (absorb, adapt to, or recover quickly from) disruptive occurrences [8]. Moreover, the standard risk assessment has proved insufficient in some recognized, low-probability, high-consequence scenarios [19].

In order for resilience engineering to be integrated with risk assessments, resilience engineers have to understand two major risk perspectives:

- Traditional perspectives: measures probability as the main component of risk
- Alternative perspective: Measures uncertainty as the main component of risk [20].

Extreme and Rare Events

Also referred to as “Black swan”, extreme and rare events risk has been the center of numerous researches recently due to the improved implementation of resilience management, and the emergence of new extreme and rare global events such as COVID-19. Black swan term was developed and used in financial market as a surprising event, but then extended as a metaphor outside the financial sector. These occurrences are usually challenging to deal with even for the massive impact of it or the surprising factor [29]. In theory, a set of unique circumstances may potentially coincide with the occurrence of a rare event. Thus, classifying and understanding them will limit the surprise factor and enhance the chance of maintaining a resilient system during their exposure [5].

Extreme events have many types depending on its occurrence, those are:

- Unknown-unknowns: Events that have never been known or faced
- Unknown-knowns: Events that have not been covered on a certain system analysis but might be covered in another
- Events that are known, but are not believed to occur due to the very low probability of occurrence [29].

Analysts, engineers, and scientists who make decisions in both the public and private businesses must realize that it is no longer acceptable to treat uncommon events as unrelated to their design, analysis, and operational strategies. A once-rare "Black Swan" occurrence can be predicted, mitigated, or even prevented to the point that it no longer qualifies as a black swan [30].

Gap Analysis

It is becoming more and more obvious by referencing numerous risk and resilience studies that, in the face of evolving threats, risk analysis alone is insufficient for conserving key infrastructure systems, especially in low-probability, high-consequence scenarios, even if it recognized. To achieve the targeted resilient system, gap analysis is shown to identify current state and propose action plan (see table 1).

Table 1. GAP Analysis

Current state	Target	Gap	Action plan
Disruptive events are defined and mitigated by risk assessment methods only	Developing a holistic resilient system in addition to the existing risk assessment	Business continuity plans, crises management plans, system testing and training material	Build a resilience management Framework that will standardize the continuously developed hazards, provide futuristic flexibility and recovery capability.
Unforeseen events or rare occurrences have been dealt with Reactively	Producing a maintenance system that can absorb and adapt when subjected to such events	Introduction of resilience management to the maintenance drainage system	
Risk register and Risk reports are the only guidelines to overcome a system disruption. Other rain and emergency plans are set, with No recovery plans.	Clear set of procedural documents that assist in hazards identification and mitigation without reliance on conventional risk assessment only	Documents that identify resilience management essentials, identify possible hazards, insist on recovery capabilities and continuously improve itself	To provide necessary documents is the form of policies, possible disruptive scenarios, monitoring & evaluation tools, testing and training

Methodology

General Approach

The evaluation of current drainage system of ASHGHAL will be based on a Framework for Assessing and Improving the Resilience of Organizations [31]. The framework will measure the current resilience capacity based set of questions, and risk assessment data that will be retrieved from ASHGHAL as the drainage systems owners in Qatar. ASHGHAL has been founded only in 2004 and risk data prior to risk team initiation was not as intense. In contrast, risk data have had three main categorization of time that will assess in identifying the resilient behavior of the risk assessment overall. This analysis will focus on risk planning, risk register forms, risk evaluation strategy and risk assessment execution. After the evaluation framework formed, Resilience management framework for drainage maintenance system will be built subsequently to overcome the major gaps in the studied drainage maintenance system.

Research Process Flow Chart

The process flow chart of the general approach for the study is shown below:

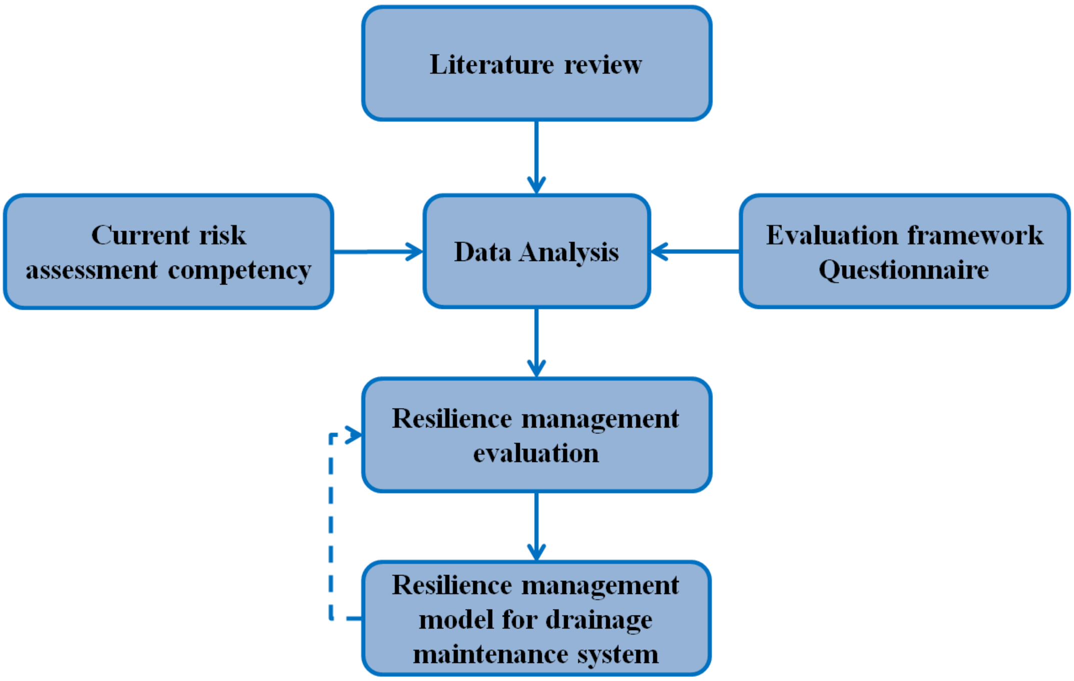

Figure 3. Process Flow Chart

Resilience Management Evaluation Framework

In 2008, a resilience management framework was introduced by then PHD student Ms. Sonia T. McManus. The author suggests in her framework that Resilience in a system that is complex, dynamic, and sophisticated depends on the ability of the organization to achieve:

- *Situation awareness:* is a gauge of how well an organization understands and perceives the entirety of its working system. This includes recognizing opportunities as well as crises, realize their impact, identify their triggers, and clarify comprehension of the minimal operational standards from the standpoint of recovery.
- *Management of keystone vulnerabilities:* identifies the management and operational elements of an organization that might have a negative influence during a crisis.
- *Adaptive capacity:* is an indicator of an existing culture and dynamics that enable it to make decisions that are prompt and suitable in both routine operations and disruptive situations [31].

The framework will be applied as an evaluation criteria for resilience capability of the current maintenance system, and assess in continuous improvements by setting gaps. The table below illustrates the resilience indicators the author applied for resilience capability.

Table 2. Resilience Evaluation Indicators

Attribute	Resilience Indicator		Description
situation awareness	Roles & responsibilities	SA_1	knowledge of internal staff roles and responsibilities as well as its external stakeholders
	Understanding of hazards & consequences	SA_2	Awareness of the diverse hazard categories and the effects they may have on the organization.
	Connectivity awareness	SA_3	Understanding how internal and external Stakeholders of the organization are interconnected (customers, local authorities, consultants, competitors etc.)
	Insurance	SA_4	Understanding the responsibilities and restrictions associated with any business interruption insurance policies and other insurance plans that the company may.
	Recovery priorities	SA_5	Understanding the basic operational needs, the priorities for achieving the set goals, and the expectations of major stakeholders
Management of keystone vulnerabilities	Risk management & planning	KV_1	Involvement level of the organization in planning processes such as risk, business continuity, and emergency/ crisis management planning
	Exercises	KV_2	Knowledge of the extent of participations in external emergency drills or designed internal drills for internal and external stakeholders
	Internal resources	KV_3	Competence of resources associated with people, processes, and other resources to fulfill anticipated minimal operational conditions in a crisis includes the stability of structure and economic status.
	External resources	KV_4	Anticipation of the organization on the accessibility and efficiency of outside resources to help it during a crisis.
	Connectivity	KV_5	Measurement of How the organization has partnered with other entities to guarantee the availability of resources in case of a crisis
Adaptive capacity	Silo mentality	AC_1	Realization of the silo mentality's negative consequences on the organization and the presence of techniques for minimizing them
	Communication	AC_2	Efficiency of all internal and external communication means and interactions in routine and disruptive situations for all stakeholders.
	Strategic Vision	AC_3	Degree to which the organization has created a strategic vision for its future operations and how well it has been able to communicate that vision inside the organization.

	Information & knowledge	AC_4	Capacity of knowledge and information gathering, maintenance, and sharing inside the organization and across external stakeholders
	Leadership & management	AC_5	Degree of supporting innovation by the, as well as how well decision-making functions under pressure.

Resilience Indicators will be rated by giving the organization a score of very high to very low depending on the resilience capability of the organization in each indicator captured from retrieved risk data or a set of questions asked while interviewing the firm/ company to evaluate their resilience envelope. The list of questions contains:

- To what extent are employees aware of their own unique roles and responsibilities well within organization?
- To what extent are employees aware of roles and responsibilities of others within the organization?
- How much latitude do the workers have in terms of their roles and responsibilities inside the organization?
- What kinds of risks do you believe this organization is subject to?
- What effects do you believe these hazards will have on the organization?
- How much control do you believe the organization has in managing them?
- To what extent is this organization engaged with its network of stakeholders?
- How effectively does the organization interact with and try to capture ideas and feedback from its employees?
- What kind of external funding or business interruption insurance is offered to the organization?
- How well suited is this to the anticipated threats and the impacts those hazards will have on the organization?
- What does the general public likely to anticipate from this organization in a time of crisis? How is this being comprehended?
- In the face of major catastrophes, how well do you believe other organizations and stakeholders will be capable of satisfying needs of your organization?
- In contrast to other organizations, to what extent is the organization aware of its significance to the society in the event of a crisis?
- Does this organization have:
  - Risk management planning
  - Business continuity planning
  - Crisis management planning
- How are current planning strategies integrated on the organization
- Who or what in the organization is the main driving force behind this kind of planning?
- How does the management of incidents/ emergency plans formulated in this organization
- What kind of crisis management drills does this company conduct? And how often?
- What are the main obstacles to involve in drills in this organization?
- Is the organization allocating spare operating rooms/ facilities in case of an event of main facilities failure?
- If so, how comprehensive and well-equipped is the spare facility?

- Is the organization prepared for an event of loss of power or communications? To what extent is the planning of those scenarios?
- How simple or challenging is keeping employees in the organization currently
- How simple or challenging would it be to involve, manage, or assist employees following a crisis?
- To what extent is this organization prepares for the effects a significant crisis will have on its employees both during and after it?
- How this organization is preparing for succession of current employees?
- How well-prepared are the employees for a situation where normal business needs to resume while the emergency is handled?
- How effective are the current systems and procedures?
- How does the organization perform financially?
- What kind of connections does this organization have with other businesses, such as vendors, service providers and other interested parties?
- What particular steps have been taken to foster positive connections with important stakeholders in this company and to sustain them?
- What do this organization expects from the other stakeholders during crisis?
- Is there existence of silo mentality in the organization? if so, where it is coming from?
- How simple or challenging is intercommunications between employees of different levels in the hierarchy of the organization?
- Is there a strategic vision or mission statement for the organization?
- How well has this been communicated throughout the organization?
- How closely do daily activities adhere to this vision and mission?
- How much is this vision likely to affect the organization's performance before, during, and after a crisis?
- Does the organization value the term “recovery” in crisis management?
- How is decision making formulated in this organization? does this differentiate in the presence of crisis?

Then, indicators will be combined for each attribute to formulate a chart as shown below.

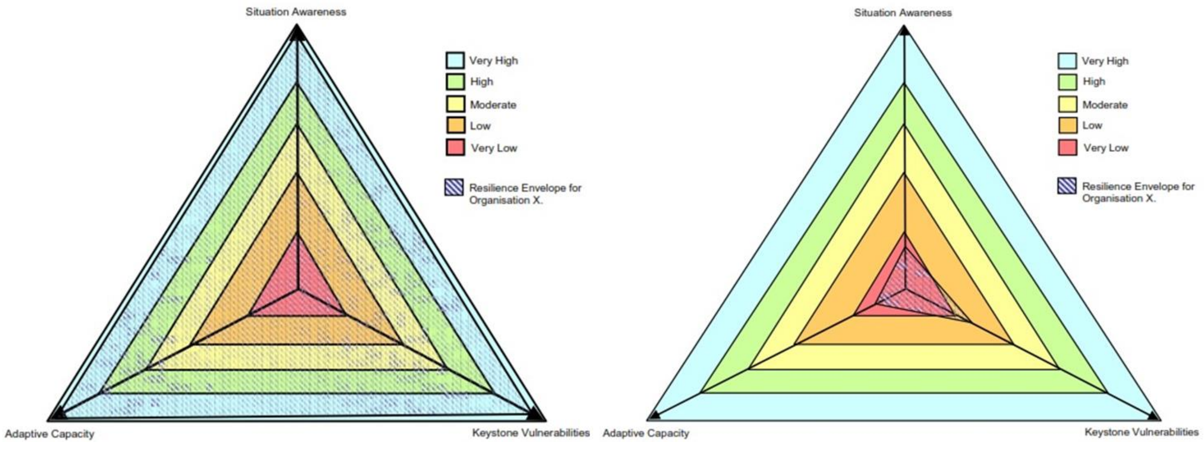

Figure 4. Evaluation Chart of V.High & V.Low Organizations

Data Sources

In this study, the data analyzed are grouped into three main groups

- Risk assessment data collection groups "historical data from drainage company":
    A. Data group #1: Risk data before initiating risk team.
    B. Data group #2: Risk data before emergence of COVID-19.
    C. Data group #3: Risk data after COVID-19 peak/assumed first wave.

Data Analysis for Each Group

For each of the data groups, several points were evaluated in the shape of answering the questions below:

1. Data group #1:
    A. Was there an inclusion of resilience management related risks that covers catastrophes and their mitigation plan? (Illustrated in pie chart yes/no).
2. Data group #2:
    A. Was there a noticeable pattern or similar risks for similar maintenance jobs? (Illustrated in pie chart yes/no).
    B. Was there an inclusion of resilience management related risks that covers catastrophes and their mitigation plan? (Illustrated in pie chart yes/no).
3. Data group #3:
    A. Was there a noticeable pattern or similar risks for similar maintenance jobs? (Illustrated in pie chart yes/no).
    B. Was there an inclusion of resilience management related risks that covers COVID-19 effects and/or other catastrophes and their mitigation plan? (Illustrated in pie chart yes/no).

Results of the 3 data groups will assist in:

1. Preparing resilience management assessment plan/chart for the suggested shocks of the maintenance system
2. Applying the proposed resilience management on maintenance job as a case study to evaluate the effectiveness of adding it

Results and Discussion

Results

Data group #1

First data group has been extracted from the risk assessment data of drainage maintenance system prior to initiating a risk team. At that period, the risk assessment was conducted by brainstorming meetings of engineers and experts in assessed fields, and documented by a consultant. In this kind of risk assessment, risks are initiated instantaneously without referring to a past risk files and organizational performing assets. The chart above analyzes 237 risk items dated between 2013 and 2019 before risk team initiation. As seen above, 11 0f all risks (5%) are covering rare events that affect resilience. Most of the risks registered during that period were very specific due to the risk initiation being held by field expertise individuals rather than risk assessment experts. Knowledge and prediction of resilience affecting scenarios and events require more than knowledge of the maintenance system itself.

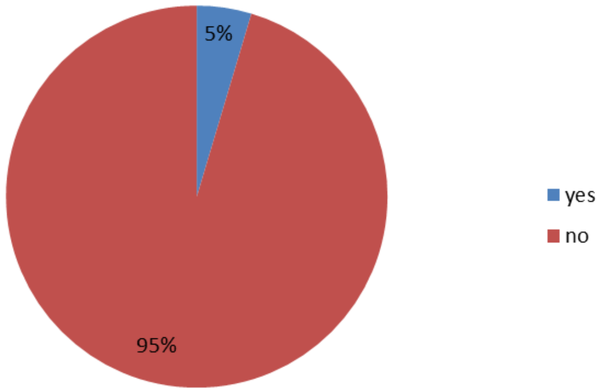

Figure 5. Coverage of Rare Events that Affect Resilience, before Risk Team Initiation

Data group #2

Second data group has been extracted from the risk assessment data of drainage maintenance system after initiating associated risk team, but before the emergence of COVID-19 (see figure 6).

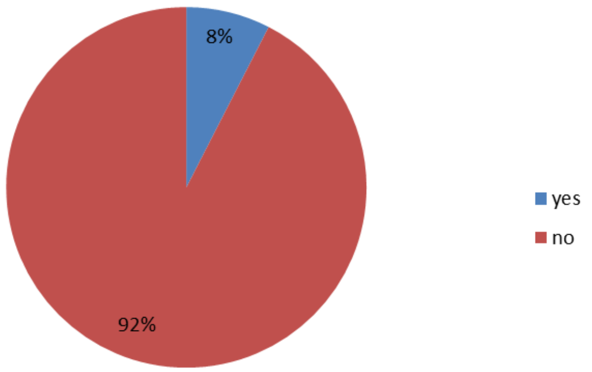

Figure 6. Coverage of Rare Events that Affect Resilience, after Risk Team Initiation

The chart above analyzes 53 risk items dated between May 2019 and January 2020 after risk team initiation but prior to COVID-19 emergence in Qatar. The data sample was limited in size due to the limitation of time, but the concentration of risks after the team initiation increases from 39/year to 71/year –as demonstration of density increase-. As seen above, 4 of all risks (8%) are covering rare events that affect resilience -war, rain events, force majeure and risk related to special events-. A slight increase in the percentage due to the concentration on general risks that my affect any system rather than specific risk items. The presence of risk assessment experts in the association led to a continuous reliance on the previous historical data to assist forming current risk assessments. Also, a pattern in risks was observed in different maintenance systems mainly because of the formation of the risk team. These patterns are analyzed and shown in the chart below.

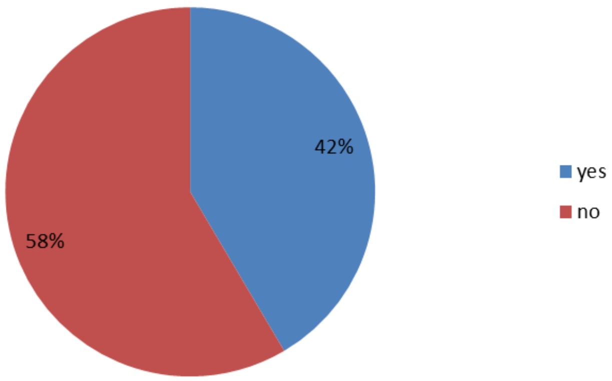

Figure 7. Pattern of Rare Events that Affect the Resilience, after Risk Team Initiation

As can be seen, 22 risk assessment items (42%) has been a similar to other risks that have been applied elsewhere during the period of the data collection. This pattern can be seen across other fields of the maintenance system, or other periods of risk assessment. Documentation of risk data throughout time will lead to form firm organizational performing assets where risk assessment of any new asset or newly assessed assets will not start from scratch. 58% of the risks are specific for the system or general ones that will be a pattern for futuristic assessments of a similar asset.

Data group #3

Third group of risk assessment data covers all risk assessment that occurs after emergence of COVID-19 (see figure 8).

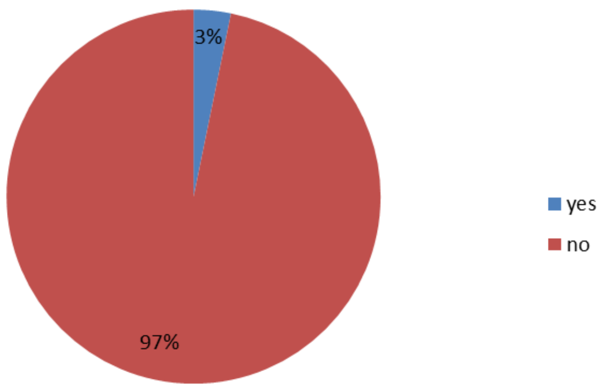

Figure 8. Coverage of Rare Events that Affect Resilience, after Emergence of COVID-19

The chart above analyzes 187 risk items from March 2020 till January 2022. The annual risk assessment data density got even higher to around 98/year. The emergence of COVID-19 lead to identifying new risks that was previously dealt with as a low likelihood risks to daily risks that need to be adapted. As seen from the chart, 6 risks (3%) are covering rare events that affect resilience. the increase in the bulk of newly assessed assets led to a further decrease in the general resilience affecting percentage compared to the risk team startup period (data group 2).

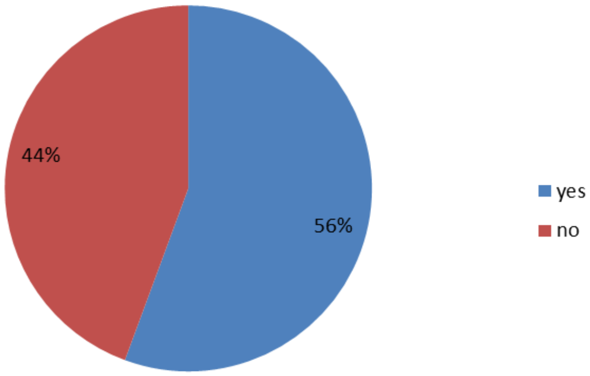

Figure 9. % of Overall Risks that have been within Pattern, after Emergence of COVID-19

As seen from figure 9, the development of the risk team and risk data management results in increase in the pattern of risk across the maintenance system assets to almost 56% (104 risk items). With proper documentation of risk assessment and coverage of all current and upcoming assets, this percentage will be in continuous increase to ease the risk assessment of similar assets.

Evaluation and Framework Formation

Resilience Management Evaluation Framework

Huge part of the resilience management framework for drainage maintenance system is the continuous improvement, and the system will not improve without efficient evaluation criteria. Evaluation criteria will help identifying the current resilience situation, identifying the gaps and propose the necessary actions to improve the resilience system subjected to resources availability. The article [31] suggested a model that is designed to evaluate the current resilience situation based on three main attributes 1) situation awareness, 2) Management of keystone vulnerabilities, and 3) Adaptive capacity. The author further suggested resilience indicators that are used to rank the three main attributes. The table below shows the form to be filled (see table 3).

Table 3. Resilience Evaluation Form

		Indicator	**Drainage operation & maintenance system**
situation awareness	Roles & responsibilities	SA_1	
	Understanding of hazards & consequences	SA_2	
	Connectivity awareness	SA_3	
	Insurance	SA_4	

	Recovery priorities	SA_5
	Summary	$\mathbf{SA_{COMP}}$
Management of keystone vulnerabilities	Risk management & planning	KV_1
	Exercises	KV_2
	Internal resources	KV_3
	External resources	KV_4
	Connectivity	KV_5
	Summary	$\mathbf{KV_{COMP}}$
Adaptive capacity	Silo mentality	AC_1
	Communication	AC_2
	Strategic Vision	AC_3
	Information & knowledge	AC_4
	Leadership & management	AC_5
	Summary	$\mathbf{AC_{COMP}}$
OVERALL RESILIENCE		

The table is filled with grading (very low, low, moderate, high, very high) by following the explanation from table 2, answering the set of questions that will give an idea about the grading, alongside risk data analyzed from data groups 1 to 3. The graph that is produced will then identify the performance of the current system as opposed to resilience and will paint a picture for further improvement. Below is a chart that illustrates the results of the four evaluated entities (see figure 10).

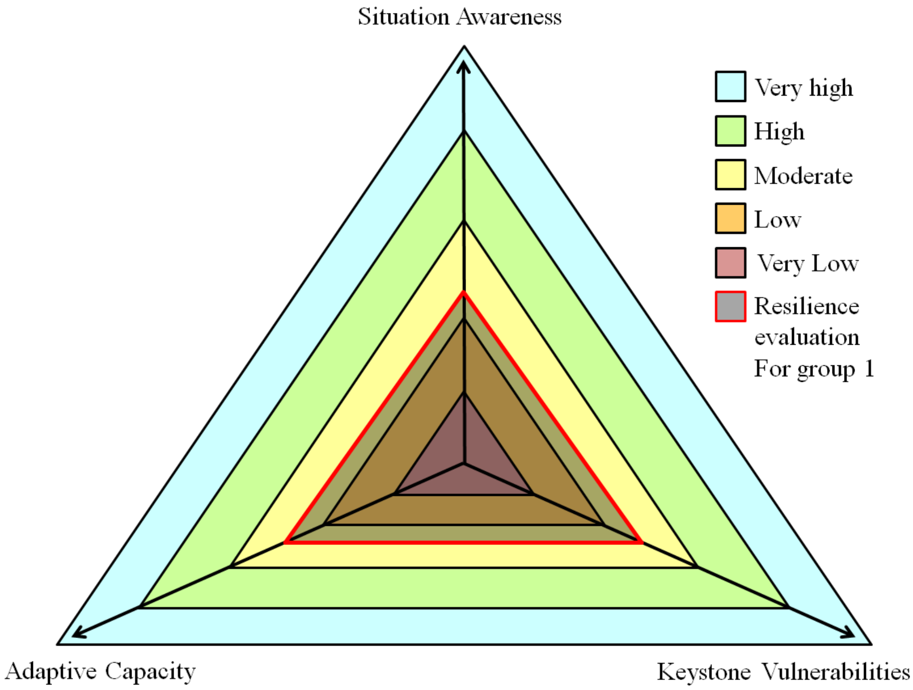

Figure 10: Resilience Envelope for Current Drainage System

The figure above shows the resilience envelope for the current drainage operation and maintenance system with a noticeable deficiency in resilience performance of the evaluated system due to the lack of resilience application as a standard procedure. Subsequently, a framework will be built based on the current disruption situations barrier and the transition to the proposed model.

Resilience Management Model for Drainage Maintenance System

The model below shows proposed model that will suit the resilience approach to cover drainage system from major disruptive scenarios. The model has been formulated based on the evaluation of current drainage system, alongside gap analysis that was formulated at the start of the study. Formulating the framework will be in three steps: i) identifying/ evaluating current status ii) presenting tools and techniques to formulate resilient system essentials, and iii) the proposed resilient form.

Table 4. Drainage Resilience Management Model

Conventional Disruptions Management for Drainage Maintenance System	Tools, Techniques & Standards	Resilient Disruptions Management for Drainage Maintenance System	
Risk Management "RM"		**Risk Management "RM"**	Resilience evaluation "Using resilience evaluation framework [31]"

• Risk Assessment
  • Risk ID
  • Risk Analysis
  • Risk Evaluation
• Risk Treatment depend on Resources Availability
• Risk assessment done separately by O&M SMEs with Risk Knowledge
• No Communication, Reporting or Recording Criteria
	• ISO 31000
	• Local Standards/ Legislations
	• Stakeholder Engagement
	• Asset Criticality
		• Risk Policy
		• Scope, Criteria & Context Knowledge Aligned With Policy
		• Risk Assessment
		  • Risk ID
		  • Risk Analysis
		  • Risk Evaluation
		• Risk Treatment depend on Risk Evaluation/ Asset Criticality
		• Risk Assessment done by an Associated Team With O&M SMEs Feedback, and Stakeholder Engagement
		• Risk Monitoring And Review Periodically, or Subjected to any Change in Operation/ Maintenance	

Business Continuity Management "BCM"	• ISO 22301 • ISO 22313 • ISO 22320 • Local BCM Legislation • Business Continuity Planning Lifecycle • Plan, Do, Act, Check cycle • Stakeholder Engagement • Benchmarking	**Business Continuity Management "BCM"**	

• Business Continuity Policy
• Drainage Networks O&M Incident & Emergency Management Classes
• Rainy Season Work Procedure
		• Business Continuity Policy
		• Business Continuity Plan
		• Drainage Networks O&M Incident & Emergency Management System, including
		  • Classes
		  • Triggers/ Disruptive Situations
		• Rainy Season Work Procedure	

Crises Mngement "CM"		**Crises Management "CM"**	
• Crisis Management Organizational Plan • Crises Types • Crisis Communications Guidelines	• ISO 22361 • Stakeholder Engagement • Benchmarking/ Stakeholders Crises Triggers • Brainstorming	• Crisis Management Organizational Plan • Crisis Management Policy • Crisis Management Control Center Allocation • Crises types/ Disruptive Situation • Crisis Communication Plan for each Situation • Crisis Recovery Plan for each Situation • Crisis Situation Trainings	

As discussed above, the drainage resilience management model contains three main parts linking current and proposed resilient model by a set of tools, techniques & standards in order to achieve resilient system, the system has to be supported by tools, techniques and standards that will assess the transition. These tools, techniques and standards are common use catalysts that came by national organizations, benchmarking or general experience.

Standards are found by an organization, country, or other global associations of similar systems. Standards are mostly relied upon to:

- Give direction and guidelines by making the best practice available
- Promotes knowledge sharing capability
- Establish a mandatory norm for whom ever rely on these standards to facilitate their systems

These standards assist in making design manuals, operation guidelines, corrective maintenance procedures, preventive maintenance procedures, and other documents all the way up to policies until singular asset plans. These standards set a common practice that might not fit every organization, but can be tailored to. ISO standards applied in resilience management model are:

- *ISO 31000 ISO 31000:2009 Risk Management – Principles & Guideline:* ISO (International Organization for Standardization) is a global federation of national standards. ISO 31000 is a standard that offers organizations concepts and guidance for risk management. Initiatives to ensure compliance with regulations are often relevant for those operating in a certain field and most of the time is country-specific. However, ISO 31000 is created to be applied in any size of organization. Its ideas are applicable to the public and private sectors.
- *ISO 22301 Security and resilience – Business continuity management systems - Requirements:* This standard emphasizes the framework and standards for building and maintaining a business continuity management system (BCMS) that develops continuity of operations according to the amounts and types of disruption that an organization might be subjected to following an interruption. Regulations, organizational and industry requirements, as well as the products and services provided, affect the outputs of business continuity management system (BCMS). The size and structure of organization, as well as the needs of its stakeholders, are all factors to consider. It majorly defines business continuity objectives, and gives major guidelines to establish, determine and control them. This standard is general, and can be applied in all organizations or parts of organizations regardless of specialization or size of the part that standard being applied on.
- *ISO 22313 Security and resilience — Business continuity management systems — Guidance on the use of ISO 2230:* This document generally founded to provide guidelines on the requirements specified in ISO 22301, not all the business continuity procedures. This guideline explains and clarifies the meaning and purpose of ISO 22301 and it requirements, as well as to support in the resolution of any ambiguities.
- *ISO 22320 Security and resilience — Emergency management — Guidelines for incident management:* With the massive technological and industrial revolution, it is expected that disasters and system disruptions will disappear. However, there are even new disaster shapes and forms that are being introduced in different system in a daily basis. Thus, in order to decrease the consequence of those

disasters, an incident management system must be in place.

This standard offers tips to firms on how to control the damages of all types of disasters. Multiple incident management activities are frequently shared amongst companies and agencies, regional organizations, and governments. As a result, all parties concerned must be guided on how to prepare for and implement incident management. The approach of this standard is to mainly guide the communications when disaster occurs, set roles and responsibilities and gave general mitigation steps to be followed once being subjected to such a system disruption.

- *ISO 22320 Security and resilience — Crisis management — Guidelines:* This standard offers crisis management guidance to assist systems in planning, maintaining, reviewing, and continuously improving crisis management competency. In other words, the standard intends to assure that the organization has the necessary procedures in place to deal with a crisis, which is becoming increasingly likely to occur at some time. Additionally, it emphasizes the significance of taking into account other organizational disruptions prevention elements like risk management, business continuity, or incident/ emergency management.

Risk Management "RM" Model

Risk management in conventional disruptions management for drainage maintenance system is mainly risk assessment only. Risks are identified, analyzed and evaluated. Without guidelines, there are no risk treatment priority criteria, no risk assessment triggers, and no communication plan. Moreover, Risk assessment will be done purely based on resource availability or once a disruption happen to a system. Even risk assessment procedure will be random if it is not standardized by a procedural document.

Results from data groups 1,2 and 3 suggests that a risk assessment that risk assessment must be standardized and documented to produce risk registers with minimum duplication and maximum efficiency. A dedicated team should not only perform risk assessment, but should perform a holistic risk management that understand its capability and document its strategies.

By applying ISO 31000 and local legislations as risk management guidelines, the standards will establish a norm of resilience into its system and will subsequently produce further documents to guide the overall resilient management system. Some of these outputs are:

- *Risk policy:*

  The Risk Policy outlines the methods for risk management, identifies a uniform approach for risk across the organization, and specifies the duties of top managers and risk ruling entities. Risk policy will assure that any risk plan produced has to align with risk strategies as well as organizational strategies.

  Risk policy will also enhance the risk aware culture in organization by communicating this policy to the employees of the organization. Also, risk policy will set the base for continuous improvement of the risk overall management by setting performance measures and evaluating risk status periodically.
- *Risk criteria, plans & procedures*

Risk criteria are not limited to determination about the importance of the risk to be evaluated, but also covers communication, reporting and recording criteria.

On the other hand, Risk plans are the main document that will run the risk management. Plans will be identifying risk assessment process, risk mitigation, treatment, monitoring, review and contingency plan for all the different types of drainage assets, aligning with risk policy.

Risk treatment plan will be assessed in a way that is not circumstantial and reactive. It will utilize asset criticality alongside monitoring and review technique to prioritize risk treatment actions. Also, monitoring and review of risks will have a plan for periodic review and reviews once a change occurs to any asset operating status.

Business Continuity Management "BCM" Model

Business continuity is simply Ability of the firm to carry on providing goods or services after a disruptive occurrence at required levels. Having a business continuity management system is having A holistic management approach that identifies potential threats to an organization and the effects those threats might have on business operations. This offers a framework for enhancing organizational resilience so that it can respond effectively to threats in order to protect the interests of its major stakeholders, its reputation and its value-creating activities.

Similar to risk management, by applying ISO 22301 alongside other local and global standards as business continuity guidelines, the standards will establish a norm of resilience into the system, leading to produce further documents to guide the overall system. Some of these documents are:

- *Business Continuity policy*

  This policy will be established by the top management of the organization. The main purpose of this policy is to develop and formally implement business continuity essentials for the system. This will aid in the creation of a thorough, consolidated, uniform, and consistent framework that can guarantee the continuous availability of an operating drainage system in the event of a significant business disruption while protecting human lives, reputation, and adherence to legal, contractual, statutory, regulatory, and organizational requirements. This policy also outlines the standards for creating, running, maintaining, using, and enhancing a business continuity files throughout the whole organization.

  The policy provides a statement that the organization will incorporate a resilience management system that: i) Is aligned with purpose, mission and vision of the organization. ii) Provides a clear framework or model for the Business continuity system. iii) Commit to comply with its requirements. iv) Include continuous improvement plans. This policy have to identify its direction towards resilience management by briefly explaining what is resilience management and what are the outcomes that this will be under the governance of this policy.

  Also, this policy briefly defines the communication during disruptive event and throughout the year, defining collaboration and documentation of all systems within resilience management system. The policy also assures regular reviewing of itself to ensure that it is thorough, adequate, and in line with current and future business imperatives. This will ensure that it continues to be fit for purpose and reflects the changing needs of management, customers, stakeholders, interested parties, and the government.

- *Business Continuity Plan*

  This plan is set to grasp the essential tasks and actions carried out by drainage operation and maintenance team and how they impact stakeholders. The strategy should be created to allow operation teams to carry on with business as usual within the predetermined Recovery Time Objective , which has been decided upon with top management.

  The applicable Incident and Emergency Management Plans should be updated regularly, and the business continuity plan should be evaluated and updated earlier if there have been any changes to the structure or processes on the system.

- *Drainage networks incident and emergency management plan*

  All organizations, especially those that provide critical public services, should be prepared to deal with situations that have the potential to disrupt their ability to deliver the needed service. This plan will define those disruptive events and identify mitigation plan for them.

  This incident and emergency management plan is based on fundamental ideas such as preserving customer service delivery, safeguarding public and employee health and safety, maintaining asset stewardship, partnering with key stakeholders, and developing a reputation as trusted service provider. Drainage networks incident and emergency management plan will also classify operating condition into business as usual “BAU”, alert, incident and emergency and will identify the trigger for each operating class for each drainage operating system type.

Crisis Management “CM” Model

Although they are extremely rare to happen, crises can have hugely damaging consequences to assets and reputation. A governance framework is needed to handle disruptive circumstances that led to crises in compliance with the laws, regulations, and best practices in a safe, thorough, effective, and efficient way. The organization is devoted to recognizing that disruptive events have the potential to disrupt the achievement of business objectives and providing services in keeping with the organization's mission, vision, and values. Thus, by applying necessary tools, techniques and standards, the organization shall produce a holistic crises management system that is governed by the following documents:

- *Crisis management organizational plan*

  The purpose of risk management is to detect threats and put in place procedures to either prevent them from happening or minimize their impact if they do. However, certain hazards are difficult to avoid, while others are so unlikely that no risk assessment can accurately forecast them. It is vital to have plan in place to minimize the effects of certain situations when there could be a serious impact. These plans are what crisis plan management covers.

  Crisis Management plan is primarily directed for the higher management of organization, who are responsible for strategic accountability and overseeing the Crisis Management plan itself. Rainy season work procedure should be aligned with this classification and included as part of drainage networks incident & emergency management plan.

Similar to incident management plan, crisis management plan will have to identify what is a crisis for the organization, what are the effects of those crises, and establish communications internally and externally with supreme committee of crisis management in Qatar. For this plan to be able to manage crises, it needed to identify what a crisis is. Crises can be divided into many categories:

- Technical crises: these crises are ranging from technological advancement that are not within the organization scope to loss of a product, service or asset
- Economic crisis: could be internal from the company like bankruptcy or failed investment, but also can be external as currency drop or oil and gas price drop which will affect any foreign dealings massively
- People/ individual crises: such as vandalism, terrorism or kidnapping
- Social crises: like COVID-19 uncontrolled pandemic spread or next wave of cases increase. Also, political crises such as embargo/ dispute between countries
- Organization crisis: illegal activities or sudden/ forced takeovers

The list of identified crises will differ from organizations depending on the likelihood of facing them either internally or locally. Also, list of disruptive events for Incident management plan could be used with the condition of adding “crisis” level that is more severe than normal incident. Some examples of drainage system disruptive events that might lead to crisis are:

- Severe rainy event/ weather condition
- Loss of workforce from major stakeholder
- Asset disruption
- Loss of connection
- War or political disruption

These can be further specified depending on the reoccurrence and size of the organization. The fact that most of crises have extreme rare percentage of occurrence might result in panic once it occurs. So, crisis management will appoint crisis management team, but will also identify responsive crisis management scenario where:

- There is no plan for an unseen crisis and actions have to be taken simultaneously.
- There is plan, but it is shaded by governmental plan that instruct to await direct orders from their side

Once crisis occurs and rectified, a process of crisis recovery has to start. It is the crisis team responsibility to:

- Resume business as usual
- Mitigate emergency and temporary situation
- Restore reputation by engaging media in other concerns or interesting news

Recovery plan need to be set in the crisis management plan and to be followed by the crisis management team in a set of steps or milestones to assure its completion.

- *Crisis management policy*

Responsive crisis management puts the policy as main guide and deal with any unanticipated setbacks while adhering to the standards that offer the essential direction for efficient Disaster Recovery. Communicating with stakeholders, informing staff, and developing adaptive solutions are all part of this process. Responsive Crisis Management is utilized in situations where a quick response is required, such as financial or people disasters.

Crisis management team will have their responsibilities, structure, communication and scenario based missions explained. Also, training has to take place periodically to measure performance of individuals and the system itself.

The organization is devoted to recognizing that disruptive events have the potential to disrupt the achievement of business objectives and providing services in keeping with the organization's mission, vision, and values. Organization shall also uses crises and events as learning opportunities to continuously strengthen the handling capacity and competency of disruptive situations.

The policy shall also introduce the importance of communication plan once a disaster occur. The communication plan shall cover how communication should be done internally and externally once a disaster occurs, who communicate with the public, and the intensity of the massage alongside other considerations

Finally, create a culture that is geared toward resilience planning and disaster recovery to prepare for disruptive occurrences. This is achieved by Sharing and integrating the policy across the company to serve as a roadmap for the creation of pertinent plans and procedures.

- *Crisis management control center allocation and training methodology*

Crisis team shall allocate a room/ venue to be crisis management control center – even if not fully devoted for that reason- and other backup room preferably in other building. This will ease the communication and gathering of crisis team immediately, and prepare the room with necessary resources for crisis situation and for training.

Training material is very vital and complicated for crisis management. Crisis is a situation that stimulates randomness and improvisation could lead to escalation of the crisis situation. Training material shall be prepared for each disruptive situation and tested fully by informing stakeholders internally and externally. External stakeholders should also present their crisis situation and involvement of the organization to avoid any duplication in crisis preparation.

Conclusion

Recommendations

Since it was found that:

- Resilience management will not negate or contradict the presence of risk assessment, but it will be complimenting each other by reducing the vulnerability of the system
- Some hazards with very low probability and very high consequence are to be mitigated with a way other than conventional risk assessment

Based on that, a model was recommended that will include risk assessment to resilience management plan that additionally contains:

- Risk management “RM” model
- Business continuity management “BCM” model
- Crisis management “CM” model
- Resilience evaluation model

Resilience Management is an ongoing investment in the general health and prosperity of the company and its network of stakeholders, including the larger community. Organizations should not view it as a direct crisis response barrier and recovery strategy. Resilience management is not intended to be used as a one-time crisis management tool, but rather as an iterative process for long-term organizational development.

Limitations

Due to the study being limited to Qatar only, data collection of drainage maintenance system was limited to only one organization and comparing two or more authorities would have enrich the study. Also, the authority has been founded only in 2004 and risk data prior to risk team initiation was not as intense. Finally, the model explanation and events listings were on example basis because of the concentration of the thesis mainly on promoting the model and evaluation criteria.

Futuristic Work

In the future, this study could thrive if the following points are to be achieved:

- Taking a survey globally communicating with other drainage authorities across the world with similar uniqueness of size and characteristics of Qatar to check resilience applicability.
- Completing a whole resilience policy, incident and crisis management plan which requires project on an organization size to obtain ISO certification and contact with all the organization from top management across the whole organization
- In order to keep organizations engaged in the process, more work has to be done to develop maturity models of resilience. These models must include concrete, attainable goals for organizations to become more resilient. Develop ways for comparing the resilience of organizations across and within market sectors as well.
- Building resilience evaluation envelope for the maintenance system besides the other contributing parties such as other affairs or operating contractors since their resilience will contribute to the system.

To sum up, having risk assessment as the only resilience management plan is an insufficiency. Also, have it run by field experts instead of specialized risk experts will also affect its reliability. Resilience management is the modern approach to assess risk, mitigate incidents and absorb crisis impact to pass any system disruptions with minor permanent systematic distortions. A resilience evaluation method will ensure clear measurement of current situation, and suggests future improvements.

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