



**Environmental Enforcement Technology Adoption:
Marine Environment in the Kingdom of Bahrain**

A thesis submitted for the degree of Doctor of Philosophy

By

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Abstract

Research Background: Entities responsible for environmental enforcement around the world are facing increasing pressure to deal with the alarming rate of environmental degradation and crime, despite the limited resources available to them. They are continuously searching for technological advancements to enhance their effectiveness and efficiency. This research aims to explore and develop effective technology adoption insights for environmental compliance and enforcement in the Kingdom of Bahrain.

Research Gap: Existing technology adoption studies in law enforcement were mainly conducted on criminal law enforcement. Studies conducted on technology adoption of users involved in environmental enforcement were very scarce, especially from the perspective of environmental enforcers. Environmental enforcement was found to be a unique field of law enforcement with unique challenges and characteristics. This gap in the literature gives interest to acquire further knowledge and understanding of the technology use and adoption of users involved in environmental enforcement.

Methodology: This study has adapted a qualitative approach with multiple case studies triangulated with onsite observations, documents, and interviews with relevant stakeholders to explore the use and adoption of technology in environmental compliance and enforcement in the Kingdom of Bahrain.

Findings: Numerous significant findings were made during the research. The research found that technology use in the field of environmental enforcement in the marine environment in Bahrain has a significant impact on the effectiveness and efficiency of these systems, mainly through providing increased accuracy, speed, cost reduction and transparency. The technologies vary from basic technologies such as GPS to complex integrated systems, the type of technology utilized is mainly driven by the role and task of the organization or individual. The research also finds many aspects of theories from previous studies on technology adoption in the field of law enforcement to be applicable to this research's field, mainly the M-TAM which is based on the TAM model. The research found that technology adoption in environmental enforcement in the Kingdom is mandatory in nature, in which intent to use the technology has no influence since the user does not have the choice not to use the technology provided. Rather the extent to which the technology is used is influenced mainly by attitude, perceived usefulness, degree of necessity of the use of the technology, and various external factors (management style, cognitive acceptance, and stakeholder environment). Furthermore, the research identified additional unique factors affecting technology adoption in

Environmental Enforcement Technology Adoption

environmental enforcement, mainly the stakeholder's environment. The study's findings led to the development of a modified model of technology adoption for environmental enforcement. The model illustrates the complex interaction between many factors influencing users' adoption and usage of technology in the field of environmental enforcement in the Kingdom of Bahrain.

Implications: The model illustrates the factors that influence technology adoption by users involved in environmental enforcement in the Kingdom of Bahrain. The main contribution of the research and the model is the ability to predict and explain technology adoption of users in the unique field of environmental enforcement. This knowledge is critical for the Kingdom, which has made significant investments in technological solutions across a variety of sectors, including environmental enforcement. Understanding and taking into account the factors influencing technology adoption will increase the likelihood of effective technology being adopted successfully in the Kingdom of Bahrain, resulting in more efficient usage, increased productivity, and ultimately improved performance toward the achievement of goals and targets.

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Publications and Presentations during PhD

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Table of Contents

Abstract	<i>i</i>
Acknowledgments	<i>iii</i>
Publications and Presentations during PhD	<i>iv</i>
List of Tables	<i>ix</i>
List of Figures	<i>x</i>
List of Abbreviations	<i>xi</i>
Chapter 1.....	<i>Introduction</i>
.....	<i>1</i>
1.1 Background	<i>1</i>
1.2 Research Context.....	<i>5</i>
1.3 Problem Statement.....	<i>11</i>
1.4 Purpose statement.....	<i>12</i>
1.5 Research Aim & Objectives.....	<i>12</i>
1.6 Relevance of Research	<i>13</i>
1.7 Research Methodology	<i>13</i>
1.8 Structure of Research.....	<i>14</i>
Chapter 2	<i>Literature Review</i>
.....	<i>15</i>
2.1 Environmental Compliance and Law Enforcement.....	<i>17</i>
2.2 Shortcomings of Current Environmental Enforcement Systems	<i>19</i>
2.2.1 Weak Institutional Capacity and Commitment.....	<i>21</i>
2.2.2 Weak and Uncommitted Legal System	<i>22</i>
2.2.3 Lack of Clear Authority	<i>24</i>
2.2.4 Inadequate Collaboration and Coordination, Including Civic Engagement.....	<i>25</i>
2.2.5 Weak Understanding of Environmental Laws and Regulations.....	<i>26</i>
2.2.6 Critical Observation.....	<i>27</i>
2.3 Technology in Environmental Compliance and Enforcement	<i>28</i>

Environmental Enforcement Technology Adoption

2.3.1	General Technologies.....	29
2.3.2	Crowdsourced Technologies.....	32
2.3.4	Satellites Technologies.....	37
2.3.5	UAV and Drone Technologies	39
2.3.6	Data Management and Analysis Systems	42
2.3.7	Artificial Intelligence in Law Enforcement	50
2.3.8	Summary of Technologies and Critical Observations	53
2.4	Technology Limitations	56
2.5	Theoretical Framework of Research.....	60
2.5.1	Overview of Technology Acceptance.....	60
2.5.2	Innovation Diffusion Theory	61
2.5.3	Theory of Reasoned Action	64
2.5.4	Theory of Planned Behavior.....	67
2.5.5	Technology Acceptance Model	68
2.5.6	The Unified Theory of Acceptance and Use of Technology	75
2.5.7	The Task-Technology Fit Theory	79
2.5.9	Summary	85
2.6	Conceptual Framework of Research.....	86
2.6.1	Technology Acceptance Models in Law Enforcement.....	87
2.6.2	Technology Acceptance in Mandatory Settings.....	95
2.6.3	Critical observations and Gaps.....	98
2.6.4	Research Questions.....	108
Chapter 3.....	Research Context	110
3.1	Kingdom of Bahrain’s Geography and Environmental Issues.....	110
3.2	Environmental Initiatives in the Kingdom of Bahrain.....	112
3.3	Institutional Governance of Environmental Protection in Bahrain.....	117
3.4	Bahrain Coast Guard Technological Application in Enforcement	118
3.5	Technology Applications in Enforcement in the Kingdom of Bahrain.....	123
3.6	Summary	127
Chapter 4	Methodology	129

Environmental Enforcement Technology Adoption

4.1	Philosophical worldview of the research.....	130
4.2	Qualitative Approach	132
4.3	Research Design.....	133
4.4	Participants	136
4.5	Researcher Role	138
4.6	Data Collection	139
4.7	Data Analysis Procedure (Thematic Analysis)	143
4.8	Reliability and Validity of the Research.....	148
4.8.1	Trustworthiness	148
4.8.2	Six Strategy Validity.....	152
4.9	Summary	156
Chapter 5 Data Analysis, Findings, and Discussion		157
5.1	Background Information	157
5.2	Theme 1: Current Technology Usage.....	159
5.2.1	Task.....	162
5.2.2	Role.....	163
5.2.3	Benefits	172
5.3	Theme 2: Applicability of M-TAM	176
5.3.1	Technological Context.....	177
5.3.2	Social Context.....	181
5.3.3	Implementation/ Process Context	182
5.3.4	Local Context.....	184
5.4	Theme 3: Stakeholder Context Influence on Extent of Use.....	184
5.4.1	The Strength and Commitment Influence on the Extent of Use	185
5.4.2	The Knowledge and Clarity of Legislation’s Influence on Extent of Use.....	187
5.4.3	Clarity and Unity Between Related Entities Influence on Extent of Use.	189
5.4.4	Integration of Technology Influence on the Extent of Use.....	191
5.5	Theme 4: Mandatory Setting	194
5.5.1	Degree of Necessity	195
5.7	Discussion.....	196
5.8	Main Findings	216

Environmental Enforcement Technology Adoption

Chapter 6.....	Conclusion
.....	224
6.1 Summary of the Research	224
6.2 Theoretical Contribution	225
6.3 Implications.....	230
6.4 Limitations of Research	233
6.5 Future Research.....	235
References.....	236
Appendix A: Interview Protocol BCG and related stakeholders.....	254
Appendix B: Interview Protocol BCG and related stakeholders (Arabic).....	256
Appendix C: Interview Protocol for Public.....	257
Appendix D: Interview Protocol for Public (Arabic)	258
Appendix E: Invitation to Participate.....	259
Appendix F: Invitation to Participate (Arabic).....	260
Appendix G: Consent Form	261
Appendix H: Consent Form (Arabic).....	263
Appendix I: Sample of Researcher Observations	265
Appendix J: Thematic Maps	267
Appendix K: Thematic Analysis Sample	269
Appendix L: Ethics committee approval.....	279

List of Tables

Table 2. 1 Overview of technologies in law enforcement and their use	53
Table 2. 2 The Adopted Determinants of (PU) in the TAM2	73
Table 2. 3 Technology Acceptance Theories	85
Table 2. 4 M-TAM factors.....	92
Table 2. 5 Summary of technology acceptance literature in law enforcement.....	94
Table 2. 6 Details of previous studies on technology adoption in law enforcement and mandatory settings	99
Table 4. 1 Four Worldviews and their Elements.....	131
Table 4. 2 Conceptual framework outlining the main themes and sub-themes	146
Table 5. 1 Demographic data for the interview participants.....	158
Table 5. 2 Summary of Technology Used by the BCG and stakeholders	160

List of Figures

Figure 1. 1 Adapted M-TAM.....	5
Figure 1. 2 Map of Bahrain.....	6
Figure 1. 3 Components of BCG Surveillance System	8
Figure 1. 4 BCG Display System Features.....	10
Figure 1. 5 Real-Time Map Display	11
Figure 2. 1 Logical flow of Literature Review chapter	15
Figure 2. 2 Illustration of source selection and inclusion for literature review	17
Figure 2. 3 Developing a criminal case.....	19
Figure 2. 4 Citi-Sense-MOB system overview.....	35
Figure 2. 5 City-Sense Proposed Project Layers	49
Figure 2. 6 Features of TrailGuard.....	52
Figure 2. 7 Diffusion of innovations.....	63
Figure 2. 8 TPB.....	68
Figure 2. 9 TAM.....	69
Figure 2. 10 TAM2.....	72
Figure 2. 11 The UTAUT Model.....	76
Figure 2. 12 UTAUT 2	79
Figure 2. 13 Task-Technology Fit	81
Figure 2. 14 Integrated TAM/TTF Model	82
Figure 2. 15 M-TAM.....	91
Figure 2. 16 Adapted M-TAM by.....	93
Figure 2. 17 Technology Acceptance Model variables.	94
Figure 2. 18 Gaps, Objectives and Questions of the research	109
Figure 4. 1 Summary of various parts of research methodology	130
Figure 5. 1 Enviro-TAM (Technology acceptance model for environmental compliance and enforcement).....	217

List of Abbreviations

AI:	Artificial Intelligence
AIS:	Automatic Identification System
BCG:	Bahrain Coast Guard
GIS:	Geographic Information System
GSS:	Geographic Security System
IDT:	Innovation Diffusion Theory
IoT:	Internet of Things
MDT:	Mobile Device Technology
MOI:	Ministry of Interior
M-TAM:	Mobile Technology Acceptance Model
PEOU:	Perceived Ease of Use
PU:	Perceived Usefulness
SCE:	Supreme Council for Environment
TAM:	Technology Acceptance Model
TPB:	Theory of Planned Behavior
TRA:	Theory of Reasoned Action
TTF:	Task-Technology Fit Model
UAV:	Unmanned Aerial Vehicle
UTAUT:	Unified Theory of Acceptance and Use of Technology

Chapter 1 Introduction

This Chapter will introduce the research background, research problem, purpose, and objectives to provide clarity on the research topic's context and direction. This Chapter will outline the scope and aims of the study. It will also identify the research questions, objectives, and their relevance. Finally, it will introduce the methodology and structure of the thesis.

1.1 Background

This section will provide information on the research's overall background and context.

Ineffective compliance and enforcement systems

Environmental protection has become increasingly important in an era of growing concern about environmental degradation. Nations and organizations around the world have recognized that their efforts to attain economic development and growth rates will always be hampered by the current unsustainable levels of environmental degradation and carbon emission.

According to research information, given the speed and magnitude of environmental degradation and the implications that result from it, a number of initiatives have been launched to address the problem, including the introduction of legal measures and the establishment of natural preserves. These choices, while adequate in terms of their scope and speed of implementation, appear inadequate in terms of dealing with the magnitude and increasing pace of environmental degradation. According to the United Nations Environment Programme (2014), present national legal systems only exist "on paper." According to the agency, when it comes to the fight against carbon emissions and climate change in an effort to safeguard the environment, such law is meaningless if it is not properly enforced.

Despite the fact that massive systems of national and international laws, treaties, and agreements exist, compliance assurance and enforcement are essential to

Environmental Enforcement Technology Adoption

international and national environmental organizations to achieve their goals, given that it compels persons and groups to adhere to the right standards of development and, as such, good governance (Paddock, Qun, Kotze, Markell, Markowitz, and Zaelke, 2011; Munang and Mgendi, 2016; UNEP 2019). Various factors have been found to contribute to the ineffective nature of the current policy system in tackling environmental issues. Deficient compliance and enforcement were found to be one of the most significant (Macrory, 2014; Jones, 2016).

Importance of Technology in Environmental Compliance and Enforcement

The inclusion of technologies into law enforcement systems, especially environmental enforcement, is a critical aspect in enhancing the efficiency and efficacy of these systems (Cakar, 2011). As technology continues to evolve, environmental compliance and law enforcement agencies have adopted and deployed numerous and varied technologies, so the impact of technology on environmental compliance and enforcement cannot be overlooked. Advanced and emergent technologies have been implemented into different areas of law enforcement systems, thereby affecting the strategies that the law enforcement agencies and justice systems use in enforcing laws, including environmental law (Fiorino, 1998).

Adopting more sophisticated technologies by law enforcement agencies to combat violation and crime is a crucial element in enhancing environmental compliance and enforcement practices and processes. To ensure people do not violate laws as they interact with nature and with each other, the criminal justice sector has been employing cutting-edge systems, tracking devices, and more technologies (Fang et al. 2017).

Technology is becoming increasingly fundamental to environmental compliance and enforcement. Glicksman et al. (2016) suggested various ways in which technology plays an important role in environmental compliance and enforcement. One area in which they find technology to be helpful is environmental monitoring. Technological tools can vary in use from measuring ambient environmental conditions to tracking release of pollution. These tools are helpful in tasks such as identifying regulated entities in violation of pollution control regulations or permits and providing

Environmental Enforcement Technology Adoption

evidence in enforcement actions taken against those entities. They also suggest that the technological advancements in data generation and analysis have the potential to enhance compliance and empower stakeholders in the decision-making process and implementation. Other ways in which technology enhances compliance and enforcement processes is by providing accurate and low-cost data, thereby lower cost of labor. Also, faster and easier data sharing and coordination helps regulatory entities' capacities to identify, diagnose, address concerns, enhance public participation, and increase transparency (Glicksman et al. 2016).

Although prior studies have highlighted the potential advantages in implementation and adoption of technology on environmental compliance and enforcement, they have also found various concerns or limitation to technological advancement in compliance and law enforcement. The limitations range from privacy issues to technical difficulties and high costs of acquiring of some technologies.

Technology Acceptance

User acceptance and confidence in any new technology is crucial for their success. Organizations are increasingly facilitating their platforms to increase personnel efficiency, reduce costs and increase productivity. This has increased interests in understanding the factors that affect user acceptance of new technologies. Many technology acceptance theories and models have been devised through research in this field. Some of these models include the Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Unified Theory of Acceptance and Use of Technology (UTAUT), and many more, including their extensions. User acceptance is very important to the successful development, implementation, and growth of implementation of the new technology (Taherdoost, 2019).

According to Cakar (2011), user issues are a bigger factor than technical issues in the adoption and implementation of technology. Successful implementation and adoption of technology requires effective interaction between the user and the technology, and the technologies effectiveness is affected by the user's willingness to use the technology and may also lead to failure of technology. Therefore, determining

Environmental Enforcement Technology Adoption

user acceptance and the deficits in a new technology is crucial. Research also suggests that understanding the user's perceptions, needs, and expectations of the technology is crucial to the successful implementation and adoption of a new technology and increase the user's ability to utilize the technology efficiently (Cakar, 2011; Momani and Jamous, 2017). Technology acceptance theories and models aim to provide the means to understand and accept the new technologies by the users and how they may use it. During the process of assessment of a new technology many variables affect the individuals' decision-making process about how and when they will use it (Momani and Jamous, 2017).

Literature on technology adoption has been expanding substantially in various disciplines but there still deficiency of research in particular fields and domains. Law enforcement is one of these fields and especially in environmental law enforcement. Various studies have explored the factors that influence technology acceptance and adoption in law enforcement. The literature available on technology adoption in the field of environmental enforcement is very scarce, especially from the perspective of environmental enforcers.

One of the modified models which was found to be of interest to this research is the M-TAM developed by Lindsay, Jackson, and Cooke (2011). The M-TAM is a complex model which can be used in other law enforcement contexts. Other research has applied the Technology Acceptance Model (TAM) in law enforcement but were concentrated on a specific law enforcement organization and did not specifically consider mobile technology adoption and whether the model could be generalized to other contexts.

Lindsay, Jackson, and Cooke (2014) conducted a further study to validate and enhance the M-TAM and to explore if the model is transferable to other UK police forces, and potentially worldwide. Figure 1.1 shows the model of the adapted M-TAM. Their study finds the M-TAM to be transferrable to other law enforcement forces with differing types of mobile devices in place. Also, it was found that the model can be utilized as a valuable tool for law enforcement agencies and similar organizations around the world that are planning on mobilization of their technology implementation. The model provides a wide range of factors needing attention for the successful mobilization of technology.

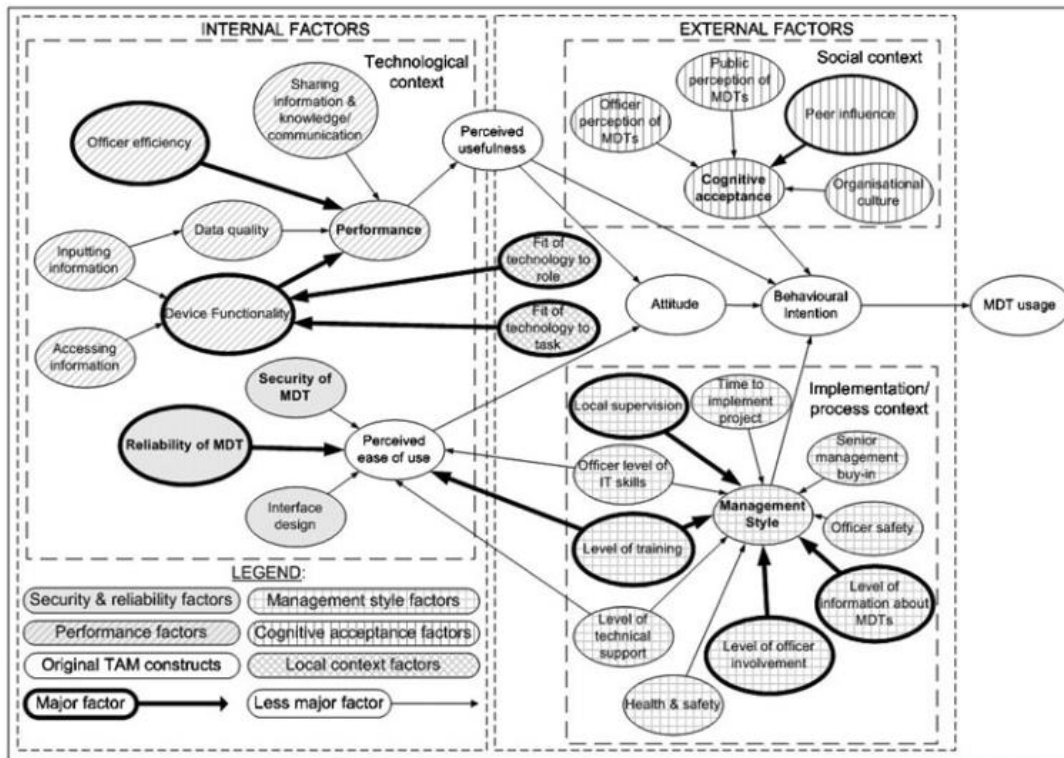


Figure 1. 1 Adapted M-TAM (Lindsay et al. 2014)

1.2 Research Context

The Kingdom of Bahrain is an archipelago consisting of more than 84 natural and man-made islands. The kingdom has 33 natural islands and 36 small islands which are part the Hawar Islands. The Kingdom is located in the middle of the southern coast of the Arabian Gulf. Bahrain’s land mass covers a total area of 769.6 km² with a total marine area of 7497.1 km² falling under the jurisdiction of the Kingdom (General Directorate of Statistics, 2017). Its climate is arid and humid and is characterized by high temperature and low rainfall. The average summer and winter temperatures recorded during the period of 2009-2013 are 35.14°C and 18.82°C respectively. The annual rainfall noted during this period ranged between 20.2 to 98.9 mm (E-government authority, 2020).

The marine environment is a vital source of resources and has a significant environmental importance. Geographically, it is quite large in comparison to the Kingdom of Bahrain’s terrestrial environment, accounting for nearly 90% of Bahrain’s area (General Directorate of Statistics, 2017). Figure 1.2 displays a map of the Kingdom of Bahrain borders and marine protected areas. Bahrain’s maritime

Environmental Enforcement Technology Adoption

environment is self-sufficient in fish production and is home to a diverse range of species and habitats. Maritime and terrestrial pressures, mostly from residential and industrial initiatives, have had a significant impact on the marine environment, especially coastal ecosystems. Additionally, the sea is harmed by desalination facilities, wastewater treatment plants, reclamation and dredging activities, pollution caused by the dumping of leftovers and wastes from numerous sources, and overfishing. These activities have harmed marine environments, particularly sea grass, coral reefs, and mangroves, and have resulted in a decline in fisheries and biodiversity (Naser, 2016).



Figure 1. 2 Map of Bahrain showing marine borders and marine protected areas (Naser, 2016)

Environmental Enforcement Technology Adoption

Bahrain environmental compliance and enforcement systems are multi-stakeholder systems, in which the Supreme Council for Environment (SCE) is the central authority responsible for legislation and implementation as well as overseeing the actual compliance and enforcement process. Various government ministries and institutes have essential roles in the monitoring and implementation process of environmental compliance and enforcement in the Kingdom of Bahrain (Naser, 2016). Some of these are the Ministry of Interior; Ministry of Works, Municipalities, and Urban Planning; Ministry of Industry, Trade and Tourism; and the Governates (Capital, Muharraq, Northern, and Southern). Other entities have been helpful in monitoring and enforcement process, such as local NGO's.

Bahrain Coast Guard (BCG) is one of the Directorates of the Ministry of Interior that is a significant enforcer of environmental laws and regulations, including fisheries management. This is particularly true when it comes to marine environmental laws and regulations. Their relative superior technological and human skills are critical elements determining their ability to implement maritime law. Their major responsibility is to safeguard territorial waters, which includes environmental protection. The BCG has implemented technical solutions and support systems to assist in managing the territories under their jurisdiction, which are vast geographically in comparison to terrestrial Bahrain, accounting for 90.6 percent of the kingdom's total area (E-government authority, 2020).

The Bahrain Coast Guard are heavily invested in technological solutions to enhance their operations and processes. They have implemented several technologies and information systems to help enhance administrative and operational procedures and practices, including environmental law enforcement. They have an integrated system of sensors and data management and analysis tools to help deliver accurate, fast, and relevant data and analysis (BCG headquarters, 2020).

They have a complex array of radars, cameras (short and long range, with heat sensors) and tracking devices (AIS) which are mandatory by law to be fixed on all vessels in the kingdom, from small fishing boats to commercial vessels. The latter sensors are connected and integrated by various systems and are fed to analectic systems such as the GSS to give further information to be used for planning and

decision making. The application of these technologies in the coast guard have ranged from reporting of crime or violations to resource allocation and budgeting. Figure 1.3 Illustrates some of the main components of the BCG surveillance system.

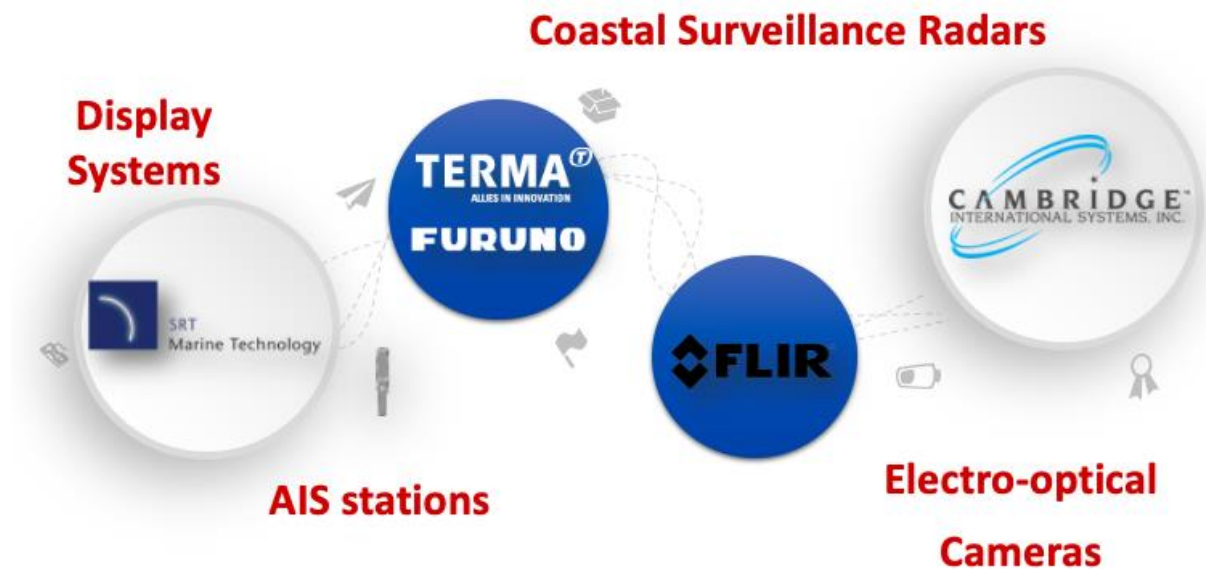


Figure 1. 3 Components of BCG Surveillance System (BCG)

One of their main technological applications is the electronic geo-fence system, which was launched in 2011, which identifies the targets in territorial waters. The electronic geo-fence system consists of a coastal surveillance radar system, electro-optical camera systems, and an Automatic Identification System (AIS) for merchant ships, where all ships whose tonnage exceeds 150 tons are bound by the laws of the International Maritime Organization (IMO).

Targets are monitored through this system at the Maritime Operations Center under the command of the Coast Guard and its bases. They deploy a technology which is essentially an electronic geo-fence system by installing automatic identification devices for small ships that send an information package that includes the ship's location, information about the owner and his contact numbers, and the devices themselves are equipped with a button to send a distress call in the absence of means of communication in the event of an emergency occurrence at sea.

Environmental Enforcement Technology Adoption

The Coast Guard leadership has established a special team for the electronic geo-fence system project to oversee its maintenance and hold training courses. The team also conducts quality studies and research that keep pace with the steady technological development in the field of electronic monitoring and coastal monitoring, and also generate daily reports on the workflow in general. The team is also responsible for visiting the radar towers to find out the extent of their readiness, as well as inspecting the electro-optical cameras and maintaining communication with the relevant companies for the operations of repairing, sending, and receiving devices.

Due to the Coast Guard leadership's keenness to adhere to international standards and raise the level of competence, the technical team was trained to climb towers and obtain internationally recognized licenses that would allow them to climb communication towers to carry out installation and maintenance operations, as well as licenses authorizing the leadership to carry out training courses for climbing and to obtain regular climbing licenses.

The initiative is unique in that every boat is fitted with a government issued identification transceiver coupled with a monitoring system that is specifically designed to deliver multiple benefits to all maritime stakeholders. The system fuses multiple sophisticated sensor systems such as radar, CCTV and AIS and uses state of the art data analytics to create a high resolution, high integrity data set on the marine domain.

Typically, maritime monitoring systems rely solely on radar which has limited range and does not identify vessels, and where identification transceivers are deployed, they are only deployed on selected boats. Additionally, monitoring systems are normally focused on single specific applications such as search rescue, or security or environmental monitoring. Figure 1.4 Presents some of the main attributes and display features of the system.

Environmental Enforcement Technology Adoption

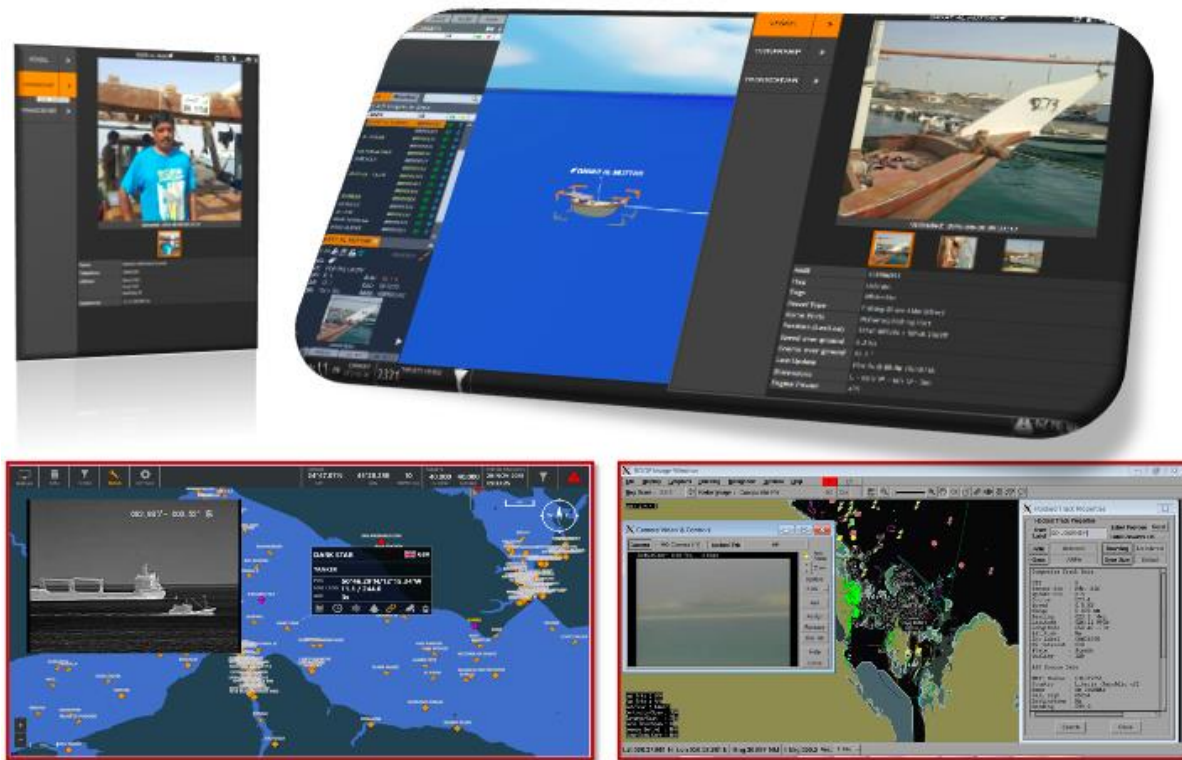


Figure 1. 4 BCG Display System Features (BCG)

The main benefit of this technology in the context of environmental compliance and enforcement is ensuring sustainable fishing activity and preventing illegal and unregulated fishing – both commercial and leisure. All fishing boats are accurately tracked and licensed. The system allows continuous monitoring of fishing activity – which in turn prevents illegal and unregulated fishing and more positively, allows a co-operative approach to fishing activity considering fish stocks, movements, and environmental conditions. This ensures that the sensitive marine environment is protected through monitoring of vessel movement and activity in real-time, as well as providing evidence in cases of violations. Figure 1.5 displays a sample of the real-time and heat maps available to the BCG.

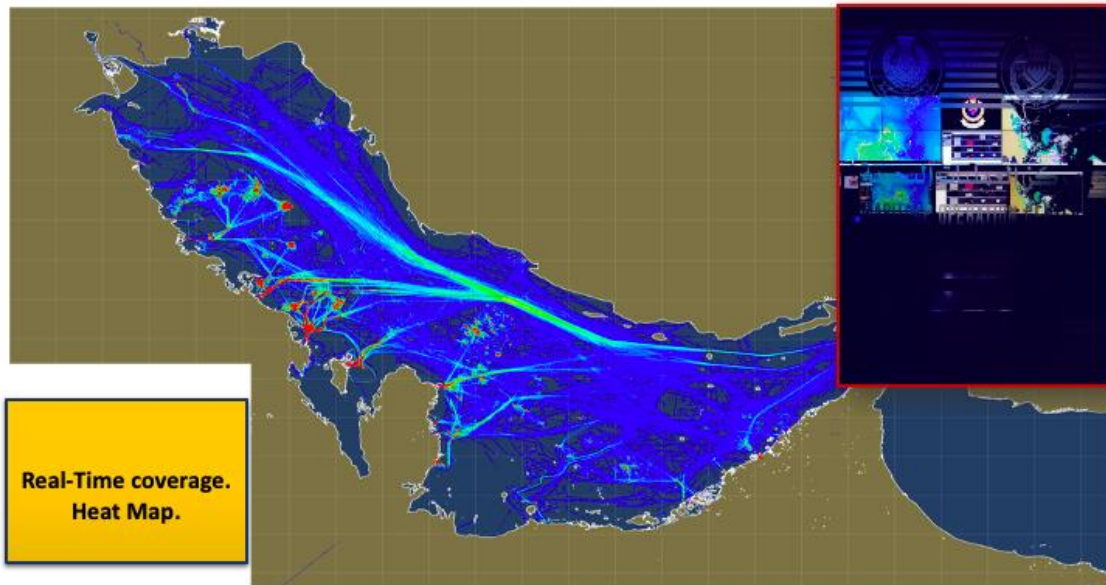


Figure 1. 5 Real-Time Map Display (BCG)

1.3 Problem Statement

The technology adoption theories have been extensively studied and accepted for many disciplines and fields. These include the fields of healthcare, education, e-commerce, and law enforcement. In the field of law enforcement, various studies explored and investigated the use of technology and the factors influencing technology adoption. The literature on technology for environmental protection was numerous, but very few studies were conducted on technology use and adoption of technologies in the field of environmental compliance and enforcement, especially from the perspective of individuals involved environmental enforcement. Only one study was found by the researcher directly related to the topic. This gap in the literature gives interest to acquire further knowledge and understanding on technology use and adoption in environmental enforcement. Further previous studies of technology adoption in law enforcement have researched and examined various factors that influence technology adoption but have not extensively examined the issue of mandatory setting technology adoption and use of the technologies. Most of the technologies in enforcement systems are mandatory, especially when it comes to the enforcers' use, although some of the studies deal with variation in the voluntariness of

use of these technologies. Regarding the studies that examine mandatory setting technology adoption which are in various fields and domain, but not in law enforcement, discrepancies were found between some of the factors and constructs particularly in the Technology Acceptance Models. They suggest a weak explanatory power of the TAM in mandatory settings.

The research's formulated problem statement is as follows:

“What factors influence technology use and adoption of users involved in environmental enforcement in the marine domain in the Kingdom of Bahrain?”

1.4 Purpose statement

This research explores technology use and adoption of users involved in environmental compliance and enforcement in the marine environment in the Kingdom of Bahrain. For this qualitative study, technology refers to the use of any technology as a tool enabling environmental compliance and enforcement.

Environmental compliance and enforcement is defined as the process of ensuring that the requirements of laws and regulations related to the protection of the environment are met through self-compliance and direct enforcement. The knowledge and understanding gained from this research will provide a comprehension on technology's impact and adoption factors for environmental compliance and enforcement to enhance its effectiveness in line with the overall goal of environmental protection in the Kingdom of Bahrain.

1.5 Research Aim & Objectives

The study aims to explore the factors that influence technology use and adoption of users involved in environmental enforcement, and more specifically in the context of the marine domain.

The research firstly explores the technologies used and their impact on users involved in environmental enforcement and the results in the marine environment in Bahrain. Secondly the research explores the factors that influence technology adoption of users in the same domain. Thirdly the research explores the effect of

mandatory settings on technology adoption. This can be useful to practitioners in that they can identify the current technologies being used, understand their impact on environmental compliance and enforcement, and understand the factors that influence technology adoption for efficient adoption and implementations of these technologies to ensure optimized use for environmental compliance and enforcement in the Kingdom.

The research objectives of the study are as follows:

- To explore nature of technology usage of users involved in environmental enforcement in the Kingdom of Bahrain
- To explore factors that influence technology adoption of users involved in environmental enforcement in the Kingdom of Bahrain
- To develop a research model based on previous research for technology adoption of users involved in environmental enforcement in the Kingdom of Bahrain

1.6 Relevance of Research

Environmental degradation is increasing at an alarming rate, even with an increase in environment protection policies. In an attempt to deal with the issues of insufficient environmental compliance and enforcement, various technological solutions are being adopted and implemented to enhance environmental compliance and enforcement systems around the world. The successful completion of this research will provide essential knowledge and understanding of technology use and adoption to optimize effectiveness of the technology's adoption of users involved in environmental compliance and enforcement to improve the overall goal of environmental protection.

1.7 Research Methodology

This study has adapted a qualitative approach with multiple case studies triangulated with onsite observations, documents, and interviews with relevant stakeholders to explore the use and adoption of technology of users involved in environmental compliance and enforcement in the Kingdom of Bahrain. The primary source of data for the research is interviews conducted on BCG personnel and other

related stakeholders, including the public entities. The researcher further utilizes a thematic analysis to analyze the data collected from the interviews and secondary data. The researcher chose this qualitative approach to attempt to acquire an in-depth, holistic, and realistic understanding of technology use and adoption of users involved in environmental compliance and enforcement, specifically in the context of the marine environment in the Kingdom of Bahrain.

1.8 Structure of Research

Chapter one consists of a brief background of the research, aim of the research, objectives of the research, relevance of the research, methodology, and structure of the research. Chapter two provides the literature review, theoretical and conceptual framework, which includes general strategies and processes of environmental compliance and enforcement systems, current technologies utilized in environmental compliance and enforcement and their implications on the strategies and processes, and also review some of the technology adoption models which will be used to understand technology adoption in environmental compliance and enforcement. Chapter three is the research context. Chapter four is the research methodology in which details of the methodology used in the research will be presented. Chapter five will present and explain the results of the research based on the data analysis. Chapter six provides the conclusions of the research and highlights implications, limitations, and recommendations.

Chapter 2 Literature Review

This Chapter gives a literature review of the implementation and impact of technology, including the Internet of Things (IoT), crowdsourcing, remote sensing technologies, and data management and analysis technologies in law enforcement. The chapter will begin by reviewing the current environmental compliance and enforcement processes and procedures. Next, it will give a summary of the factors affecting environmental compliance and enforcement. The chapter will then explore the current technological application in environmental compliance and enforcement, as well as other relevant technologies from other law enforcement agencies. Finally, the chapter will explore the various technology adoption models and technology adoption in environmental compliance and enforcement, and other law enforcement fields. The following **Figure 2.1** illustrates the logical flow of the literature review in this chapter along with the main driver for each transition.

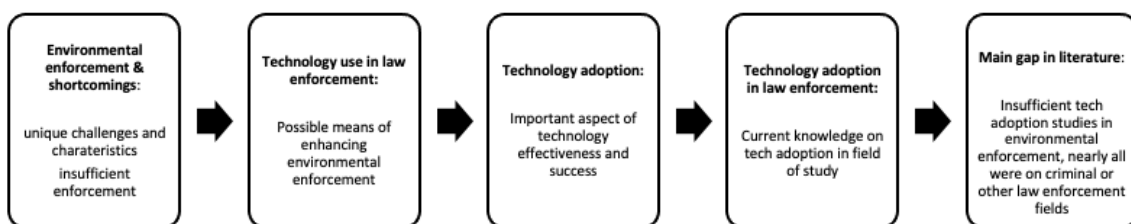


Figure 2. 1 Logical flow of Literature Review chapter

In identifying sources for this literature review, several databases were used. The initial database used was Google Scholar which was used to identify article type and availability. This provided the initial research and peer-reviewed article sources to establish a research article list. This was achieved by using broad search terms which included *Environmental, enforcement, compliance, and technology*. From this list the researcher further refined and evaluated the article search through the Brunel University library search database. Some of the databases used include SAGE, JSTOR, Elsevier, Emerald, and Taylor & Francis.

The search terms were later expanded to include *environmental, enforcement, compliance, protection, technology, technology adoption, technology acceptance, law*

Environmental Enforcement Technology Adoption

enforcement, police, and mandatory, and respective articles were selected for the literature review. The terms were combined using the command “AND” and through other various methods in an attempt to obtain the most narrowly defined and appropriate articles. Most of the articles identified were through Google Scholar, and others through other databases, including the Brunel University library search database. In addition to these databases, articles were searched and identified through the reference list of some of the articles (Snowball method). The selection of these specific search terms was to narrow down to the most appropriate and relevant articles to the focus of the literature review of this research.

The researcher implemented several criteria to include/exclude and analyze the sources:

1. The sources had to be in line with the literature review’s purpose based on the articles’ research question and purpose.
2. Sources had to be primary source research or highly relevant to the topic in case of secondary source research.
3. The sources had to be from peer-reviewed journals.
4. The types of journals had to include research articles that were thematically aligned with this research purpose.
5. Articles had to be in English.
6. No date limitation was implemented except for literature regarding studies on technology adoption in law enforcement, and that was set to articles published 2010 onwards.
7. Although the criteria were applied to most of the data sources, some exceptions were made to include a few secondary research papers that were relevant and applicable, especially to wider concepts and contexts.

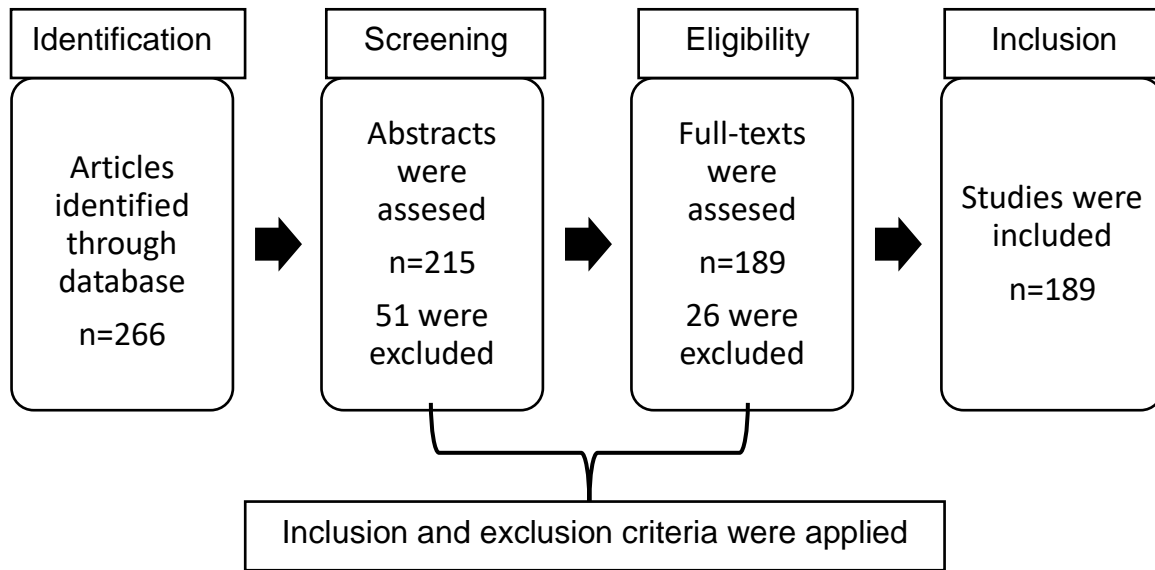


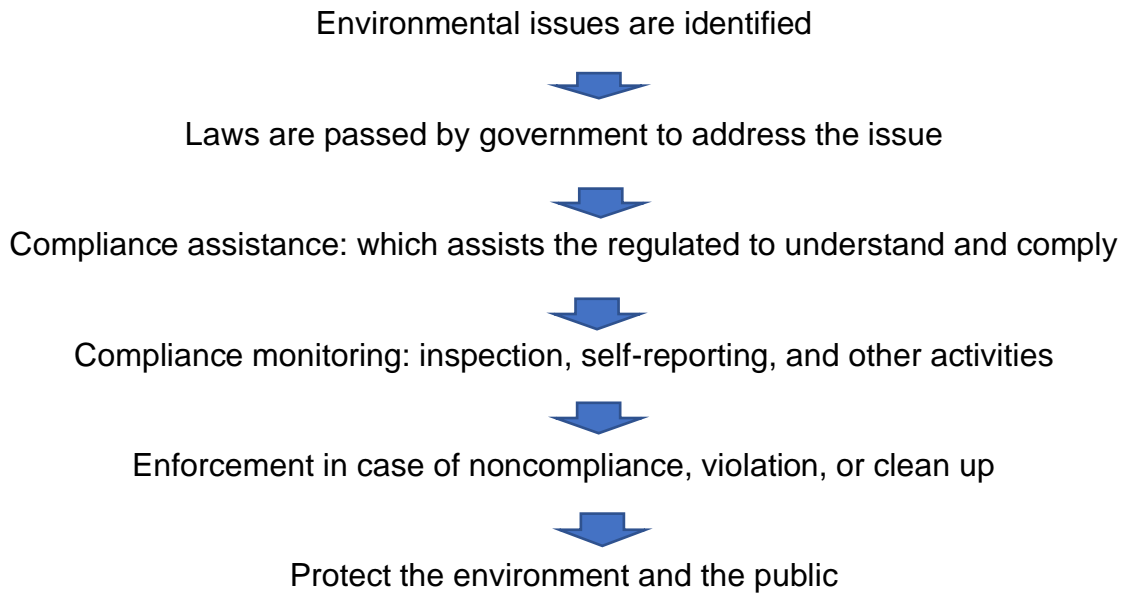
Figure 2. 2 Illustration of source selection and inclusion for literature review

2.1 Environmental Compliance and Law Enforcement

Enforcement, according to UNEP (2014) refers to a range of procedures and actions that a state employs, the competence of authorities and agencies to assure that individuals and groups of people showing reluctance in complying with environmental policies are successfully transformed to law-abiding citizens through the use of administrative or criminal action (Riesel 2020; Rose, 2013; UNEP, 2019).

In general, the process of environmental compliance and enforcement are similar in most countries when it comes to national laws and regulations, with some variation in step and procedures adopted in different regions and countries (UNEP, 2019). The US Environmental Protection Agency's (EPA) compliance and enforcement processes are a good example of how most countries conduct this process and are as follows: (Blundell et al. 2020)

Environmental Enforcement Technology Adoption



The compliance and enforcement processes in the Kingdom of Bahrain's Supreme Council for Environment (SCE) are similar to the processes of the EPA (SCE).

The most relevant stages of the regulatory process to the scope of our study are compliance assistance, monitoring, and enforcement, which we will try to emphasize on. As for the enforcement stage of the regulatory process, the cycle varies depending on the agencies implementing the enforcement and the action being enforced.

According to UNEP (2014) there are three main courses of action in environmental enforcement. Administrative enforcement, civil enforcement, and criminal enforcement. Administrative actions are taken by the regulatory agency that are nonjudicial (Gallay, 2020; Riesell, 2020), for example, an order (with or without penalties) to fix a violation. Civil actions help government and nongovernment stakeholders and individuals to use civil or alternative remedies to assist in ensuring compliance and enforcement of requirements. Some of the results of civil enforcement are settlements, civil penalties, and mitigation (Blundell et al. 2020). Finally, criminal enforcement actions are taken by law enforcement agencies against an organization or individual through criminal actions. Criminal enforcement can result in criminal penalties and prison (Riesel, 2020; UNEP, 2019).

Environmental Enforcement Technology Adoption

The processes during each of the actions differs. Administrative enforcement actions are conducted by the regulatory agency directly and usually occur after inspections (compliance monitoring) and are related to non-serious violations which can be corrected by the violator. In the case the violator has a previous history of violation, the agency may decide to upgrade the enforcement action which may lead to criminal enforcement (UNEP, 2019).

The second form of enforcement is civil enforcement actions, which are usually the second step after administrative actions. The civil actions are taken if the regulated identity does not comply with regulatory requirements, an administrative order, or is required to clean up or pay costs of clean up. The process requires the case to be sent to court for settlement or mitigation implementation (Riesel, 2020).

For serious violations and environmental crimes, criminal enforcement is implemented (Riesel, 2020). The EPA's process in building a case is as follows:

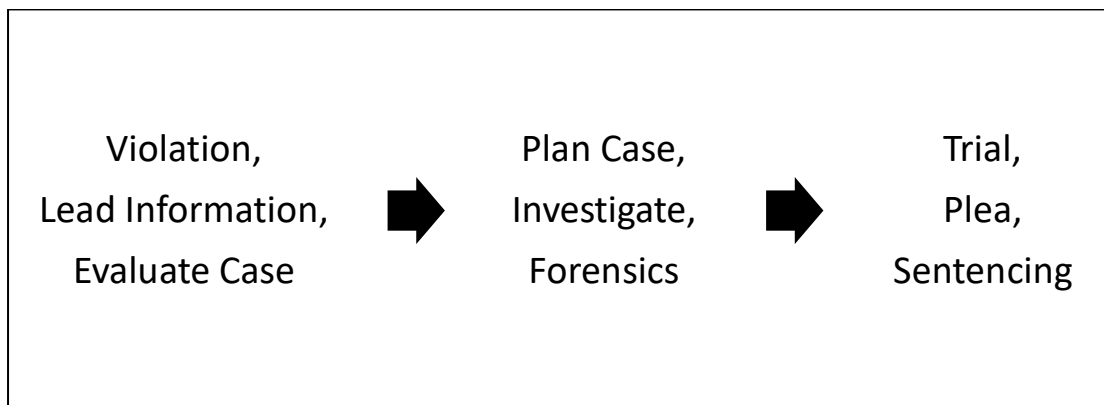


Figure 2. 3 Developing a criminal case

2.2 Shortcomings of Current Environmental Enforcement Systems

Previous research has found that a sufficient level of enforcement is vital, given that it compels persons and groups to adhere to the right standards of development and, as such, include good governance (Giles et al., 2021; Milmanda & Garay, 2020; Munang & Mgendi, 2016; Paddock et al., 2011). The research purports that an acceptable degree of enforcement has become of central importance in both the

Environmental Enforcement Technology Adoption

developing and the well-established nations given that the issue of climate change is threatening the environment at a distressing rate. This has come despite the fact that a massive system of national and international laws, treaties, and agreements exist. Macrory (2014) and Jones (2016) indicated that there might be a series of factors that contribute towards the ineffective nature of the current policy system in curbing the detrimental results of climate change on the environment.

The above finding was affirmed by UNEP (2014) and Zinn (2012). UNEP (2014) purported that the current national legal systems only exist on “the books.” The agency added that such legislation is not of any meaning when it comes to the fight against carbon emission and climate change in an attempt to protect the environment. Zinn (2012), on his part, purports that an effective environmental regulatory system is largely dependent on the enforcement system. The researcher (Zinn, 2012) further elucidated that the enforcement regime has to emphasize on cooperation among governments, the private sector, and the individual citizens.

In another research by Ijaiya and Joseph (2014), it was documented that inadequacies of penalties and punishment, along with the lack of clear authority directly responsible for enforcement, are the primary factors affecting the enforcement of the current regulations. While B. J. Preston Chief Judge (2013) acknowledged these issues as well, the scholar voiced that inadequate collaboration and coordination, insufficient circulation and sharing of information, and weakened understanding of environmental laws and regulations has contributed significantly towards ineffective environmental protection law enforcement.

Other chief contributors were identified as commitment without proper enforcement, inadequate incorporation of international laws into the local legal system, corruption, lack of specialized courts and understanding of the ecological laws by judiciary systems, few civil suits, and the lack of necessary resources are critical hindrances to optimal enforcement (Giles et al., 2021; Komaki & Fluharty, 2020; Milmanda & Garay, 2020; Nemesio, 2014). The enforcement regime has to emphasize on cooperation among governments, the private sector, and the individual citizens (Zinn, 2012).

Environmental Enforcement Technology Adoption

From previous research several factors were identified that affect the compliance and enforcement of current environmental policies implementation. The factors identified were those pertaining to the direct enforcement process and the institutions directly involved. The external factors affecting the effectiveness of environmental compliance and enforcement, such as socioeconomic and environmental factors, were not reviewed. The following section will present some of the factors identified in more detail (Giles et al., 2021; Komaki & Fluharty, 2020; Milmanda & Garay, 2020; Nemesio, 2014):

1. Weak institutional capacity
2. Weak legal systems
3. Inadequate fines and penalties
4. Corruption
5. Lack of clear authority directly responsible for enforcement
6. Inadequate collaboration and coordination
7. Inadequate civic engagement
8. Insufficient circulation and sharing of information
9. Weakened understanding of environmental laws and regulations
10. Inadequate incorporation of international laws into the local legal system
11. Lack of specialized courts and civil suits

For the purpose of the review, the shortcomings will be categorized into five categories and discussed: weak institutional capacity and commitment, lack of clear authority, inadequate collaboration and coordination (including civic engagement), and weak understanding of environmental laws and regulations. Some of the previously identified factors affecting the effectiveness of environmental compliance and enforcement systems were either incorporated in the 5 presented categories or excluded from the discussion.

2.2.1 Weak Institutional Capacity and Commitment

Creating institutional capacity is essential to achieve successful legislation (Giles et al., 2021; Milmanda & Garay, 2020; Nemesio, 2014; UNEP, 2014; UNEP, 2019). Weak and uncommitted environmental institutions result in noncompliance.

Institutions which are incapable of effective monitoring, inspection, prosecution, and deterrence of environmental violations can result in the belief by the regulated entities that violations may go unpunished, resulting in noncompliance by some. This is applicable to all related entities involved in environmental compliance and enforcement (Komaki & Fluharty, 2020). This lack of strength and commitment often results in the decline of natural resources, environmental degradation, and increased crime and corruption (UNEP, 2014). The lack of compliance is an indicator of the state of commitment and seriousness of government and institutions to enforce environmental laws and regulations (UNEP, 2019).

The allocation of adequate resources, such as funding and human resources, is major factor affecting the institution's capacity, whether it is government, public, or private. No institute can function effectively without proper and sufficient resources (Giles et al., 2021; Nemesio, 2014). Although initial investment is essential in determining the institution's capacity, it also requires further continuous commitment to ensuring long term capacity and effective operations through proper training and development of human resources, as well as allocating sufficient resources and manpower (UNEP, 2019).

Quality and efficiency of human resources is crucial to the institute's capacity. No institute can function efficiently without the availability of highly qualified and trained personnel. "People are the heart of any institution, and institutions are only as capable as their staff." (UNEP, 2019). Recruitment of highly qualified staff and providing them with proper incentives and tools to ensure better performance is essential to the effective building of institution capacity. Also, to enhance resource allocation and quality, both personnel and the institute should be provided with clear mandates (Milmanda & Garay, 2020; Otto et. al, 2009).

2.2.2 Weak and Uncommitted Legal System

This can range from the legislative strength to the number of resources available to ensure environmental compliance and enforcement. International protocols and national legal strategies also have a significant impact on the

effectiveness of environmental law enforcement. In this regard, the strength of the legal system of the state plays a huge role in environmental law compliance and enforcement (Giles et al., 2021; Glicksman et al., 2019). Ijaiya & Joseph (2014) also find inadequacies of penalties and punishment. In localities with strong legal systems, the stipulated environmental laws are followed strictly, for instance, practices that adhere to pollution regulations strive to be aligned with the law of the region. This type of structure is mostly seen in developed nations that take environmental conservation seriously. Additionally, in such countries, there exist high numbers of environmental activists who lobby for best practices. This drives sustainable practices to be on the rise (Ijaiya & Joseph, 2014).

On the other hand, in nations where the legal system is relatively weak, the inaction of set environmental laws is often challenged. For instance, in India, there are a number of legislation and Acts that support sustainable living (Glicksman et al., 2019). Nonetheless, the environmental issue in the country is in a wary condition. This is because of the continued high rates of pollution, which is highly contributed to by continued emission of dangerous and untreated gases from factories. Additionally, deforestation is prevalent with the ineffective protection of wildlife. This provides proof that there is ineffectual enforcement of set environmental laws. Some of the factors that contribute to such a condition are high rates of corruption, the ineffective legal system, and availability of capitalists who are highly driven by profits over the protection of the environment and people (Glicksman et al., 2019).

Other factors within the legal system are the inadequate incorporation of international laws into the local legal system (Milmanda & Garay, 2020; Nemesio, 2014). The level of political commitment and adoption of the international laws can be a hindering factor to not only the international environmental effort, but the national effort as well (UNEP, 2019). The integration of these laws into the national or local legal systems help create a unified effort that is transparent and measurable.

Also, there is the factor of lack of specialized courts and civil suits (Nemesio, 2014). The availability of specialized environmental courts that have a clear understanding of environmental laws and the impacts of environmental crime and degradation helps achieve effective results in ensuring compliance through strong

deterrence of environmental crimes and violations. Through fair and strong prosecution of violators the institutions capacity is increased because of the rise of integrity of the institutions involved in environmental compliance and enforcement and effective deterrence (UNEP, 2019).

The integrity of the institution is a determinant factor of the institution's capacity. Trust and accountability are key factors influencing public perception and involvement in the compliance and enforcement process (Nemesio, 2014). Civil suits also increase the accountability of the institutions and increase public involvement in compliance and enforcement, especially with the availability of institutes with high integrity. Also, it can aid in reducing the pressure on enforcement institutions by spreading the responsibility across a wider range of entities to achieve effective compliance and enforcement of environmental laws and regulations (Nemesio, 2014; Preston, 2013; UNEP, 2019).

2.2.3 Lack of Clear Authority

Effective environmental compliance and enforcement requires institutions involved in environmental protection to have clear and transparent mandates, including their authority and jurisdiction. This enables the institutions to focus on enforcement efforts (UNEP, 2019). The lack of clear authority and mandates is one of the primary factors responsible for inadequate enforcement of the current regulations (Ijaiya & Joseph, 2014; Komaki & Fluharty, 2020).

Many countries lack clear environmental authority and confusion of roles because too many agencies are involved in environmental compliance and enforcement. This results in either regulatory overlap or underlap. Regulatory overlap occurs when several entities have authority, resulting in potential competition and conflict between institutes and confusion to the regulated community. Regulatory underlap occurs if there is no clear authority for institutions, resulting in an orphan issue or cause for which there is no effective government oversight (UNEP, 2019).

Nemesio (2014) purports that effective environmental protection and enforcement requires a central entity with an exclusive mandate to promote and

ensure environmental goals are achieved. While also acknowledging that too much centralization can result in failure of enforcement because of the inability to tailor strategies and policies to specific regions or situations. Popa et al. (2019) also find that the position of the central authority has influence on the forest inspector's intention to engage in forest law enforcement.

While some researchers find centralization of environmental institutes effective others find a more decentralization approach is more effective. Zhang (2017) in the study on centralized approach to pollution control in China finds that due to the many challenges of the centralized approach such as data verification and trust the centralized enforcement approach is arguably ineffective addressing ineffective policy implementation. The adoption of authority and approach should be specific and applicable to the countries and regions characteristics and structure (Milmanda & Garay, 2020; UNEP, 2019; Nemesio, 2014; Zhang, 2017).

2.2.4 Inadequate Collaboration and Coordination, Including Civic Engagement

Researchers such as Paddock et al. (2011) and Munang and Mgendi (2016) purport that the issue of climate change is threatening the environment at a distressing rate, despite the fact that a massive system of national and international laws, treaties, and agreements exist. Macrory (2014) and Jones (2016) indicated that there might be a series of factors that contribute towards the ineffective nature of the current policy system in curbing the detrimental results of climate change on the environment, collaborative measures in environmental policy implementation being one of them.

The enforcement regime has to emphasize on cooperation among governments, the private sector, and the individual citizens (Giles et al., 2021; Milmanda & Garay, 2020; Zinn, 2012). Inadequate collaboration and coordination, insufficient circulation and sharing of information, and weakened understanding of environmental laws and regulations has contributed significantly towards ineffective environmental protection law enforcement (Giles et al., 2021; Milmanda & Garay, 2020; Preston, 2013).

Various researchers have indicated that collaborative approaches have positive impact on environmental policy implementation. Newig & Fritsch (2008) state that “There is no denial that public participation *can* contribute to deliver effective, legitimate and efficient environmental policies in a multi-level context.” They also acknowledged that current international and European Union environmental policies increasingly promote collaborative and participatory decision-making on appropriate and multiple governance levels as a means to attain more sustainable policies and a more effective and lasting policy implementation.

Koontz & Newig (2014) indicate that inclusion of multiple stakeholders and sources of information, which are participatory approaches, are expected to be solutions to addressing challenging environmental problems. Ubiquitous crowdsourcing and participatory sensing solutions enable monitoring of the state of the physical world (e.g., measure pollution levels) and can at the same time also contribute to raising people’s awareness of the issues at hand. Therefore, the motivation for collaboration in pollution assessment is twofold (Koontz & Newig, 2014).

Within the issue of inadequate collaboration and coordination lies the issue on insufficient circulation and sharing of information between all related entities. The degree of information circulation and sharing between related entities was found to hinder the collaboration and coordination process as well as the environmental compliance and enforcement process as a whole. Various studies identified this factor to impact the efficiency of environmental compliance and enforcement (UNEP, 2019; Preston, 2013; Nemesio, 2014). All the previous studies find that Information should be transparent and accessible by all the stakeholders including the public. This can aid in ensuring the accountability of all parties involved as well as increase the integrity of the institutions which should lead to increased trust and public participation.

2.2.5 Weak Understanding of Environmental Laws and Regulations

The knowledge and understanding of legislation ranges from the general public’s knowledge and understanding of the legislations to the enforcers and judiciary entities knowledge and understanding of the legislations. Various researchers found

weakened understanding of environmental laws and regulations were major factors resulting in inadequate environmental enforcement and compliance (Ijaiya & Joseph, 2014; B. J. Preston Chief Judge, 2013; Nemesio , 2014). Giles (2020) studied the next generation compliance program initiated by the Environmental Protection Agency (EPA) and found that one of the reasons the water pollution of a secondary sewage plants was successfully reduced because of legislation and regulation had unambiguous rules to every plant which made it clear what the rules of the road are. That helped the related entities get a clear understanding and have knowledge of legislations, required practices, and the level of compliance with minimal regulatory intervention, which in turn made it easier for environmental enforcement to monitor and enforce the regulations with minimal resources (Giles, 2020).

Popa et al. (2019) also found that unsuited regulation affected the behavioral intention of the newly formed Forest Inspectorates in Romania. The study used the Theory of Planned Behavior to investigate the intention of forest inspectors to engage in forest law enforcement and highlighted the effect of ambiguity on behavioral intention since they state very descriptive legislation can be a source of bureaucracy.

2.2.6 Critical Observation

From the previous review on environmental enforcement and the factors that hinder the effectiveness of these systems, various factors were discovered. The five main factors identified were weak institutional capacity and commitment, lack of clear authority, inadequate collaboration and coordination (including civic engagement), and weak understanding of environmental laws and regulations.

The previously presented factors indicate the uniqueness of the domains in which the environmental enforcement systems operate. Many of the factors that were identified have been previously researched, established, and resolved in other law enforcement fields, while remaining relatively under-researched and unresolved in many environmental enforcement systems around the world. This gave increased interest to study technology adoption in the unique field of environmental enforcement

since technological solutions are increasingly being adopted and used to deal with some of these factors and enhance these enforcement systems.

The knowledge attained from this section of review gave increased interest to explore technology adoption in the field of environmental enforcement as a potential enhancing factor to the effectiveness of environmental systems which have unique characteristics and challenges. This led the researcher to review the current nature of technology's use in the field of environmental enforcement and other enforcement fields. This will be reviewed in detail in the following sections.

2.3 Technology in Environmental Compliance and Enforcement

Various technologies are being applied to the implementation process of environmental law and criminal law in an effort to maximize efficiency and effectiveness of environmental enforcement strategies and processes. Technologies have been studied, adopted, and implemented to mitigate various shortcomings and issues facing effective environmental compliance and enforcement (Thomas, 2021). Koper et al. (2014) identify five fields central to law enforcement processes and good practices. Information technologies used for collecting, sharing, and managing data; analytic technologies (e.g., Crime analysis); communication technologies; surveillance and sensory technologies; and identification technologies. The same applies to other enforcement types, such as environmental enforcement.

Technology is becoming increasingly fundamental to environmental compliance and enforcement. Glicksman et al. (2016) suggested various ways in which technology plays an important role in environmental compliance and enforcement. One area in which they find technology to be helpful is environmental monitoring (Joe et al. 2018; Kumar et al. 2019; Manfreda et al. 2018).

Technological tools can vary in use from measuring ambient environmental conditions to tracking release of pollution. These tools are helpful in tasks such as identifying regulated entities in violation of pollution control regulations or permits and providing evidence in enforcement actions taken against those entities (Joe et al.

2018; Tygai et al. 2020). They also suggest that the technological advancements in data generation and analysis have the potential to enhance compliance and empower stakeholders in the decision-making process and implementation (Glicksman et al. 2016).

Other ways in which technology enhances compliance and enforcement processes is by providing accurate and low-cost data, thereby lower cost of labor (Xin, 2020). Also, faster and easier data sharing and coordination help a regulatory entities capacity to identify, diagnose, and address concerns; enhance public participation; and increase transparency (Joe et al. 2018; Manfreda et al. 2018; Xin, 2020).

Although prior studies have highlighted the potential advantages in implementation and adoption of technology on environmental compliance and enforcement, they have also found various concerns or limitations to technological advancement in compliance and law enforcement. The limitations range from privacy issues to technical difficulties, and high costs of acquiring of some technologies.

2.3.1 General Technologies

This section is a literature review of the technology including IoT, and its applications in environmental compliance and enforcement.

In enforcing environmental law, particularly concerning the Clean Water Act, smart solutions that support monitoring of water quality have been integrated to ensure industries and individuals conform to water quality standards as they dispose of substances and garbage (Paddock & Crowell, 2020). Communication technology is aiding this move. Use of sensors has impacted the tracking process by easing the monitoring of water quality. Geetha & Gouthami (2016) reported the use of a fabricated buoy, which is a type of sensor that is effective in parameter monitoring. Different versions of fabricated sensors have been integrated to enhance Clean Water Act regulation, including power model, Lion- battery, and power cell module. The sensors are often connected to micro-controllers and other signal processing devices. Using this technology, law enforcement experts can study and keep track of the quality of

Environmental Enforcement Technology Adoption

water resources, including seas, oceans, and rivers. Any company that attempts to channel its waste into these sources is detected, and legal procedures are taken accordingly. The technology has reduced the use of excessive human efforts in guarding the water bodies made the process more accurate than when only police officers were used in guarding (Paddock & Crowell, 2020).

Internet of Things has helped in enforcing the Clean Air Act, providing clean urban cities, and reducing the work of police and other legal officers in safeguarding the city environments. Liu et al. (2015) studied reports on the use of IoT in controlling urban environment and creating smart cities. The authors argue that IoT has been implemented in urban sensing as a means of controlling and tracking the status of the urban surroundings (Liu et al., 2015).

The IoT has been fundamental infrastructure in realizing sensing in the towns and is flexible enough to support different requirements of the application as well as effective management of urban infrastructure (Patel & Patel, 2016). Using technological strategies for law enforcement, the legal system can detect environmental pollution in real-time (Kumar et al. 2021). Various cities have erected centralized controllers with multiple sensor devices at different locations to enable the law enforcement system to get environmental and infrastructural data in real-time. The process gives a digital approach to the management of the urban environment, including the detection of air pollution, land encroachment, and exploitation of other urban resources (Kumar et al. 2021; Patel & Patel, 2016). Similarly, these sensors have made law enforcement shift from human-human interaction during reporting to machine-machine strategies (Patel & Patel, 2016).

Straus et al. (2010) performed a study to explore the effectiveness of communication technologies and mobile technology in the enforcement of the law. The bottom line was that BlackBerry technology is prevalent in law enforcement and detection. The authors used semi-structured interviews, where they interviewed a sample of 45 users in two law enforcement agencies in America. After examining how mobile technology impacts the departments' systems regarding law enforcement strategies, the researchers discovered two themes: ease of tracking mobile sources concerning emissions and ease of reporting. Agencies use smart technologies in

Environmental Enforcement Technology Adoption

detecting vehicles that are emitting carbon dioxide through their exhaust pipes and others that do not comply with the Clean Air Act of America (Straus et al., 2010). After identifying parties that violated laws, the law enforcement personnel were able to communicate more comfortably and faster than before amongst them (Straus et al., 2010).

Technology has facilitated data management and increased the accuracy of reporting and crime identification, including environmental related crime and violations (Burgin, 2021). As in any other industry, big data has been an essential element of the justice system thanks to its ability to generate over 2.5 quintillion bytes within one day (Huijboom & Van den Broek, 2011). This aspect of data collection has been pivotal in criminal justice as it assists legal experts in numerous ways. Fingerprints and DNA can be taken and stored within databases and utilized in the identification of suspects quicker than ever. This data has reportedly helped law enforcing agencies to recognize crimes faster and take immediate actions.

By use of big data and data analytics, legal experts have been able to increase investigations transparency and give a clearer perception of crime due to comprehensive and fast data reporting (Burgin, 2021). The N-DEx system, an element of big data, bills itself thereby enabling experts within the judiciary to conclude or deduce information as indicated by data, thus making better predictions and conclusions than when only humans were involved (Huijboom & Van den Broek, 2011).

Positioning, detection, and monitoring technologies help in detecting and solving illegal activities as they happen, therefore, facilitating enforcement of environmental laws and other rules more effectively than before (Jennings, Fridell, & Lynch, 2014). The use of surveillance cameras helps to capture events in specific areas and offer law enforcement authorities with treasurable information and insights. Use of GPS (Global Positioning Systems) helps to both enable police officers to view crime areas and locate human beings easier as they interact with the environment. They also assist departments in managing the police force well, because police officers' dissemination maps ensure coverage of broad areas (Jennings, Fridell, & Lynch, 2014).

The law enforcement body can use GPS and enjoy robust data due to the seamless inclusion of location services during reporting (Hegarty, Lamb, & Attwood, 2014). Detection technology is useful in criminal law enforcement, whereby the technology helps in detecting gunshots to give police officers immediate access to shooting scenes as well as get helpful information like the number of shooters present and the total of shots fired (Yu et al., 2015).

2.3.2 Crowdsourced Technologies

This section presents a review of the literature on crowdsourced innovations and their impact on environmental enforcement and other fields of enforcement. The existing body of the literature provides crucial insights regarding the applications and benefits of crowdsourced innovations. This section presents the applications and theories presented in previous studies.

Technological innovations, including synchronization of crowdsourcing source data mining and automated social media have been implemented in different regions to facilitate law enforcement. Cities are using crowdsourced techniques to engage communities and the public in environmental law enforcement and community development initiatives through collaboration tools (Omand, Bartlett, & Miller, 2012). Environmental law experts and officers are now gathering information, views, and proposals via web-based arenas and apply the same in formulating policies or taking actions that improve the enforcement of environmental law. From Facebook to LinkedIn, social media algorithms when integrated with crowdsourcing data mining paradigms have made law enforcement approach to be more collaborative and technology-based than centralized and labor intensive (Omand, Bartlett, & Miller, 2012).

Glicksman et al. (2017) finds that environmental information generated by the community already contributes to federal and state government efforts across the U.S. to implement and enforce the environmental laws. Officials have used and encouraged the use of information gathering by citizen initiatives, including the initiatives that are designed to promote compliance. They gave examples to initiatives that have resulted

Environmental Enforcement Technology Adoption

in direct enforcement through citizen science. One of these examples was in Tonawanda, New York in which air quality sampling done by a community activist prompted the state Department of Environmental Conservation to conduct follow-up studies which detected unsafe concentrations of benzene linked to a coke plant that was later indicted, convicted, and ordered to pay fines and conduct community impact studies. They find that current initiatives “merely scratch the surface of the potential to use data generated by community groups and individuals with access to new and cheaper information technologies to bolster compliance and enforcement”.

Vera & Salge (2017) have explored opportunities that arise from crowdsourcing and policing. They suggest that the areas of idea generation and public participation to be the primary areas in which crowdsourcing is applicable in policing. They find that crime prevention programs is one of the applicable aspects. The program’s success relies on collaboration between the law enforcement, public, and broader civil society. Public participation and idea generation combined together also have the potential to engage a wide range of the public in security-related legislative processes. An example is ‘Policing Act Wiki’ in New Zealand where the public were empowered by engaging in dialogue with the parliamentarians responsible for drafting new police law. The research finds that the most promising application of crowdsourced law enforcement is that it can include the ability to involve many citizens more directly in crime investigation and other activities, such as manhunts or missing persons. Micro tasking is also a potential crowdsourcing approach, for example, public monitoring of CCTV online, which has been found effective in the UK.

The Boston Marathon bombing was one of the first direct crowdsourced collaborations of the public and law enforcement. In their study Nhan, Huey, & Broll (2017) on how the public, through Reddit (an online social platform), attempted to assist law enforcement through conducting their own investigation. The researchers found that the users shared and searched for information to help identify the perpetrator, and some even some expert knowledge to find clues to help with the investigation. Even though the public did not themselves solve the crime, the potential is clear. The researchers investigated how the users (Reddit) participated in the online discussion and found several categories, which will be listed according to number of users. First, most used the platform for self-expression. Second, they shared and

distributed information and data. Third, they provided assistance to victims. Forth, they discussed information directly related to the investigation.

Other crowdsourced applications for law enforcement have been used in crime reporting and crime prevention. Furtado et al. (2010) conducted their study on the WikiCrimes system, which is meant to provide a common area of interaction among people so that they can report and monitor locations where crime is occurring. They found that there are three main goals of the system: 1) Increase transparency and publicity of information on crimes, 2) citizen prevention, and 3) increased crime reporting in areas with unreported crime. The researchers suggest that this platform can be considered as an auxiliary source of information collection that may add more quality to the data gathering process.

Other studies also give several examples of crowdsourced crime prevention and reporting applications. Ariffin, Solemon, & Abu Bakar (2014) evaluate mobile crowdsourcing for crime watch. They use six mobile applications related to crime; Enforce Crime Map, CrimeWatch Mobile, Community Against Crime, Malaysia Crime, Community Alert, and MyDistress. Through their evaluation, they suggest that crime related information is essential, since it increases the local authorities' (e.g., law enforcement agencies) ability to analyze information to help prevent similar crimes occurring.

Stevens & D'Hondt (2010) assert that solutions using participatory sensing and crowdsourcing are applicable to both monitoring the physical world and raising people's awareness. NoiseTube which a low-cost approach to monitoring noise pollution which uses the public and mobile devices as noise sensors. Stevens & D'Hondt (2010) suggest that this initiative is an effective tool in gather data on noise pollution to support policy and decision making. It can also be used by citizens for a range of things, from increasing awareness to gathering evidence.

Air quality monitoring technologies have had significant advances in innovation. English, Richardson, & Garzon-Galvis (2018) give several examples of innovation in crowdsourced innovation of air quality monitoring. One such example is in the Imperial Valley of California, where a community-based air quality low-cost monitoring system

Environmental Enforcement Technology Adoption

which measures particles, temperature, humidity, and has a microcontroller to allow real-time wireless data transfer. Members of the public were trained in maintenance and troubleshooting of the monitor and involved in identifying the monitoring locations. A website (www.ivanair.org) shows the data created in real time and gives health warnings and answers question. Data from the system are being evaluated for public health actions. Another example of the use of crowdsourcing innovations in environmental monitoring and awareness is Citi-Sense-MOB project, which are monitors that allow users to monitor air quality (English, Richardson, & Garzon-Galvis (2018)).

Castell et al. (2014) suggest that the project (Citi-Sense-MOB) will develop the infrastructure to monitor environmental data continually using micro-sensors fixed on moving platforms, such as vehicles. The project consists of several process and applications which are illustrated in Figure 2.4. The project's final output will provide real-time data on air quality and CO₂ emissions at road level for both authorities and citizens. The project is also expected to increase awareness on climate change. and air pollution as well as awareness of the health impacts of air pollution. The project will focus on promoting behavioral changes to reduce air pollution.

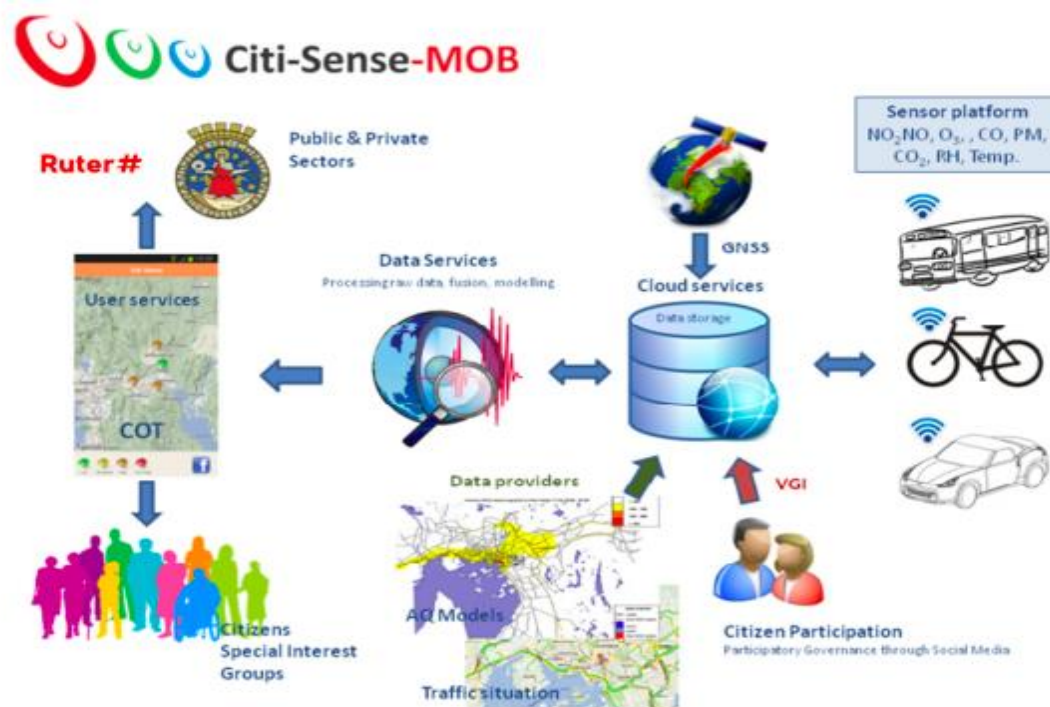


Figure 2. 4 Citi-Sense-MOB system overview (Castell et al.2014)

Environmental Enforcement Technology Adoption

Albers, Lange, & Xu (2017) proposed a project that creates a tool for environmental monitoring and awareness through a mobile application (PAN) available to the participants. The users can take images of point of interests using smartphones and the PAN App. The user is directed to a certain location and is then guided to photograph in a certain direction. The images are processed to time-lapse videos to show changes. These data can be used for long term monitoring. They also expected awareness through certain features in the PAN app, such as digitally guided tours.

One of the tools which have been studied and used in environmental protection is social media. Toivonen et al. (2019) states that enhanced understanding of human nature interactions is essential to conservation science and practice, but retrieving relevant information is still challenging. Although social media has become an important source of data on human-nature interactions, analyses of social media is still limited and are not applied to their full potential. In the study they gave several examples of current social media data sources and methods of mining and analysis of the data. They mainly focused on social media platforms that they found were most popular and helpful in studying human nature interactions. The main platforms were Facebook, Twitter, Instagram, Flickr, and Weibo.

Ghermandi & Sinclair (2019) also find that the importance of social media analysis can be influential in enhancing human-environment interaction understanding and shaping future environmental conservation and management. Through their analysis of 169 studies in uses of social media data in environmental disciplines, they support the idea that this data source offers unique opportunities to extend the scope, scale, and depth of environmental research. They also find that most studies focus on the analysis of people's behavior and perceptions of the environment, followed by environmental monitoring and applications in environmental planning and governance.

The IoT has helped to reduce the cost of human labor and reduce corruption concerning environmental law enforcement (Bennett et al. 2014). By using tracking systems and centralized controllers in cities, the number of police or experts needed to examine and keep the cities environs in check is lessened. As a result, the amount

spent on wages is reduced, as the enforcement strategy is less manual and more computerized than when IoT is not used. Additionally, as the integration of technology removes human interaction in some areas, more transparency is evident in the system and corruption reduces (Fang et al. 2017).

2.3.4 Satellites Technologies

For some time, earth observation through satellites technologies have been utilized in environmental enforcement and compliance. However, substantial advances in these technologies have brought new opportunities in combating environmental crime Although in some cases not implemented and used to full potential (Mahfud et al. 2021).

Prudy (2009) clarifies three uses of satellite earth observatories in compliance assurance and enforcement: Monitoring as part of enforcement strategy, monitoring of high-risk offenders, and historical evidence. The researcher gives examples for each of the uses:

- 1) Monitoring as part of enforcement strategies: In Australia satellite images are utilized to decrease illegal deforestation by showing past places in which individual trees were located and then removed by farmers. Enforcement agencies are alerted without the need for physical inspections. Another study by Mahfud et al. 2021 show the application of satellite imagery and sensing in illegal logging monitoring in Indonesia (Mahfud et al. 2021).
- 2) Monitor high-risk offenders: A person in the UK was prosecuted in 2005 storing scrap cars without a waste management license. Monitoring through later satellite images in 2006 revealed that the offender is still storing scrap cars and did not comply with the court order. The satellite images lower the need for direct inspection (Prudy, 2009).

- 3) Historical evidence. In the UK an offender was prosecuted in 2006 for managing an illegal landfill site where hazardous waste was burned. At trial, the regulator believed that the offence took place in 2005– 2006. However, historical satellite images later accessed showed that there was burned land at the site in 2004, which suggested illegal activity had been taking place for longer than thought. If this evidence had been available at court, prosecutors could have pushed for a tougher sentence (Prudy, 2009).

The Australian Government acting through the Murray–Darling Basin Authority conducted a case study for compliance monitoring using satellite imagery in 2018. Murray–Darling Basin Authority (2018) find that remote sensing through satellite imagery has great potential in assisting compliance assurance and enforcement processes. They find this to be true especially when dealing with measurements of water availability and use in large spatial scales. In their study they used over a hundred images from Sentinel 2, which is a free, open, and publicly available satellite. through the review and analysis of their data, no or small changes were found, which implies a low probability that any significant compliance issues occurred. They also purport that remote sensing is an essential factor if an effective compliance network, which must be combined with other sources of data.

Onoda & Young (2018) Earth observation by satellite remote sensing provides a powerful tool for monitoring various features of the Earth's environment not only because of the wide range of measurements that can be performed, but also because of the high frequency and large area for which data can be acquired. The digital era has made it possible to perform, store, analyze, and share data globally in a way that no one could imagine half a century ago. Available technology allows Earth observation data to be disseminated widely, and the need is stronger than ever to devise ways to put the data to work in meeting societal challenges (Chugg et al. 2021).

Prudy (2009) find that satellite technologies cannot replace ground-based monitoring but could support current enforcement methods. However, by cutting the number of physical inspections, EO technologies could potentially reduce overall

monitoring costs. This would also improve safety for inspectors who often face violent and threatening behavior when conducting investigations.

2.3.5 UAV and Drone Technologies

UAVs are unmanned aerial vehicles which are operated by remote or with autonomously preplanned flight plan. UAVs include various configurations of unmanned aircraft, multirotor helicopters, and balloons/blimps of different sizes and shapes (Klemas, 2015). Klemas (2015) suggests that UAV provide a possible alternative to conventional platforms for obtaining high-resolution remote sensing data at a lesser cost, as well as enhanced operational flexibility.

Drones are being considered for use by law enforcement agencies in a number of countries to perform specific tasks. UAVs and drones have begun to be used by law enforcement entities to search for wanted and missing individuals, investigate crimes and accidents, and preserve and document crime scenes, among other things. The use of drones can aid law enforcers in the performance of their responsibilities more efficiently in a variety of ways (Barrows, 2021; Klemas, 2015). A large number of law enforcement personnel from across the world have already been trained in the usage of unmanned aerial vehicles. Unmanned aerial vehicle (UAV) projects have been formed or are in the process of being established by a large number of public safety agencies.

The current use of UAV and drone technologies in law enforcement provide benefits and support for a variety of law enforcement tasks and responsibilities, which will be reviewed in the following:

Search and Recue

Search and rescue is one of the most widely utilized applications of drones by law enforcement. Drones can cover an area far more swiftly and efficiently than more traditional methods such as foot and car patrols. Additionally, drones can fly and reach previously unreachable locations. For example, they can fly between buildings and

Environmental Enforcement Technology Adoption

reach tight spaces, allowing them to access areas that helicopters cannot. When properly outfitted with a thermal camera, a drone may readily detect missing individuals concealed in darkness or behind buildings or objects (Barrows, 2021; Price, 2019).

Location and apprehension of wanted persons

Law enforcement drones can be deployed to aid in apprehending fleeing felons. With object tracking capabilities, the drone can trace and monitor a suspect fleeing the site of a crime, providing information on the whole situation, and assisting authorities in apprehending the person safely (Barrows, 2021; Price, 2019).

Aerial views can be essential in risky situations such as active sniper scenarios or in the investigation of illegal operations. The eyes in the sky can assess the situation by capturing both the wide picture and, with zoom cameras, minute details, all while increasing the safety of law enforcement agents. Drones can also be used to make high-risk traffic stops safer (Price, 2019). When a suspect refuses to exit a car, cops may use a drone to examine the situation and even broadcast recorded messages from a safe distance. Drones can also play a critical role in crowd surveillance, allowing operators to survey the whole scene for suspicious activity or to find distressed individuals (Barrows, 2021).

Crime and accident investigation

Cameras are critical for seeing both the big picture and the tiny details. Reporting and Analysis is when an aerial viewpoint is used in combination with mapping software to recreate traffic crashes or criminal scenes (Barrows, 2021; Price, 2019). Drone camera images and maps may be used to analyze the sequence of events leading up to an accident for accident reports, as well as to piece together the events surrounding a crime (Barrows, 2021).

Numerous benefits have been discovered through the employment of these technology in law enforcement (Barrows, 2021; Klemas, 2015; Price, 2019). One of the most significant benefits is the greater safety of law enforcement officers and the

general public (Barrows, 2021). Another advantage is that it may save law enforcement agencies time and effort, since it is capable of reaching needed locations and situations faster and covering a larger region (Barrows, 2021; Price, 2019).

Drones were also discovered to save money, as they may be less expensive to operate, store, and maintain than more traditional vehicles such as helicopters (Klemas, 2015). With the use of UAVs, drones, and other technology, law enforcement organizations can do their tasks more quickly and efficiently. It is impossible to predict the extent to which drone technology will impact public safety in the future due to the rapidity with which it is growing at this time (Barrows, 2021; Klemas, 2015; Price, 2019).

Drones and UAVs for environmental protection

Sandbrook (2015) also suggests that UAVs offer flexible, accurate, and lower cost solutions environmental enforcement. UAVs currently can be equipped with high tech sensors such as high-resolution imagery, radar, and infrared sensors, and are utilized a wide range of environmental applications. The researcher suggests that UAV technology has the capability to fill current environmental remote sensing gaps and provide essential data for a variety of environmental issues, such coastal wetland mapping, flood, and wildfire surveillance, tracking oil spills, ecosystem monitoring, and damage assessment (Klemas, 2015).

Sandbrook (2015) identifies two main types of applications of UAVs for conservation, research, and direct applications. The most common use of UAVs is for law enforcement and monitoring of illegal activities. Some examples of the applications are illegal hunting, boundary patrols, illegal deforestation. The UAVs can be used to locate violation to help ground law enforcement personnel, provide high resolution evidence, and as a deterrent. They are also useful when monitoring large and difficult to reach areas.

Burgues & Marco (2020) in their review of literature on chemical sensing using small drones, find that drones can be a useful measurement and detection tools law enforcement agencies, including environmental agencies, to ensure compliance with

air emission regulations. They find that the potential for chemical sensing using drone for law enforcement expanding especially with the availability of low-cost sensors and attainable drone technologies. They find that they can be a time and effort saving tool especially in difficult situation and locations. The drone can provide fast and very accurate measurements of chemicals. The research gives several cases in which drone sensing was implemented for chemical monitoring and detection (Burgues & Marco, 2020).

In the Netherlands, Denmark, Norway, and Singapore the maritime authorities are utilizing drones to search ships coming through their ports for any violations of emissions laws and regulations such as the fuel sulfur content (Explicit-ApS, 2018; Topali & Psaraftis, 2019). Another example is in countries where some people use illegal material under environmental law to heat homes, such as garbage, low quality coal, and scrap wood. Some law enforcement agencies in these countries have begun to use drones equipped with specialized sensors to monitor detect and test for elevated concentrations certain chemicals that indicate burning of hazardous or illegal material in residential areas (Burgues & Marco, 2020).

2.3.6 Data Management and Analysis Systems

Effective environmental data management and analysis is an essential factor in retrieving and applying environmental data. Sensor technology advancement have made sensors more compact, low cost, and smart and power efficient. Which in turn, has led to deployment of large numbers of sensors for generation of real-time spatiotemporal environmental data and environmental monitoring. Effective environmental data management systems are dependent on the integration and consolidation of the sensor data streams (Gong, Geng, & Chen, 2015). In this section we will reviewing currently used data management and analysis systems and their effect on environmental compliance and enforcement strategies and processes.

2.3.6.1 Geographic Information System (GIS)

A geographic information system (GIS) is a computer system that collects, develops, manages, and analyzes various types of data. "GIS has a comprehensive

set of analytic and data transformation tools to perform spatial analysis, data processing and geo-statistical analysis” (Gargiulo et. al, 2016). This delivers an advanced tool for mapping and analysis that is utilized in almost every field from science to policy implementation. GIS facilitates understanding of patterns, connections, and geographic context. The systems can provide many benefits such improved collaboration and enhanced decision-making and management (Huang, 2017).

The GIS has both hardware and software components. GIS integrates many different kinds of data layers using spatial location. Most data have a geographic component. GIS data includes a variety of formats such as imagery, remote sensing data, digital data, base maps, and spreadsheets and tables. All these different types of data are overlaid on top of one another on a single map (Huang, 2017). The GIS further facilitates analysis of this data spatially for evaluation, prediction, estimation, interpretation, investigation, and other processes which can be beneficial for decision and policy making (Lu, 2019).

GIS in Law Enforcement

Various research has identified several benefits and potentials of GIS applications in law enforcement including environmental law enforcement. Wang (2012) identifies six major areas in which GIS in law enforcement have a major contribution in policing efficiency. These applications are support for field officers, crime investigation and prevention tools, policy implementation and evaluation tools, police force planning tools, tools for testing crime theories, and communication tools. These areas are applicable to environmental compliance and enforcement. Some of the factors found to be affected positively by GIS implementation in law enforcement are accuracy, resource management, time, data sharing, crime prevention and transparency (Wang, 2012).

Steele (2018) also purports that proper GIS implementation in law enforcement agencies can be an effective time saving tool, effective resource management, transparency, data sharing, and crime prevention. Speed and enhanced resource management are due to the GIS software’s ability to reduce time and labor in

gathering, managing, and analyzing data which is done by the software. The software also has the ability to provide accurate and visible data for crime prevention and operation planning, through better decision-making processes. The data can also be shared faster and with other department and agencies or even the public for fast, accurate, and transparent data managing and sharing (Borum, 2020; Steele, 2018; Wang 2012).

Gargiulo et al. (2016) also find effective resource management and crime prevention to be enhanced through GIS and other innovations in early detection of environmental violations. Gargiulo et. al. (2016) purport that GIS technologies are an easy and simple method of capturing, updating, integrating, and mapping geospatial data. They find that one of the most valuable uses of this technology is environmental forensics because of its ability to examine spatial relationships between environmental observation and other historic and mapped data.

GIS and spatial analysis technologies are important to studying illegal activities but the effectiveness of a GIS in environmental forensics is often related to the number of the data/layers managed by the system and the specific know-how of the expert involved in the investigation activity (Borum, 2020). Another way in which this technology is beneficial is in smart policy making (Gargiulo et. al, 2016). Larsen (1999) also purports that GIS systems are tools to be utilized in decision making especially through environmental modelling which are an important feature of the GIS system. Each GIS includes a set of interactive maps and other views that show features and relative relationships on the earth's surface. Various map views of the underlying geographic information can be constructed to support query, analysis, and editing of geographic information. Maps can also be used to access geographic modelling tools that are used to derive new information (Gargiulo et. al, 2016; Larsen 1999).

Another study proposes a system that integrates various innovations such remote and smart sensors, Autonomous Underwater Vehicles (AUV), radar and modified GIS (Volunteered Geographic Information System-VGI) that includes data from volunteers that input data through specialized apps to enhance the monitoring and deterrence of marine activity, pollution, and violations (Martinelli & Moroni, 2018). One of the important features of the proposed systems is that it merges the public or

volunteer's data with authoritative data collected from other devices in order to produce a clear image of the status of the ocean and resolving the ambiguities that might occur from singular data sources might suffer (Martinelli & Moroni, 2018).

2.3.6.2 Blockchain Technologies

This section presents a review of the literature on blockchain technology and its impact on environmental enforcement. The existing body of the literature provides crucial insights regarding the applications and benefits of blockchain technology. The section begins with the definition of blockchain technology and its application in various industries. This is followed by the analysis of the impact of blockchain technology on environmental enforcement. Therefore, this section presents the findings and theories presented in previous studies.

Basics of Blockchain Technology

Blockchain is regarded as a digital list of records in which involved parties record transactions in blocks (each block is an encrypted piece of data) and link them using cryptography. Once they fill a block with data, they seal and add it to the blockchain in a chronological manner. Once sealed, no alteration is done without the consensus of the parties involved. Scholars agree that blockchain technology is promising since it places trust and authority in a decentralized network (Al-Saqaf & Seidler, 2017; Abreu, Aparicio, & Costa, 2018).

The thought of eliminating a centralized authority makes the technology applicable to solving national and global challenges. For example, blockchain technology is applied in banking (Al-Saqaf & Seidler, 2017), auditing (Abreu, Aparicio, & Costa, 2018; Bible, Raphael, Taylor, & Valiente, 2017), and the energy sector (Andoni et al., 2019), with the intention of bringing significant benefits and innovation. According to Andoni et al. (2019), blockchain technology ensures transparent, tamper-proof, and secure systems. Therefore, in line with the objectives identified in chapter one, it is critical to assess the application of blockchain technology on the enforcement

of environmental laws and regulations, as lawmakers and regulators understand the need to protect the environment (Andoni et al., 2019).

Kshetri (2017) posited that players of leading technology firms are heavily investing in blockchain: for instance, IBM has about 2,200 workers and \$230 million invested in blockchain-powered Internet of Things. The practical purpose of blockchain is transforming the manner in which individuals do business or operate their daily businesses. Proper evaluation and implementation of these applications are essential. Unstructured experimentation of blockchain applications without strategic value evaluation of feasibility or usefulness means that several organizations will not see a profit on their savings (Kshetri, 2017).

Abeyratne & Monfared (2016) identified various domains in which blockchain technologies are, or can be, applied, such as the financial sector, social sector, and legal sector. One of the applications in the legal sector that is increasingly getting attention as a means enhancing the execution assurance and enforcement process is smart contracts. The making of daily agreements through smart contracts might come sooner than people believe.

Abeyratne & Monfared (2016) postulate that smart contracts are self-automated software that achieve actions after certain actions or criteria are met (e.g., automatically transfers assets after payment is received). Also, smart contracts might theoretically automate the colossal quantity of legal resources needed to prepare, execute, and enforce contracts, hence lowering the need for manpower. The making of daily agreements through smart contracts might come sooner than people believe.

According to Shackelford & Myers (2017), most of the things that people buy are not made by a single entity, rather through several entities in the supply chain that provide components for the end product, for instance, graphite for pencils is provided by a different entity than the final brand. The issue with this system is that if one of these mechanisms fails, the brand takes the backlash brunt. Effective tracking of the components is essential to achieve the quality and quantity needed by the final entity. Blockchain application have been increasingly used as an effective tool across the

supply chain to achieve transability of the components and products (Kouhizadeh & Sarkis, 2018).

Truby (2018) finds that knowing the source of the supply chain is a very vital thing. This assists in ensuring that quality is guaranteed and protects the business from the poor choices of other people. The notion behind using blockchain for this could be that the ledger on the blockchain offers a clear and encrypted manner to ensure people are buying what they believe in safely. The economists list Skuchain and Provenance as up and coming players in a blockchain-enabled supply chain tracker industry (Shackelford & Myers, 2017).

Blockchain in Environmental Enforcement

Various entities have an essential role to play in protecting the environment, where following laws and regulations help in protecting the environment, including businesses. A study by Abreu, Aparicio, & Costa (2018) investigated the application of blockchain technology in environmental auditing. According to the findings, environment protection agencies stand a better chance to achieve their objectives using the blockchain technology. For example, the technology allows a decentralized system, where personnel on the ground can record data. Once they fill a block with data, they seal and add it to the blockchain in a chronological manner. This is critical in environmental enforcement since no one is allowed to alter the data at a later date.

Once sealed, no alteration is done without the consensus of the parties involved. Therefore, it becomes easier for environmental law enforcement agencies to handle cases transparently. As noted by Andoni et al. (2019), blockchain technology ensures transparent, tamper-proof, and secure systems. Xu, Weber, & Staples (2019) agree with Andoni et al. (2019) that it is difficult for people to tamper with the initially entered data once blockchain technology is applied. For law enforcers, this is critical for availing accurate, transparent, and tamper-proof data on how individual or firms are observing laws and regulations. It is through such benefits that environmental enforcement is significantly improved since it will facilitate the provision of the much-needed evidence (Andoni et al., 2019).

Environmental Enforcement Technology Adoption

Herweijer, Waughray & Warren (2018) researched and analyzed more than 65 blockchain technologies and applications for environmental protection from a range users of block chain technologies across industry, big tech, research, and government. They identify several blockchain “game changers” with great potential to deliver innovative solutions to environmental challenges. They summarize them as 8 “game changers”:

1. “See-through” supply chains
2. Decentralized and sustainable resource management
3. Raising trillions – new source of sustainable finance
4. Incentivizing circular economies
5. Transforming carbon (and other environmental) markets
6. Next-gen sustainability monitoring, reporting, and verification
7. Automatic disaster preparedness and humanitarian relief
8. Earth management platforms

The two game changers we find to have potential in the field of environmental compliance and enforcement are the “see through” supply chain and the Next-gen sustainability monitoring, reporting, and verification.

The “see through” supply chain through blockchain has the potential to create transparency in the supply chain. The blockchain provides immutable record provenance data through recorded transactions throughout the supply chain, which provides a traceable source of data from the source to the store (Herweijer, Waughray & Warren, 2018). This aspect can have potential to trace violations and illegal trade (Allena, 2020 ; Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020). One such example is a pilot study conducted in the Pacific to trace the tuna fishing industry from landing of fish to the consumer (Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020; Visser & Hanich, 2018). The aim of the project is to improve tuna traceability to help stop illegal and sustainable fishing practices in the Pacific Islands tuna industry (Visser & Hanich, 2018).

In Next-gen sustainability, monitoring, reporting, and verification game changer, the blockchain technology can potentially transform the sustainability assurance and

reporting process in corporations, especially if combined with third-party verification and monitoring tools (e.g., sensors), which would give independent and accurate data. This method (third-party reporting and assurance) increases transparency and data authenticity. This can be achieved by implementing smart contracts to access trusted, real-time data that is difficult to manipulate (reduce fraud) (Allena, 2020; Herweijer, Waughray & Warren, 2018). Niya et al. (2018) proposed and evaluated an IoT and blockchain based distributed system for automated measurements, storage, and monitoring of water and air quality data in the environment. The researchers purport from their evaluation of their system that the data has high accuracy and authenticity which can be considered a reliable source of pollution evidence (Allena, 2020; Niya et al. 2018).

Blockchain technology has the potential to increase transparency, data authenticity, and speed of data transfer in environmental monitoring and measurement, especially when incorporated to IoT monitoring tools (smart sensors). Ibba et al. (2017) proposed a blockchain system to manage the environmental context. The proposed project named Citysense which, similar to previously reviewed projects such as CitiSense, that use IoT connected sensors (moving or fixed) to monitor the environment, such as air quality. In their research they propose to add a blockchain system (Figure 2.5), which they suggest will provide accurate real-time data which can be used to deliver real-time solutions and counter measures. They also suggest that the project will increase collaborative measures through the collaboration of the stakeholders. This project has clear potential for improving the environmental enforcement processes through collaborative blockchain IoT solutions, which can show violations and infringements in real-time. Since the data is secure and authentic it also can be used as evidence and proof of noncompliance.

CitySense: layers

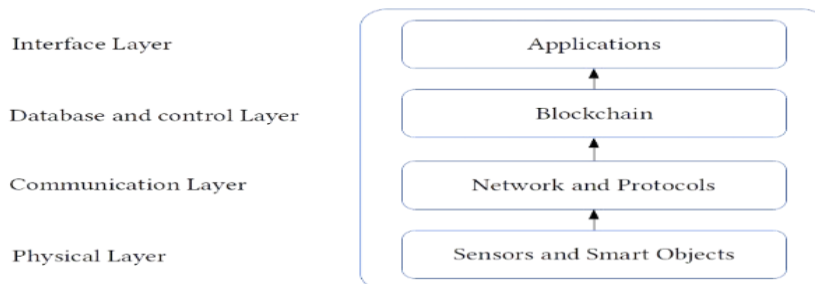


Figure 2. 5 City-Sense Proposed Project Layers

2.3.7 Artificial Intelligence in Law Enforcement

Increasingly law enforcement systems have increasingly adopted artificial intelligence to strengthen their personnel and agencies. AI can be an essential factor in law enforcement because it can assist in many areas as well as enhance efficiency (Interpol, 2019). Some aspects in which AI technologies are being used in law enforcement are by surveillance and crowd control, being increasingly used for facial identification, and scanning video footage for anomalies. AI can also help deter and solve crimes while providing society an element of safety and assurance. Alzou'bi et al. (2014) in their review of artificial intelligence in law enforcement in Jordan find that AI as a supportive technology is an important tool for policing and combating crime, including cybercrimes.

AI and robotics are a relatively new concept in law enforcement, but many countries are increasingly evaluating and adopting AI and robotics application for law enforcement. The extent of exploration and adoption varies among countries and governments. Some have already adopted or have approval for use of some AI and robotics technologies, while other are still in the exploration and evaluation stage (Interpol, 2019). Interpol (2019) further identify several application of artificial intelligence in law enforcement. The examples are as follows:

- Independent research, analysis, and response to requests of international mutual legal assistance
- Advanced virtual autopsy to aid in determining cause of death
- Robotic patrol systems
- Forecasting for predictive policing and crime hotspot analytics to optimize resources
- Computer vision software to identify wanted individuals and stolen vehicles.
- Devices for vulnerable and exploited children identification
- Behavior detection tools to identify potential criminal activity
- Fully self-reliant means of identifying and fining online scammers

Environmental Enforcement Technology Adoption

- Crypto-based packet tracing tools enabling law enforcement to tackle security without invading privacy

AI in Environmental Enforcement

Many environmental issues can be effectively addressed through artificial intelligence solutions. AI solution can aid processes such as planning, forecasting, monitoring, diagnosis, analysis, and control (Zhang et. al, 2021). Hojageldiyev (2019) also states “The tools developed based on the AI technologies and machine learning can help specialists working in the fields of HSE to advance their efforts in environmental protection and contribute to mitigating climate change and weather disaster issues, biodiversity conservation, waste reduction, water security, healthy oceans, and clean air.”

The study conducted by Zhang et. al (2021) proposes an Artificial Intelligence assisted Semantic Internet of Things (AI-SIoT) system for environmental monitoring and find great advantages and potentials for their system in enhancing environmental monitoring. Although the study is conducted on environmental monitoring, these tools can be used for understanding and prediction. The potential for monitoring and detecting environmental crime and violation is also permissible since it was found to be applicable to other law enforcement agencies (Al-zou’bi et. al, 2014; Interpol, 2019). Monitoring potential through artificial intelligence were found in various aspects of environmental compliance and enforcement. Some examples of these application are as follows (Vinuesa et al. 2020):

- The combination of AI, satellite imagery, and smart sensors can improve detection of changes in environmental conditions, including deforestation, land use, and other changes.
- Identification, monitoring, and tracking of invasive species can be achieved by combining AI and smart technology. This may even include the possibility of elimination of invasive species.

Environmental Enforcement Technology Adoption

- Data collection from remote and harsh locations and environments such as remote ocean locations, which helps species and habitat protection and can detect and track illegal fishing activities.
- AI simulations can be used as tools to detect and identify pollution sources swiftly and accurately.

AI technologies in conservation are a potential tool to help in wildlife protection through combating illegal hunting and wildlife trade (Dauvergne, 2020). With the insufficient resources to tackle the alarming rate of poaching and wildlife trade, AI solutions are increasingly being adopted and studied to help. One example given by Dauvergne (2020) is a device used to combat ivory poaching built by the nongovernmental organization RESOLVE called TrailGuard AI. The device is a deep learning camera trap that is placed in strategic location in reserves to monitor and identify vehicles entering or exiting the park. The images are sent to the parks headquarters where officials identify and decide what course of action to take. Figure 2.6 display general features and components of TrailGuard system.

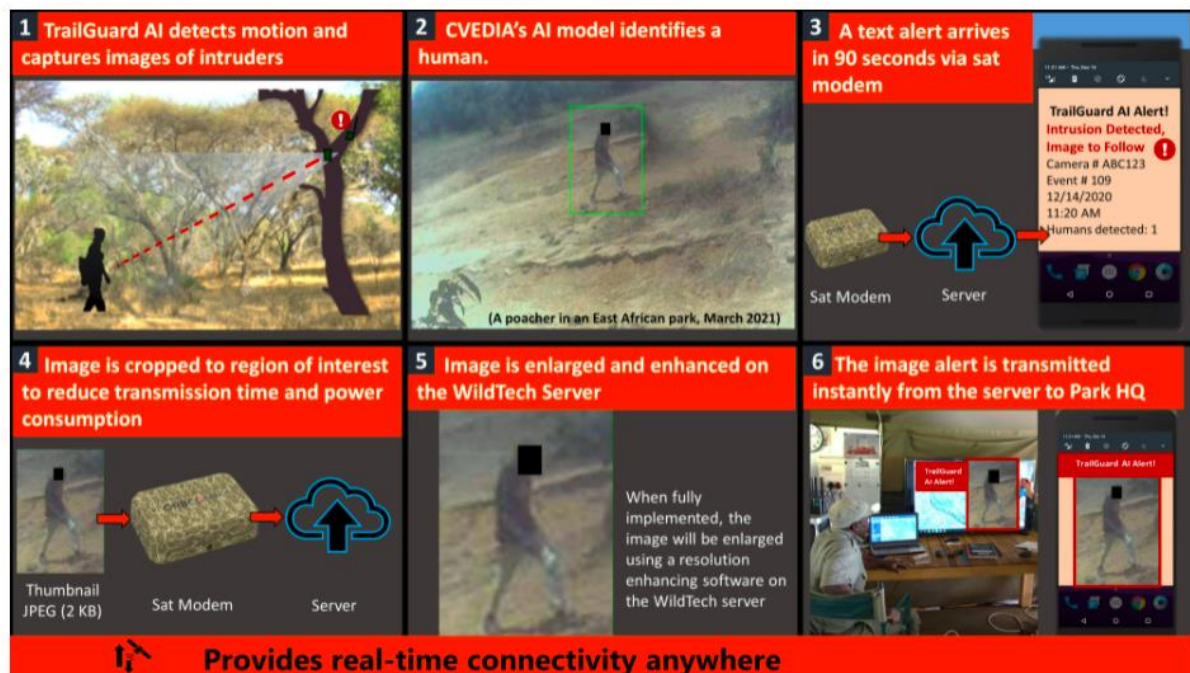


Figure 2. 6 Features of TrailGuard (Golbalconservation.org)

The TrailGuard was tested in Tanzania's Grumeti Game Reserve and led to many arrests. AI can also potentially be a tool in combating illegal wildlife trade.

Dauvergne (2020) is the example of AI technology prototype called the Chimiface. The innovation uses facial recognition systems to identify and search the internet (e.g., social media platforms and e-commerce websites) to identify chimpanzees and suspicious posts and possibly alert the appropriate authorities.

2.3.8 Summary of Technologies and Critical Observations

In the previous section, the current and potential technological applications for law enforcement, including environmental law, were reviewed. The following (Table 2-1) is a brief summary of the reviewed technologies for law enforcement.

Table 2. 1 Overview of technologies in law enforcement and their use

Technology	Uses	Application type	References
Crowdsourced	Public engagement	Crowdsourced sensors Web-based platforms Social media	Glicksman et al. 2017; Omand, Bartlett, & Miller, 2012; Nhan et al. 2017; Vera and Salge, 2017
	Information gathering/evidence	Web-based platforms Social media Crowdsourced sensors	Omand, Bartlett, & Miller, 2012; Nhan et al. 2017; Stevens and D'Hondt, 2010
	Crime reporting	Web-based platforms Mobile apps	Affrin et al. 2014; Furtado et al. 2010
	Crime prevention	Web-based platforms Mobile apps	Affrin et al. 2014; Furtado et al. 2010; Vera and Salge, 2017
	Monitoring	Crowdsourced sensors Mobile apps	Albers et al. 2017; Castell et al. 2014; English et al. 2018; Stevens and D'Hondt, 2010
	Awareness	Crowdsourced sensors Mobile apps	Albers et al. 2017; Castell et al. 2014; Stevens and D'Hondt, 2010
	Resource management	All the above	Bennett et al. 2014; Fang et al. 2017
Satellite technology	Monitoring	Imagery Sensors	Chugg et al. 2021; Mahfud et al. 2021; Onoda & Young, 2018; Prudy, 2009
	Resource management	All of the above	Onoda & Young, 2018; Prudy, 2009

Environmental Enforcement Technology Adoption

UAV and drones	Information gathering/evidence	UAV/drones with smart sensors	Sandbrook, 2015
	Monitoring	UAV/drones with smart sensors	Burgues & Marco, 2020; Explicit-ApS, 2018; Klemas, 2105; Topali & Psaraftis, 2019
	Resource reduction	All the above	Klemas, 2015; Sandbrook, 2015
GIS	Crime prevention	Integrated with other technologies	Gargiulo et al. 2016; Steele, 2018; Wang, 2012
	Investigation	Integrated with other technologies	Borum, 2020; Wang, 2012
	Data Management	Integrated with other technologies	Borum, 2020; Steele, 2018; Wang, 2012
	Planning/ Decision-making	Integrated with other technologies	Larsen, 1999; Steele, 2018; Wang, 2012
	Monitoring	Integrated with other technologies	Borum, 2020; Gargiulo et al. 2016; Larsen, 1999; Martinelli & Moroni, 2018
	Public participation	Integrated with other technologies	Borum, 2020; Martinelli & Moroni, 2018
	Resource management	Integrated with other technologies	Borum, 2020; Gargiulo et al. 2016; Larsen, 1999; Martinelli & Moroni, 2018; Steele, 2018; Wang, 2012
Blockchain	Information auditing/ evidence		Abreu et al. 2018; Allena, 2020; Andoni et al.2019; Herweijer et al. 2018; Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020; Visser & Hanich, 2018; Xu et al. 2019
	Monitoring		Allena, 2020; Herweijer et al. 2018; Ibba et al. 2017; Niya et al. 2018
	Resource management		Allena, 2020; Herweijer et al. 2018; Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020
AI	Monitoring/ Surveillance	Integrated with other technologies	Alzou'bi et al. 2014; Dauvergne, 2020; Hojageldiyev, 2019; Interpol, 2019; Vinuesa et al. 2020; Zhang et al. 2021
	Planning/ Decision-making	Integrated with other technologies	Zhang et al. 2021

Environmental Enforcement Technology Adoption

From the previous sections, several critical observations were reached regarding the nature of technology use and adoption in the field of environmental and other law enforcement systems.

Previous studies show a wide range of technological applications for various purposes in criminal law enforcement and environmental protection, but very few studies have studied and portrayed technology use in the unique field of environmental enforcement. The many technologies and their uses are summarized in the previous Table (2.1). This demonstrates a lack of literature on technology use and adoption in the field of environmental enforcement, which this study aims to explore further.

Most of the previous studies suggest great potential of adopting technological solutions on the effectiveness of environmental enforcement. This assumption was attained from the finding of technology use in both criminal law enforcement and environmental protection processes. The reviewed technologies included technologies used by the enforcers or the public to achieve their goals. This research aims to focus on the technological use and adoption from the perspective of the enforcers of environmental laws.

Most of the successful technological applications in the reviewed fields were achieved through the integration of various technologies into one system. This was shown to maximize the technologies' ability to provide enhanced outcomes and be highly accepted and adopted.

The previous observation led this research to further explore the nature of technology use and adoption in the field of environmental enforcement. This required increased knowledge and understanding from previous studies on the issue, especially on the limitations and the factors that affect the adoption of technology in the research's field of study. The review of the limitations and the technology acceptance and adoption will be discussed in the following sections.

2.4 Technology Limitations

Although prior studies have highlighted the potential advantages in implementation and adoption of technology on environmental compliance and enforcement, they have also found various concerns or limitations to technological advancement in compliance and law enforcement. The limitations range from privacy issues to technical difficulties and high cost of acquiring of some technologies. Although the previous studies discussed the limitations linked to each technology separately, for the purpose of the study, the limitations were gathered into issues with shared limitations in the form of general limitations of all technologies discussed previously. Various studies have identified various limitations to technology applications in law enforcement, including environmental compliance and enforcement (Morabito, 2017; Glicksman et al. 2017; Onoda & Young, 2017; Lum et al. 2017; Munoz et al. 2019). Some of the main limitations and concerns are as follows:

Security and privacy issues:

This seems to be one of the most important factors affecting acceptance and adoption of a technology, especially when it comes to the access and use of sensitive and personal data, even with strong security solutions (Clayton et al. 2019; Let al. 2018; Scudder et al. 2018). If the government uses technology in an unethical manner, it has the potential to have a negative impact on social stability and civil rights. In the opinion of some police officers, body cameras constitute an infringement of their personal privacy (Kim et al. 2020; Scudder et al. 2018).

One example of technologies with privacy concerns are the use of drones for law enforcement. UAVs are easily manipulated and can infringe on the privacy of a group or individual. While many people prefer to use drones to maintain security, doing so may jeopardize several personal rights in the interest of public security (Barrows, 2021). Drones may penetrate private sites or situations without the permission of the owner and without a warrant, and they may go unnoticed by nearby individuals. There is some evidence that the feeling of being watched and monitored might have an impact on how technology is viewed (Price, 2019).

Vulnerability issues:

As technology increasingly becomes more complicated and interconnected it becomes more vulnerable to being infiltrated or hacked. In some cases, this can be very dangerous and destructive, especially when dealing with financial and classified information (Clayton et al. 2019; Janssen et al. 2020; White et al. 2018).

Sometimes evidence acquired by police as part of ongoing investigations may be tampered with, wreaking havoc on both the development of cases and the administration of justice. As a result, new challenges concerning the reliability of data and what constitutes valid evidence in criminal investigations are being raised. Additionally, it requires enforcement agents to become familiar with the data that linked devices contain, as well as the methods for accessing and preserving that data (Interpol, 2019).

Certain data may be too sensitive to store, and people in authority may lack the capacity and professionalism necessary to keep it safe. Information acquired and maintained by a police agency is susceptible to leakage, all the more so given the high expense of data security in terms of training and staff. Given the sensitivity of this information, the prospect of data leaks is extremely concerning (Morabito, 2017).

Increased complexity and interconnection of technological applications in law enforcement exacerbate these systems' vulnerability. Particularly in the areas of artificial intelligence and Internet of Things-related technologies (Interpol, 2019). This will require increased investment and commitment to safeguarding these systems from infiltration or disruption, which could result in serious consequences such as the release of sensitive data to terrorist or criminal organizations (Interpol, 2019).

Integration issues:

During the adoption and implementation of any new technology, the organizations or agencies need to integrate their strategies and processes which entails major changes in management strategies and operational processes, which can lead to timely and costly procedures (Darwish et al. 2019; Munoz et al. 2019;

Glicksman et al. 2017; Onoda & Young, 2017). The increased time of implementation can have both short and long-term implications (Darwish et al. 2019).

In the adoption and implementation phase this may result in lower technology acceptance rates by user involved in law enforcement and may hinder the use of the technology (Lindsay et al. 2014). In terms of the technology's real efficiency and effectiveness, the lengthy integration procedure may result in the technology falling behind current requirements and the advancement of other rapidly rising technology applications. This may result in the existing technology becoming obsolete or losing its efficacy (Darwish et al. 2019; Glicksman et al. 2017; Lindsay et al. 2014).

Technology understanding issues:

Understanding any technology, and especially new technology, can have a big impact on acceptance and adoption of technology. If the technology is not understood by the users this could cause a waste of time and can be dangerous (Cehe et al. 2018; Glicksman et al. 2017; Lum et al. 2017; Onoda & Young, 2017). In some cases the use of technology can cause frustration in enforcers. Law enforcement officers are frequently intimidated by the amount of pressure and work required to learn how to utilize and apply the vast array of tools available to them (Glicksman et al. 2017; Lum et al. 2017).

Another issue is the attention of enforcement personnel and the resulting dangers. The quantity and complexity of certain technologies in this industry necessitates additional attention and effort on the part of people, which may result in inattention to public safety concerns (Lum et al. 2017). For example, individuals assigned to patrols frequently have a multitude of technologies installed in patrol vehicles, and any inattention may result in reckless endangerment of the public (Lum et al., 2017).

Additionally, incorrect interpretations of some of the data produced by technology may have broader implications. For instance, misrepresenting and assessing data derived from certain technology can result in discrimination or false allegations. In crime statistics which may be compiled in accordance with a discriminatory policy may

generate racist projections, resulting in over policing, which may result in false data and racist predictions (Lum et al. 2017).

Cost issues:

Although most technologies are expected to lead to saving in expenditure, that is not always the case. Some technologies may require high cost especially in the initial stages. The cost may range from the acquisition costs to the implementation costs, such as maintenance and training costs (Cehe et al. 2018; Darwish et al. 2019; Glicksman et al. 2017; Lum et al. 2017; Morabito, 2017; Onoda & Young, 2017).

Certain technology applications may incur hidden expenses that must be considered at the initial evaluation and selection phase. The hidden or unanticipated expenses may manifest themselves during the development and maintenance phases. For instance, certain technologies may incur unexpected maintenance expenditures, resulting in increasing financial harm to the entities that use the technology. (Cehe et al. 2018; Darwish et al. 2019; Glicksman et al. 2017; Lum et al. 2017; Price, 2019).

Proper planning and evaluation are essential to ensure the effectiveness and efficiency of any new technology acquisition and adoption. Lum et al. (2017) state that “Strategizing about technology application is thus essential and should involve careful consideration of the specific ways in which new and existing technologies can be designed, deployed, and used at all levels of the organization to meet goals for improving efficiency, effectiveness, and agency management.”

It is critical to identify and manage past concerns and constraints surrounding the use of technology in law enforcement before adopting regulations and procedures to address those concerns and limitations in an effective manner. In order to ensure the efficacy of the technologies and to reduce the likelihood of negative consequences from these constraints, the process of evaluating and controlling these concerns should be continuous and consistent (Lum et al. 2017).

2.5 Theoretical Framework of Research

In this section we will examine and describe various theories and models related to user acceptance of new technologies to further understand how a technology is favored over others by users, and how these theories inform the research.

2.5.1 Overview of Technology Acceptance

User acceptance and confidence in any new technology is crucial for their success. Organizations are increasingly facilitating their platforms to increase personnel efficiency, reduce costs and increase productivity (Momani & Jamous, 2017). This has increased interests in understanding the factors that affect user acceptance of new technologies. Many technology acceptance theories and models have been devised through research in this field. Some of these models include the (TAM) technology acceptance model, (TRA) theory of reasoned action, (TPB) theory of planned behavior, (UTAUT) unified theory of acceptance and use of technology, and many more including their extensions.

The technology acceptance and adoption theories seek to establish a generic framework for investigating the determinants of technology acceptance that is capable of explaining user behavior across a broad range of technological tools and user populations while also being theoretically justified. These models are beneficial not only for forecasting, but also for describing, in such a way that researchers and experts can ascertain the reason for not embracing a specific system or technology and, accordingly, take the necessary remedial steps (Davis et al. 1989). User acceptance is very important to the successful development, implementation, and growth of implementation of the new technology. The behavioral and acceptance variables must be thoroughly understood in order to prevent squandering the time and effort of a large number of researchers who develop technology. (Taherdoost, 2019).

Cakar (2011) asserts that user concerns are a more significant role in the acceptance and deployment of technology than technical concerns. Successful technology implementation and adoption involve effective interaction between the user and the technology, and the efficacy of the technology is determined by the user's

willingness to use it, which may potentially result in the technology failing. As a result, it is critical to ascertain user acceptability and the shortcomings of a new technology. Additionally, research indicates that knowing the user's perceptions, requirements, and expectations for the technology is critical for the effective installation and acceptance of the technology, as well as for the user's capacity to operate the technology efficiently (Cakar, 2011; Momani & Jamous, 2017).

Technology acceptance theories and models aim to provide the means to understanding and accepting new technologies by the users and how they may use them (Witarsyah et al. 2017). During the process of assessment of a new technology, many variables affect the individuals' decision-making process about how and when they will use it (Momani & Jamous, 2017).

The next sections of this chapter will present various technology acceptance and adoption theories and explain their attributes. These theories include the Technology Acceptance Model, Theory of Reasoned Action, Theory of Planned Behavior, Innovation Diffusion Theory, Task-Technology Fit model, IS success model, and some of their extensions and limitations.

2.5.2 Innovation Diffusion Theory

The Diffusion of Innovations is one of the theories that helps understand how an innovation is or is not adopted by people, which can be applied to fields of health, education, sociology, and various others (Rogers, 2010). The theory delivers a broad structure for understanding adoption and diffusion, which has influenced later adoption and diffusion theories (Pennington, 2004; Venkatesh et al., 2003). Straub (2009) purports that the strength of innovation diffusion theory is it delivers a comprehensive and useful framework to understand the aspects that effect the perceptions and choices an individual makes toward an innovation and has been widely used in various disciplines such as management, education, and health (García-Avilés, 2020).

The adoption is strongly related to the diffusion since diffusion explains the adoption of innovation in a population over a period of time. In the adoption process

Environmental Enforcement Technology Adoption

five stages are identified in which individuals go through during the innovation evaluation (Rogers, 2010).

1. Individuals' awareness of an innovation which is influenced by personal characteristics, socioeconomics, and media access.
2. Persuasion - individuals attain enough information about an innovation to make a judgement.
3. Decision - either adopt or reject innovation.
4. Implementation.
5. Confirmation - the individual evaluates decision and decide to continue or not.

Innovation Diffusion Theory components:

Diffusion is the process through which an invention is disseminated among the members in a social system over time (Rogers, 2010). The theory consists of five primary elements that influence the diffusion of innovations, which are the innovation, the adopters, the communication channels, time, and the social system. The diffusion process is primarily reliant on human resources. To be self-sustaining, the innovation must be broadly embraced. There comes a time in the pace of adoption when an innovation hits critical mass (Rogers, 2010).

(1) The innovation. Innovation is a broad category. Any concept, activity, or item that an individual or other unit of adoption perceives as novel might be regarded an innovation capable of being studied (Pennington, 2004; Venkatesh et al., 2003). Five attributes that influence the adoption of an innovation (Poong et al. 2009; Yuen et al. 2021).

- Relative advantage: how the individual perceives (better or worse) an innovation. Better perception leads to faster adoption.
- Compatibility: how the individual perceives the innovation's similarity to current understandings of similar and past concepts. The more compatible the innovation to current understanding the more easily adopted.
- Complexity: how the individual perceives the difficulty to understand the innovation. The less complex the higher the rate of adoption.

Environmental Enforcement Technology Adoption

- Trialability: how accessible is the innovation to trial (direct or indirect).
- Observability: availability and visibility of an innovation to the individual.

(2) Adopters: Adopters are the smallest unit of measurement. Adopters in most studies are people, but they may also be institutions, social network clusters, or even nations (Rogers, 2010).

(3) Communication channels: are the ways and means by which individuals pass information about the innovation. This component is essential to diffusion; if the information is not transferred, it will not spread in the population. Information can be sent from one unit to another using communication channels (Pennington, 2004; Venkatesh et al., 2003).

(4) Social system: External factors (such as organizational mandates) and internal influences make up the social system (such as social relationships). In a social system, there are various roles, and their sum total symbolizes the overall impact on a potential adopter (Rogers, 2010).

(5) Time. Adopters were divided into five groups based on time of adoption of innovation: Innovators, early adopters, early majority, late majority, laggards (García-Avilés, 2020). These groups rate of adoption is shown in the diffusion curve which suggests that there is a small percentage of early adopters, a large group of mainstream adopters (early and late majority), and finally a small percentage of late adopters.

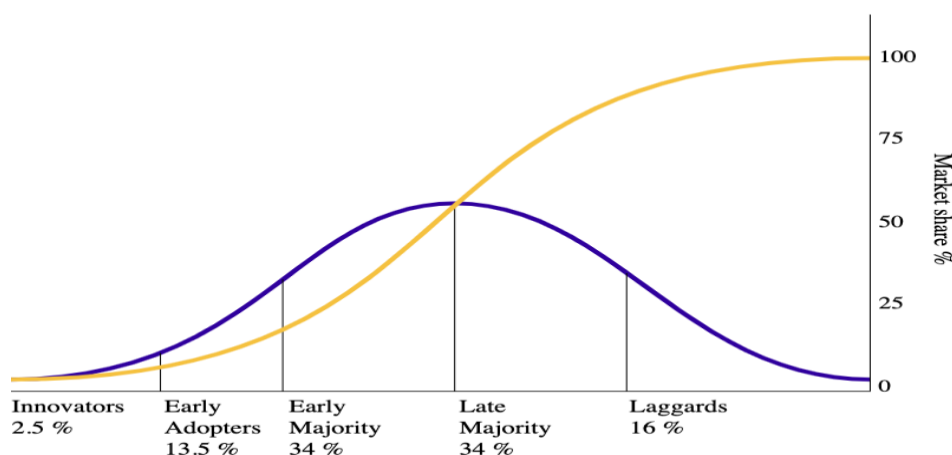


Figure 2. 7 Based on Rogers, E. (1962) Diffusion of innovations.

Limitations of IDT

When evaluating a new product or innovation, diffusion academics frequently engage with manufacturers. Prioritizing the manufacturer's interests can jeopardize the quality of these research. Additionally, producers frequently prioritize client preferences and tastes — elements that can give diffusion studies a trivial and speculative spin. When studies are focused on a business strategy rather than the social process of dissemination, the findings are frequently weaker and less accurate (Schiaivone & Simoni, 2019).

Diffusion research may also ignore cultural norms. Focusing on the product or idea while ignoring cultural customs can lead to failed attempts at diffusion. This type of campaign would benefit from an anthropological approach that examines the day-to-day perspective of the individuals involved (Min et al. 2019).

Numerous societies lack the infrastructure necessary to support and adopt new technologies. Diffusion research has frequently been more concerned with the invention itself than with these sociocultural distinctions. According to studies, technological advancements are more successful when they benefit the consumer. Many civilizations, however, encounter economic limits or legal impediments that can render an innovation's benefits or efficacy obsolete (Min et al. 2019; Schiaivone & Simoni, 2019).

Diffusion can be harmed by poorly specified attempts to introduce an idea or innovation. This lack of information lead to confusion by potential users, limiting the spread of the adoption. As a massive repository of knowledge can occasionally confuse consumers with false and contradictory facts and viewpoints (Scott & McGuire, 2017).

2.5.3 Theory of Reasoned Action

TRA is theory that aims to explain the relationship between attitudes and behaviors within human action, it focuses on a person's ability to do a given activity as a result of their behavioral intention (Ajzen & Fishbein, 1980). A person's behavioral

Environmental Enforcement Technology Adoption

intention is influenced by both their attitude and their subjective norms about the activity in question. The term "attitude" refers to a person's demeanor toward an activity and the specific act of that behavior, rather than the overall performance (Ajzen & Fishbein, 1980). A person's perception regarding whether to perform a given behavior or not is called a subjective norm, and it is dependent on the opinions of others (Venkatesh & Davis, 2000).

Main constructs of the model will be presented and described briefly in the following:

Behavior:

TRA aims to anticipate and explain a person's intention to engage in a specific activity. According to the theory, conduct must be characterized in terms of four concepts: action, target, context, and time (Ajzen & Fishbein, 1980). Behavioral intention is the major driver of conduct, according to Ajzen & Fishbein (1980), and people's attitudes and norms are the two key determinants of behavioral intention. Researchers can learn whether or not someone will undertake the targeted activity by looking at attitudes and subjective standards.

Attitudes:

Attitudes refer to how people feel about a specific activity and are one of the most important factors of behavioral intention (Ajzen & Fishbein, 1980). Two elements impact these attitudes: the intensity of behavioral beliefs about the results of performed activity (i.e. whether the outcome is likely) and the judgment of alternative outcomes (i.e. whether or not the outcome is positive) (Ajzen & Fishbein, 1977). Positive, negative, or neutral attitudes might be held toward a certain behavior (Ajzen & Fishbein, 1980). According to the theory, there is a direct link between attitudes and outcomes, such that if one feels that a particular conduct will result in a desired or good outcome, one is more likely to have a positive attitude toward that behavior (Ajzen & Fishbein, 1980).

Subjective norms:

Subjective norms are another important predictor of behavioral intention, and they refer to how significant groups or persons, such as family members, friends, and peers, may influence one's behavior performance (Madden et al. 1992). Subjective norms are felt social pressure to perform or not execute the activity (Ajzen & Fishbein, 1980). People develop specific views or normative beliefs about whether or not certain activities are acceptable (Ajzen & Fishbein, 1980). These beliefs influence one's perception of the action and determine whether or not one will engage in it (Ajzen & Fishbein, 1977). Subjective norms also consider people's drive to conform to the beliefs and perceptions of their social circle, which varies based on the context and the individual's goals (Ajzen & Fishbein, 1980).

Behavioral Intention:

Attitudes and subjective norms toward that action influence behavioral intention. Subjective norms are the social standards linked with the act, while attitudes are how strongly one has an attitude toward the conduct. The larger the connection, the stronger the attitude and the more favorable the subjective norm (Ajzen & Fishbein, 1980). However, it is doubtful that views and subjective standards would be equally weighted in predicting conduct. These elements may have varied effects on behavioral intention depending on the individual and context, hence each of them is given a weight (Madden et al. 1992).

TRA was first established as a social psychology theory, but it has since been adapted to specialized fields such as technology. TRA, for example, includes studies in 1980 that focused on how an individual adopts specific behaviors, technology, or recommendations (Ajzen & Fishbein, 1980). When it comes to technology, people are more likely to acquire and use it if they see it as beneficial (Ajzen & Fishbein, 1980).

There are three factors that might influence the link between behavioral intention and conduct, according to TRA theorists. The measure of intention must correlate with their levels of specificity, is the first criteria (Madden et al. 1992). This

indicates that the behavioral purpose must be as detailed in order to anticipate a specific behavior.

The second criterion is that "intentions must be stable between the time of assessment and the performance of behavior," (Madden et al. 1992). Between the time it is provided and the time the behavior is executed, the purpose must stay the same. The degree to which the individual has volitional control over carrying out the aim is the third criteria (Madden et al. 1992). It is always up to the individual to decide whether or not to accomplish the assignment.

2.5.4 Theory of Planned Behavior

The TPB was developed to deal with the limitations of the TRA, in which the theory assumes that the behavior is under the volitional control of users which is not always the case (Ajzen, 1991). The TRA does not explain behaviors that have a low-level of volitional control (Davis et al. 1989). The TPB extends the TRA by including the perceived behavioral control as an additional contributor towards behavioral intention (Ajzen, 1991). The Theory of Planned Behavior considers that the users or individuals do not always have complete control over whether to conduct specific behaviors.

The additional contributor of perceived behavioral control refers to the individual's perception on whether performing a behavior will be either easy or difficult. The behavioral intention will not be strong, even if the individual's attitude towards the behavior and the subjective norms are positive, if the perceived behavioral control is not strong (Ajzen, 1991). The perceived behavioral control was later further explained by Ajzen (2002) to address some of the limitations of this contributor. Ajzen (2002) suggests that the perceived control behavior compromises of self-efficacy which refers to the perceptions of ease or difficulty of performing a specific behavior, and controllability, which refers to the extent to which the performance of the behavior is up to the actor.

The Theory of Planned Behavior employs a person's personal attitude and viewpoint, in conjunction with their perceived control over the behavior and the subjective norms of their society, to impact their behavioral intention, which results in the behavior or action (Ajzen, 1991). In some circumstances, if someone has a negative attitude and believes they lack control over an activity, they will be less inclined to carry it out. Additionally, if members of society disapprove of this conduct, it will have a detrimental effect on a person's motivation for the action. According to an individual's own beliefs, their attitude and perceived behavioral control might have a favorable or negative effect on their intention and behavior (Ajzen, 2002).

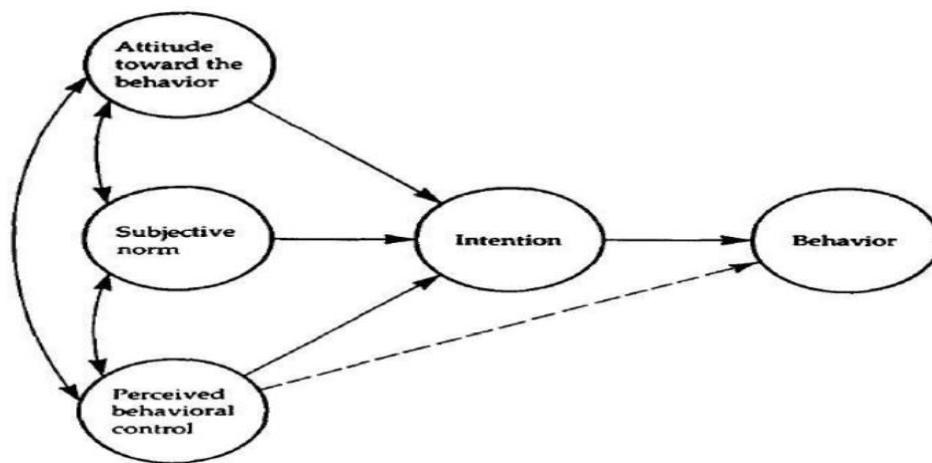


Figure 2. 8 TPB (Ajzen, 2002)

2.5.5 Technology Acceptance Model

Davis (1989) developed the Technology Acceptance Theory (TAM) which is considered one of the most studied theories of technology acceptance in various fields. The theory is based on the theory of reasoned action. It was used to understand technology's actual use based on external factors, beliefs, attitudes, and intentions. The Technology Acceptance Model's purpose is to investigate possible explanations for an individual's adoption or hesitation of adoption of a technology. TAM consists of four main constructs: perceived ease of use, perceived usefulness, intent to use, and actual use (Davis, 1989).

Davis (1989) used PEOU and PU as independent variables and system utilization as the dependent variable in a series of studies to verify TAM. He discovered that PU was linked to both self-reported current usage and self-predicted future use.

PEOU was also shown to be linked to both present and future use. Overall, he discovered that PU had a far stronger relationship with system utilization than PEOU. PEOU may be an antecedent of PU rather than a direct driver of system utilization, according to further regression analysis. PEOU, in other words, has an indirect effect on technological acceptance through PU (Ma & Liu, 2004).

TAM has gone through many modifications and expansions by various researchers and has been tailored to specialized topics by the addition of various constructs and variables (Venkatesh & Bala, 2013; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003). TAM2 was a modification of the original TAM, which was used to explain perceived usefulness and usage intentions in terms of social influence (subjective norms, voluntariness, image) and cognitive instrumental processes (job relevance, output quality, result demonstrability, perceived ease of use) (Venkatesh, & Davis, 2000). Later, other models were developed from TAM such as the TAM3 (Venkatesh, & Bala, 2013), and the Unified Theory of Acceptance and Use of Technology (Venkatesh, Morris, Davis, & Davis, 2003).

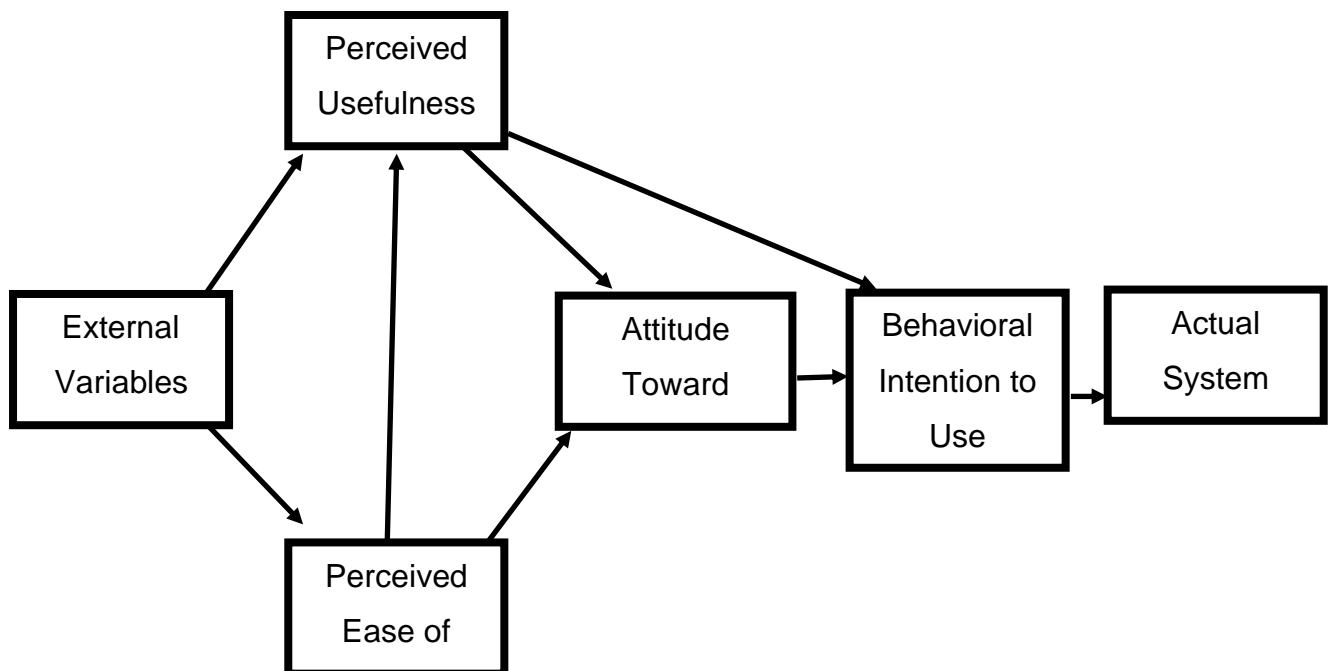


Figure 2. 9 TAM (Davis et al. 1989)

Technology Acceptance Model Constructs

The TAM consists of four constructs: The perceived ease of use, perceived usefulness, intent to use, and actual use.

Perceived ease of use: Davis (1989) defines PEOU as "the degree to which a person believes that using a particular system would be free from effort."

Perceived usefulness: Perceived usefulness is the realization that new technology will increase or improve overall performance (Davis, 1993). According to Davis et al (1989), the factor of technology performance can be an influential factor affecting the actual use of technology in the work environment, regardless of the user's attitude toward the system. If the technology enhances job performance, the user's acceptance will increase even, if the user does not like the technology overall (Yuen et al. 2021).

Intent to use: The intent to use, or behavioral intention, is the factor that leads individuals to use a certain technology. Attitude (impression of technology) to using a technology influences the intent to use it (Yuen et al. 2021).

External variables: Are the external variables that are significant components in determining user's attitude towards a technology, such as social influence. People will have positive attitudes and intention to use technology with availability positively influencing factors.

Limitations of TAM

One of the TAM's shortcomings is that it does not account for the variable relating to user behavior, which is necessarily judged subjectively via behavioral intention and interpersonal influence (Maruping et al. 2017). Nonetheless, interpersonal influence is defined as when a person is impacted by the words of a colleague or friend. While a superior can influence an employee by asking a subordinate to do a specific job using technology in accordance with their technology policy, a colleague has no direct power on workers who report to the supervisor.

Another issue is that the fundamentals of behavior cannot be properly defined in an empirical study due to a variety of subjective elements such as social norms and values, as well as individual characteristics and personality traits (Maruping et al. 2017). Thus, the claim that a relation may affect technology use by exerting social pressure seems to be not always valid. As a result, Maruping et al. (2017) recommended that behavioral expectations, rather than behavioral intention, should be utilized to predict individuals' intentions about the use of technology.

Also, it is envisaged that as organizations' technology management matures, info formality would be promoted. Thus, there will be a well-established method and regulations for utilizing an organization's technology applications (Ajibade, 2018). As a result, behavioral expectations might be quantified in connection to levels of compliance rather than just on the basis of employee views. Thus, firms' guiding principles or frameworks act as tools for controlling employee behavior and function as a predictor of how much technology is utilized by employees. Thus, implying that attitudes toward technology usage at work are determined by perceived utility and ease of use (Brown et al. 2002) may have portrayed the TAM as a purely theoretical construct.

Additionally, it should be noted that various authors and academics have criticized the model (Ajibade, 2018). The majority of the relevant existing research on the TAM treats it as a dependent variable, rather than a tool for discovering the elements that drive behavior. The TAM does not account for extrinsic elements such as age and education that may impact acceptance of and desire to utilize technology. On the other hand, one may argue that measuring behavior is exceedingly difficult, as hidden personality factors frequently inspire activity.

As a result, potential users of technology may not always base their acceptance of new technology on their perceptions of the usefulness of the technology and its ease of use, although the model does suggest that other external factors may play a role in their acceptance of the technology (Zahid et al. 2013).

Technology Acceptance Model 2

Although the TAM is widely and extensively accepted and adopted, research finds several limitations of the models' applications. For example, one of the biggest limitations is the failure of the model to explain the determinants of an individual's perception of usefulness of the system (Venkatesh & Davis, 2000) and the ease to use it (Venkatesh, 2000). Also, the model does not adequately explain the variance in the usage intention (Davis, Bagozzi, & Warshaw, 1989; Venkatesh & Davis, 2000).

In an attempt to address some of the issues with the original TAM, Venkatesh and Davis (2000) developed and extended the original TAM to TAM2 (displayed in Figure 2.8) that explains the major determinants of perceived usefulness (PU). The TAM2 determinants added to the model include subjective norms, voluntariness, image, job relevance, result demonstrability, and output quality.

In their research Venkatesh & Davis (2000) aimed at investigating the proposed model (TAM2), they conducted a longitudinal study on 156 employees from four organizations that utilize two voluntary systems and two mandatory systems. They found their model to be accepted and verified in both system types (mandatory and voluntary). They found that the factor of subjective norms has no influence in voluntary systems. Also, that as experience increases, the influence of subjective norms on perceived usefulness and behavioural intention decreases.

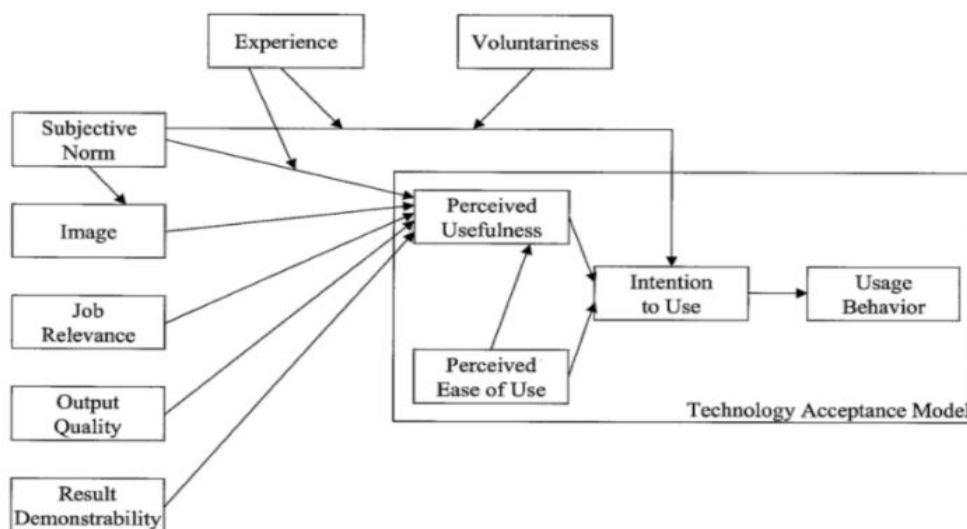


Figure 2. 10 TAM2 (Venkatesh & Davis, 2000)

Table 2. 2 The Adopted Determinants of (PU) Perceived Usefulness in the TAM2 (Venkatesh & Davis, 2000)

Constructs	Definitions
Subjective norms	The extent to which an individual believes others believe he or she should engage in the behavior (Gupta et al. 2021; Venkatesh & Davis, 2000).
Image	The extent of which the use of the technology enhances an individual's status within society (Gupta et al. 2021; Venkatesh & Davis, 2000).
Job relevance	The extent of which the technology is relevant to the task or job (Izuagbe et al. 2021; Venkatesh & Davis, 2000).
Output quality	The performance quality of the technology in the job (Izuagbe et al. 2021; Venkatesh & Davis, 2000).
Results demonstrability	The output of using the technology is tangible (Izuagbe et al. 2021; Venkatesh & Davis, 2000).

Technology Acceptance Model 3

Another more recent revision of the TAM is called the TAM3 in which its main contribution is the addition of factors addressing the determinants of perceived ease of use (PEOU) and perceived usefulness (PU) (Venkatesh & Bala, 2008). The TAM3 was developed from both the TAM2 (Venkatesh & Davis, 2000) and the model of perceived ease of use determinants (Venkatesh, 2000).

From Venkatesh and Davis (2000) the constructs used for TAM3 that influenced perceived usefulness were subjective norms, image, job relevance, output quality, results demonstrability, and perceived ease of use. The moderator factors

were output quality, experience, and voluntariness. As for the constructs from Venkatesh's (2000) model used in TAM3 were anchor and adjustment factors.

The anchor factors that influenced perceived ease of use were computer self-efficacy, perceptions of external control, computer anxiety, and computer playfulness. As for the adjustment factors that influence perceived ease of use, they were perceived enjoyment and objective usability (Venkatesh, 2000). Venkatesh and Bala (2008) find that both the anchor and adjustment factors influence the perceived ease of use of the technology.

The increase of experience decreases the influences of computer anxiety and computer playfulness on perceived ease of use, but the increase of experience increases the influence of computer self-efficacy and perceptions of external control on perceived ease of use (Venkatesh & Bala, 2008). The increase of experience also increases the influence of the adjustment factors (perceived enjoyment and objective usability) on perceived ease of use (Venkatesh & Bala, 2008; Venkatesh, 2000).

The additional constructs of TAM3 that influence the perceived ease of use and their definitions are as follows:

- *Computer self-efficacy*: The extent individuals feels that they have the ability to complete a task on the computer (Thongsri et al. 2020; Venkatesh & Bala, 2008).
- *Perceptions of external control*: The extent individuals feel resources are available to facilitate the technology use (Castiblanco Jimenez et al. 2021; Venkatesh, 2000).
- *Computer anxiety*: The extent of individuals anxiety of using the technology (Castiblanco Jimenez et al. 2021; Venkatesh & Bala, 2008).
- *Computer playfulness*: The motivation to interact with technology (Hamutoglu, 2020; Venkatesh, 2000).

- *Perceived enjoyment*: The extent individuals feel the technology is enjoyable (Hamutoglu, 2020; Venkatesh & Bala, 2008).
- *Objective usability*: Comparing technology based on the actual effort necessary to complete activities, rather than the user's perception of the work required (Castiblanco Jimenez et al. 2021; Venkatesh, 2000).

2.5.6 The Unified Theory of Acceptance and Use of Technology

One of the most favored theories of technology acceptance that have been introduced through research is the UTAUT model. The Unified Theory of Acceptance and Use of Technology (UTAUT) model is a technology acceptance model which is based on various technology acceptance models. The model aims to explain users' intentions to use a certain technology and consequent usage behavior.

The main models that the UTAUT is based on are: The Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA), the Motivational Model, the Theory of Planned Behavior (TPB), the combined TAM and TPB, the model of Personal Computer Utilization, the Innovation Diffusion Theory, and the Social Cognitive Theory (Venkatesh et al. 2003).

Venkatesh et al. (2003) evaluated the previous eight models and found the direct determinant of significant behavioral intention or behavior in the use of one or more in each model to be seven constructs. These constructs are performance expectancy, effort expectancy, social influence, facilitating conditions, attitude toward using technology, and self- efficacy. They also found that the four major constructs that have an essential role as a direct determinant of behavioral intention and use behavior to be performance expectancy, effort expectancy, social influence, facilitating conditions. Other moderators they identify are gender, age, voluntariness, and experience, which are positioned to moderate the impact of the four main constructs. The UTAUT model is displayed in figure 2.11 below.

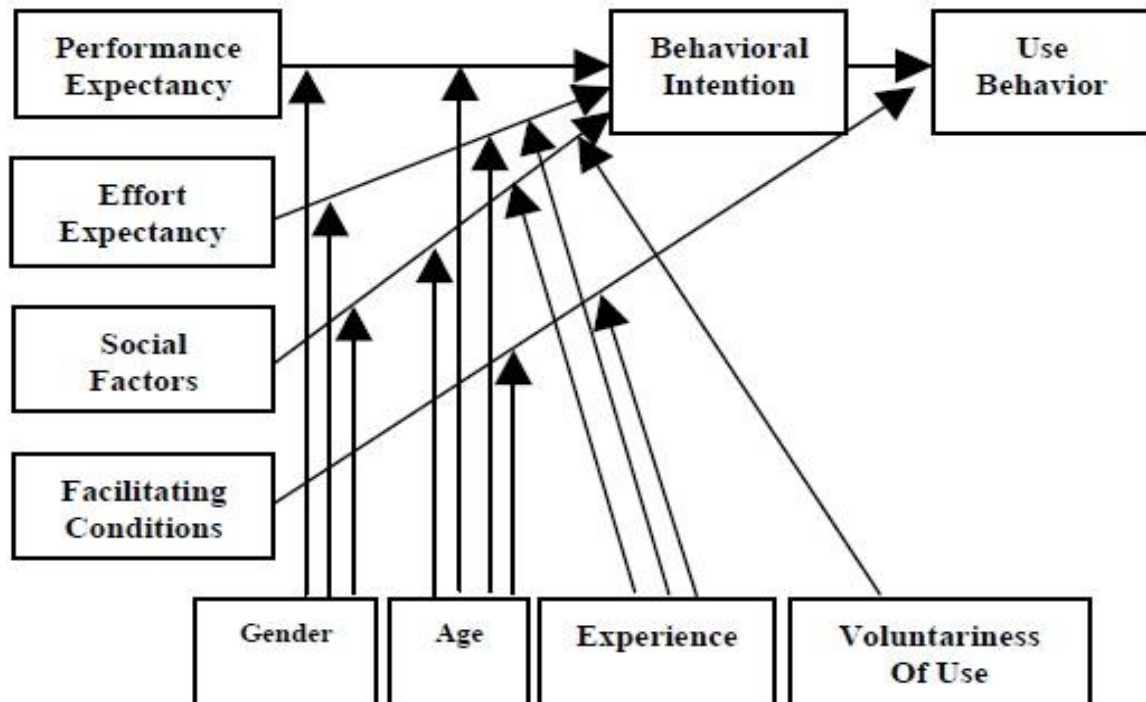


Figure 2. 11 The UTAUT Model (Venkatesh et al. 2003)

UTAUT Constructs:

1) Performance expectancy is defined by Venkatesh et al. (2003) as "the degree to which an individual believes that using the system will help him or her to attain gains in job performance". Performance expectancy originated and developed from various technology acceptance and adoption theories such as the TAM, TAM2, IDT, and others. It is a powerful predictor of usage intention in both mandatory and voluntary settings (Venkatesh et al. 2012).

2) Effort expectancy is "the degree of ease associated with the use of the system". The construct was developed mainly from the perceived ease of use from previous models (Venkatesh et al., 2003).

3) Social influence was defined by Venkatesh et al. (2003) as "the degree to which an individual perceives that important others believe he or she should use the new system". When the utilization of technology is compulsory, the impact of social

influence is substantial (Venkatesh et al., 2003). Individuals may utilize technology in a mandated setting owing to a compliance necessity, but not because of personal preferences (Venkatesh & Davis, 2000).

4) Facilitating Conditions are defined by Venkatesh et al. (2003) as "the degree to which an individual believes that an organizations and technical infrastructure exists to support the use of the system". These conditions have a direct favorable influence on intention to use, however the effect fades after the first usage. As a result, the model suggests that facilitating conditions have a direct and considerable impact on usage (Venkatesh et al., 2003).

5) Moderators: The strength of predictors on intention is determined by the moderating effects of age, gender, experience, and voluntariness of usage. All four predictors are moderated by age. The links between effort expectation, performance expectancy, and social influence are influenced by gender. The intensity of the links between effort expectancy, social influence, and facilitating conditions is moderated by experience. Only the link between social influence and behavior intention is moderated by voluntary usage (Venkatesh et al., 2003).

Limitations of UTAUT

One of the limitations discovered after Venkatesh et al. (2008) examined the UTAUT model is that behavioral intention does not adequately account for external influences that might impact behavior performance. Second, behavioral intention has a limited capacity for predicting and explaining events that occur between the time the intention is formed, and the behavior is conducted. Finally, behavioral intention is ineffective in predicting behaviors that are not entirely under an individual's volitional control. Thus, while purpose is necessary for successful activity, it is inadequate (Brown et al. 2002).

Another limitation of the UTAUT model is that failed to integrate attitude and self-efficacy as direct predictors of behavioral intention (Venkatesh et al. 2003; Venkatesh et al. 2012). Self-efficacy is treated as an indirect construct in the UTAUT since it evaluates specific self-efficacy, not general technology self-efficacy

toward a certain technology (Venkatesh et al. 2012). Additionally, the Theories of Reasoned Action (TRA), Theory of Planned Behavior (TPB), and Technology Acceptance Model (TAM) all regard attitude as a direct predictor of intention (Venkatesh et al. 2012).

The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)

The unified theory of acceptance and use of technology was later extended by Venkatesh et al. (2012). The purpose of this extension is to examine technology acceptance in the context of consumer behavior. The extension has three additional constructs added to the original UTAUT's four constructs which were hedonic motivation, price value, and habit. (Venkatesh et al. 2012). Venkatesh et al. (2012) find that the three previous listed additional factors in addition to performance expectancy, effort expectancy, facilitating conditions, and social influence behavioral intention. While behavioral intention, facilitating conditions, price value, and habit directly influence use behavior. Following are a brief description of each (Venkatesh et al. 2012):

- Hedonic motivation: The extent to which an individual finds technology enjoyable (perceived enjoyment)
- Price value: An individual's trade-off between the benefits of a certain technology and the financial expense of employing it.
- Habit: The extent to which the individual considers the action to be automatic.

The extended model (UTAUT2) posited that in addition to the moderating factors given in the original UTAUT, personal characteristics experience, gender, and age impact the relationships between the determinants and behavior intention and use behavior. Experience, age, and gender moderate the influence of the facilitating condition, habits, and hedonic motivation on intention. The influence of price value on intention is moderated by only age and gender. Further, experience is a direct moderator of behavior intention on use behavior (Venkatesh et al. 2012).

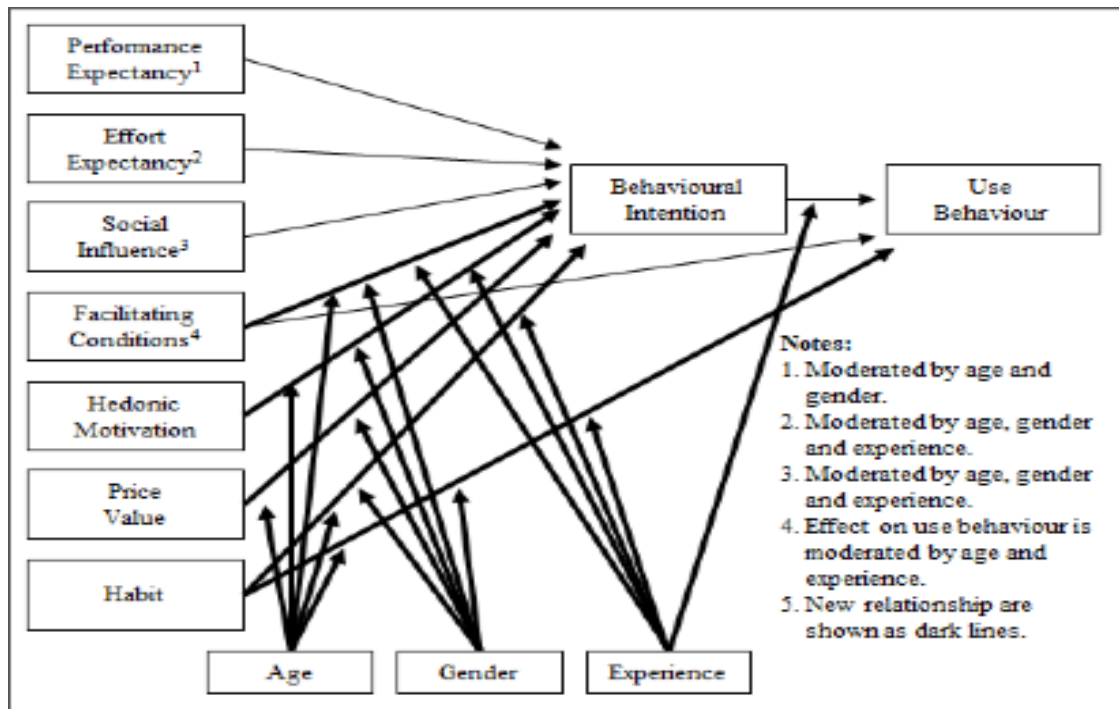


Figure 2. 12 UTAUT 2 (Venkatesh et al. 2012)

2.5.7 The Task-Technology Fit Theory

The Task-Technology Fit model developed in the foundational work by Goodhue and Thompson (1995). Goodhue and Thompson (1995) find that models are strategies to frame what we know about reality, to clarify understandings, and to convey those understandings to others. A model can drive thinking in constructive ways after it has been expressed and communicated, but it can also confine our thinking into channels that are compatible with the model, preventing us from perceiving part of what is happening in the domain we have modeled.

The basic Task-Technology Fit model provides a lens through which to view technology use and the value it generates (Goodhue and Thompson, 1995). The model's assumption is that the value/performance of technology is established by the alignment, or fit, of task requirements and technology features that allow a user to execute the tasks in a situation where technology is utilized by individuals to perform particular activities, or sets of tasks (Lee & Cheng, 2007; Goodhue and Thompson, 1995).

Environmental Enforcement Technology Adoption

Individuals in a particular setting do a variety of physical and/or cognitive acts and processes, which are referred to as tasks. Task characteristics are broken down to varying degrees of detail depending on the complexity of the activities performed (Goodhue and Thompson, 1995), and are especially evaluated in connection to the technology that supports the tasks.

When the Task-Technology Fit theory is used in diverse situations, distinct unique task features emerge. However, in the literature, the method of identifying task characteristics is similar, and it often entails examining the activities done in an environment and developing several task categories and subcategories that may be associated to Task-Technology Fit (Goodhue and Thompson, 1995; Goodhue, 1998; Lee & Cheng, 2007).

Technology is described as the instruments that people use to complete or aid them in completing activities (Goodhue and Thompson, 1995). Similarly to the description of task characteristics, individual technologies will have distinct characteristics that are determined by the researcher based on the context in which they are utilized and the tasks they are intended to assist (Goodhue and Thompson, 1995; Goodhue, 1998; Lee & Cheng, 2007).

Task-Technology Fit is defined as the degree to which technology aids an individual in accomplishing his or her activities (Goodhue and Thompson, 1995; Lee & Cheng, 2007), and it is influenced by the relationship between task features and technology functions (Lee & Cheng, 2007). Data quality, data locality, authorization to access data, data compatibility, ease of use/training, production timeliness, systems dependability, and information system interaction with users are some of the factors that Goodhue and Thompson (1995) evaluate when assessing fit.

The goal of Goodhue and Thompson's study (1995) was to demonstrate that a beneficial impact of technology necessitates a good Task-Technology Fit. As a result, when technology is tailored to the job characteristics it is intended to enable, performance should increase. The enhanced performance is often owing to the work being executed more smoothly, the cost of executing the activity being reduced, or the task being made easier to complete (Lee & Cheng, 2007).

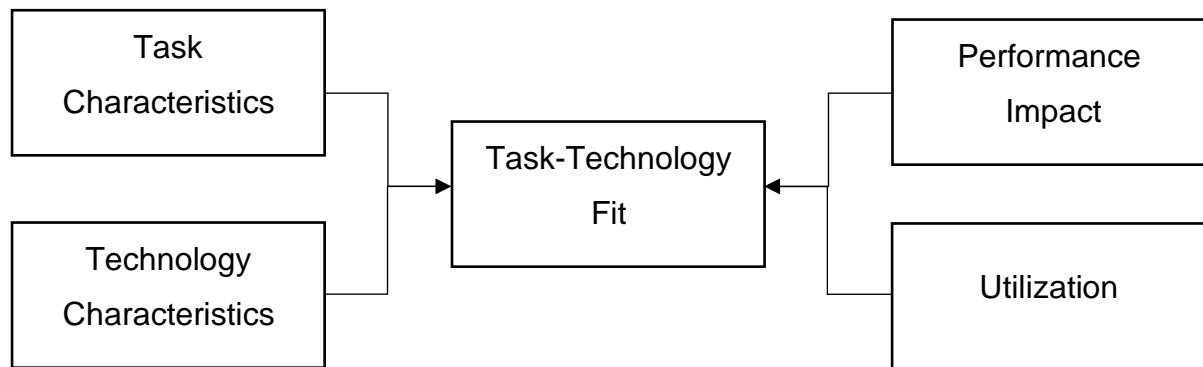


Figure 2. 13 Task-Technology Fit

Various modification and extension to the Task Technology Fit model were conducted in latter studies on of them is the merger of Task Technology Fit and Technology Acceptance Model by Dishaw and Strong (1999). And then further by merging Task Technology Fit and UTAUT (Zhou et al. 2010).

Task Technology Fit and Technology Acceptance Model

Dishaw and Strong (1999) expanded Task Technology Fit theory by merging it with TAM. According to TAM, technology usage increases cognitive evaluations in the manner of perceived ease of use and perceived usefulness, which in turn encourage behavioral intention and subsequent use (Davis, 1989). Perceived ease of use relates to the level to which technology is perceived to be effortless to use (Davis, 1989), whereas perceived performance refers to the extent to which the user believes technology increases performance (Davis, 1989).

The extension was developed with the goal of combining two major theories of technology acceptance in order to increase Task Technology Fit theory’s predictive potential, presented in Figure 2.14 (Dishaw & Strong, 1999). Task Technology Fit theory was not particularly accurate in forecasting use on its own. The model's explanatory ability was inferior to that of other theories, such as TAM. Task Technology Fit theory explained just 2% of the variance in use and 14% of the variance in performance, compared to TAM, which explained 40% of the variance in usage (Goodhue & Thompson, 1995; Davis, 1989).

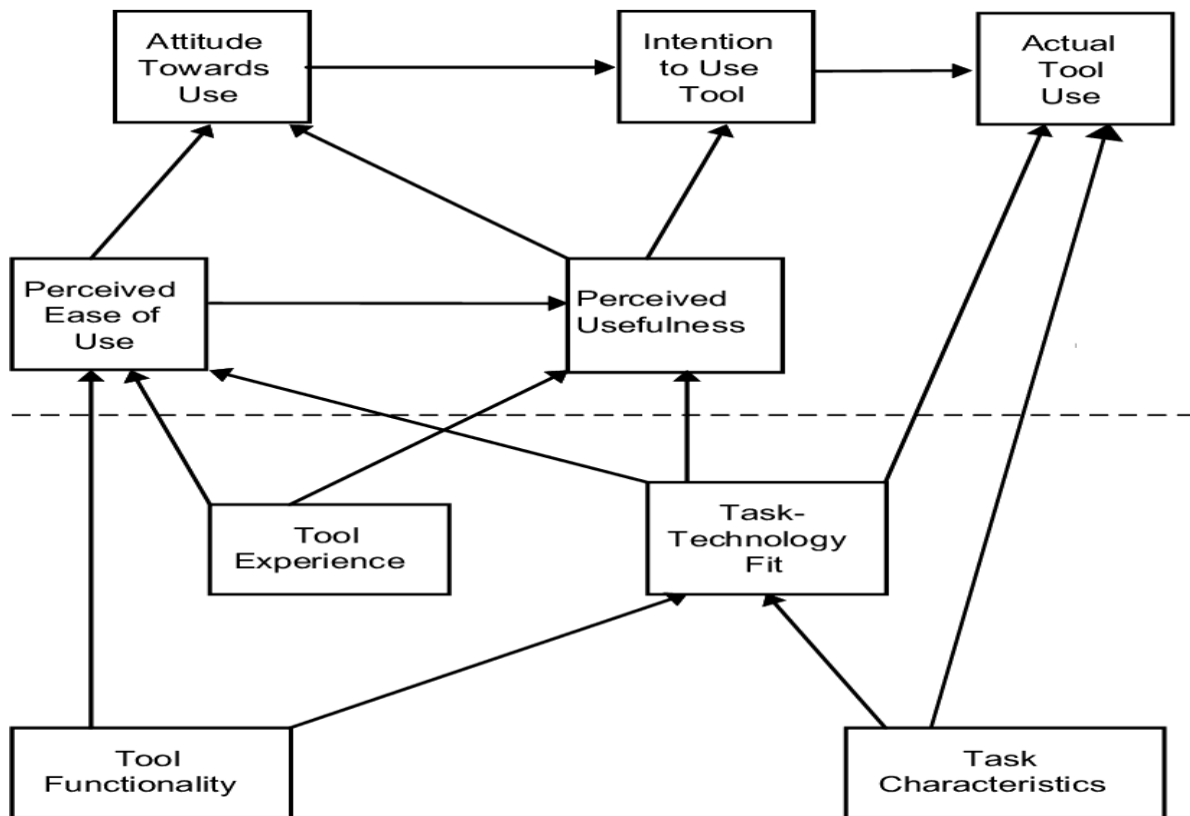


Figure 2. 14 Integrated TAM/TTF Model (Dishaw & Strong, 1999)

On the one hand, both theories take a user-centered approach to technology usage and assessment, examining outcomes such as adoption, acceptance, and performance. Task Technology Fit theory and TAM, on the other hand, give contrasting perspectives on technology utilization. TAM is concerned with the purpose of use, whereas Task Technology Fit theory is concerned with the consequence of usage. TAM is a rival hypothesis that offers an alternative perspective on technology use.

The associations between variables inside TAM and the Task Technology Fit theory model were left untouched in the extension. As with the original model, TAM depicts the interplay between perceived usefulness and perceived ease of use, which influences attitudes, intentions, and use behavior (Davis, 1989). Task Technology Fit theory is a model that examines real tool usage, which is influenced by Task Technology Fit theory and technology experience, the latter of which is influenced by

tool functionality and job requirements. The fit factor is used as a unidimensional construct to simplify measurement.

Seven new linkages were added to incorporate TAM and Task Technology Fit theory variables, as previously indicated by research. More precisely, the model implies that Task Technology Fit theory has an effect on individuals' perceptions (Dishaw & Strong, 1999). The correlations are justified by reference to the definitions of perceived usefulness, perceived ease of use, and Task Technology Fit theory (Goodhue & Thompson, 1995; Goodhue, 1995). If an individual believes that a particular technology is well-suited to the job at hand, his or her sense of usefulness and simplicity of use will increase.

Additionally, the model establishes a relationship between user experience, tool functionality, and perceived ease of use. This means that enhanced functionality is associated with the notion that the technology is smart and difficult to utilize. Thus, tool functioning will have a detrimental influence on perceived ease of use. Individuals with expertise, on the other hand, are more inclined to regard technology as simple to use. Finally, the model hypothesizes a causal relationship between task features and acceptance. The link is predicated on the premise that as a job becomes more difficult, an individual's interest in a particular technology decreases (Dishaw & Strong, 1999).

Task Technology Fit and UTAUT

The Task Technology Fit model was further updated by including a Unified Theory of Acceptance and Use of Technology (Zhou et al. 2010). UTAUT is a comprehensive framework for understanding technology adoption. It postulates that the likelihood of technology adoption is contingent on the direct effect of four core elements: performance expectancy, effort expectancy, social influence, facilitating conditions, and four moderators (Venkatesh et al. 2003).

Performance expectancy and effort expectancy are closely related to perceived usefulness and perceived ease of use in TAM, since they both refer to individuals' evaluations of technology usage and outcome based on pre-use expectations

(Venkatesh et al. 2003). Social influence relates to the notion that other people believe the technology should be adopted, whereas enabling conditions refer to the belief that technical infrastructure is available to facilitate the technology's adoption (Venkatesh et al. 2003).

The Task Technology Fit-UTAUT model posits that perceived fit between tasks and technology is predictive of technology adoption. According to the Task Technology Fit model, the fit between technology and tasks is predicted by the features of the technology and task (Goodhue & Thompson, 1995).

The original idea establishes a positive relationship between task technology fit and user adoption. It asserts that regardless of an individual's attitude toward technology, if there is a mismatch between the technology's capability and task needs, the individual is unlikely to accept it (Goodhue & Thompson, 1995). Second, the UTAUT model predicts user adoption of technology based on effort expectation, performance expectation, enabling factors, and social influence (Venkatesh et al. 2003). Third, perceived fit has an effect on performance expectations (Zhou et al. 2010).

Prior research indicating that Task Technology Fit impacts perceived usefulness supports the association between Task Technology Fit and performance expectation (Dishaw & Strong, 1999). Perceived usefulness is comparable to performance expectation in that both metrics quantify the anticipated impact of technology use on performance (Davis, 1989).

The link suggests that as technology functionality enables humans to accomplish essential jobs, their performance expectations grow proportionately (Zhou et al. 2010). Fourth, technology attributes have an effect on effort expectations. The relationship between task features and expected effort shows that higher-functioning technology take less effort to utilize (Zhou et al. 2010).

2.5.9 Summary

In the previous sections, the main theories and models of technology acceptance and adoption were reviewed and discussed. The following table summarizes the theories reviewed and provide a brief description of each of the main theories.

Table 2. 3 Technology Acceptance Theories

No	Theories	Brief description
1	Innovation Diffusion Theory (IDT)	Adopted from the application of technology to measure public perception IDT using seven key attributes.
2	Theory of Reasoned Action (TRA)	A theory that aims to explain the relationship between attitudes and behaviors within human action.
3	Technology Acceptance Model (TAM)	A theory to identify reactions and one's perception that determines a person's attitudes and behavior by making a model of a person's behavior as a function of the manner by which the objectives determined by the attitude's behavioral objectives for such behavior.
4	Technology Acceptance Model2 (TAM2)	A theory developed and extended form the original TAM that explains the major determinants of (PU) perceived usefulness. The determinants added to the model were subjective norms, voluntariness, image, job relevance, result demonstrability, and output quality.
5	Technology Acceptance Model3 (TAM3)	A theory developed from both the TAM2 and the model of perceived ease of use determinants. Its main contribution to be the addition factors addressing the determinants of (PEOU) perceived ease of use and (PU) perceived usefulness.

6	Unified Theory of Acceptance and Use of Technology (UTAUT)	A theory based on various technology acceptance models. The model aims to explain users' intentions to use a certain technology and consequent usage behavior.
7	Unified Theory of Acceptance and Use of Technology ² (UTAUT ²)	A theory extended from the UTAUT to examine technology acceptance in the context of consumer behavior.
8	Task-Technology Fit	The model's assumption is that the value/performance of technology is established by the alignment, or fit, of task requirements and technology features that allow a user to execute the tasks in a situation where technology is utilized by individuals to perform particular activities, or sets of tasks

2.6 Conceptual Framework of Research

The previous section reviewed various technology acceptance theories and models. This knowledge was used to select an existing model and then modify and develop the proposed model of this research. This chapter's main objective is to provide illustration, explanation, and justification of the conceptual framework which was based on the existing literature knowledge and gaps. The research's conceptual framework was developed through an extensive review of the literature on technology and technology adoption in environmental enforcement and relevant fields. In this section the conceptual framework of this research illustrates the variables that will be explored in the study, which are based on the research objectives. The variables are technology use and adoption in law enforcement; and technology adoption in mandatory settings.

2.6.1 Technology Acceptance Models in Law Enforcement

Literature on technology acceptance has been expanding substantially in various disciplines but there still deficiency of research in particular fields and domains. Law enforcement is one of these fields and especially in environmental law enforcement. The following section will review some of research conducted in the field of law enforcement.

One study conducted by Donne and Fortin in (2020) on factors that influence the adoption of social medias by the members of Quebec police organizations utilized the Diffusion of Innovation Theory to verify if the model is valid for studying new innovation adoption by individuals in policing organization. They confirmed the validity of the factors, such as the perception of the users on a new innovation and organizational factors, identified in previous studies and that it can help understand the reasons and how often individuals use social media in their work (Donne and Fortin, 2020).

One interesting finding from the study is that although the factors of the Diffusion of Innovation are applicable to the adoption of innovative tools in law enforcement, not all are as influencing as previous studies purport. They found that perception of relative advantage did not have a major influence on social media adoption. They find that individuals still decide to use social media for their task even if they feel there is no real benefit. They state that “adoption stems from a need, or at least that members who use SM most frequently are those who think the tool should be leveraged by police organizations to help accomplish their goals, despite its drawbacks.” The role of the individual was also found to be a unique influencer of technology adoption by law enforcement personnel (Donne and Fortin, 2020).

Another study by Gulatee et al. (2020) is on the adoption and use of technology for emergency preparedness and response (EPR) in rural communities. The research identifies and compares determinants of technology use and adoption by users involved in emergency preparedness and response from previous studies. The study identified three main categories of determinants of technology adoption and use in

Environmental Enforcement Technology Adoption

emergency preparedness and response, which are Individual determinants, organizational determinants, and contextual determinants.

Individual determinants: Individual determinants are the ways in which an individual's capabilities, skills, knowledge, views, and even personal experiences influence the type of connection that develops with a technology, hence determining its acceptance and use. It also expresses whether or not the technology takes into account human mental skills and models, as well as wants, preferences, and individual qualities (or traits). The design of a technology or interface is thus inextricably linked to the particular determinant category. Although there were many determinants within this category such as individual characteristics, cognitive absorption, and professionalism. Three main determinants were identified to be the most relevant to emergency preparedness and response, which were perceived usefulness, perceived ease of use, and individual IT knowledge/experience (Gulatee et al., 2020).

Organizational determinants: Organizational determinants are elements that develop and occur beyond the individual in an organization. These elements include an organization's structure, conventions, practices, rules & regulations, history, and expected behavioral and cultural trends. Many determinants related to the organizational context were identified such as leadership, collaboration, IT system quality, and organizational culture. The study lists main five determinants most relevant to field of their study. Organizational IT infrastructure, IT system interoperability, financial resources, organizational IT readiness, and Decision-Making Process (Gulatee et al., 2020).

Contextual determinants: When governments adopt and employ technology, contextual factors refer to the external environmental setting in which they operate. Contextual determinants are community-level elements that impact conditions and individual and organizational behavior, such as economic, cultural, technological, political, and social aspects. Some determinants related to the contextual context were identified but not listed, such as political support and government performance. The study lists main five determinants most relevant to the field of their study: Culture and social norms, IT fit to context, history of disasters, stress level effect, and vulnerability to disaster (Gulatee et al., 2020).

Environmental Enforcement Technology Adoption

Another study on the application of technology acceptance was by Prasanna & Huggins (2016). They conducted a study on factors affecting the acceptance of information systems supporting emergency operations centers. They used the TAM and UTAUT models in their study to find which factors affect technology adoption in emergency operations centers and found them to be performance expectancy, effort expectancy, social influence, and information quality. Their findings highlight a need to re-focus technology acceptance research on both mediating and moderating effects and the importance of considering domain specific factors (Prasanna & Huggins, 2016).

Various studies examined Influence of perceptions on the acceptance of technologies for law enforcement. The study by Kim et. al. (2020) examined the influence of general policing attitudes and officer's characteristics on Body Worn Cameras. They find a complex relationship between the various factors that influence the perception on Body Worn Cameras.

Kim et. al. (2020) main findings are that "Years of experience, police department, perceptions of civilian cooperation, and perceptions of aggressive law enforcement are significant in explaining officers' perceptions of BWC effects on job performance and/or community relations. Those officers with longer experience, an aggressive law enforcement orientation, and/or a positive perception of citizen cooperation tend to have positive perceptions of BWCs. The effects of police department and rank differ depending on the role of mediating variables". The study does not only explore the factors influencing Body Worn Cameras acceptance by police officers but the effect it has on their job performance and civilian perception.

Another study on officer's perceptions influence on Body Worn Cameras acceptance was conducted by Todak & Gaub (2019). They examine individual level factors influencing Body Worn Cameras by police. They find that level of acceptance of police officers wearing Body Worn Cameras is influenced by various factors. The main influencers discovered in the study were the amount of time wearing the cameras (the longer they wear the cameras, the higher level of acceptance), their supervisor's

Environmental Enforcement Technology Adoption

attitudes and perception, and their need for protection from inside and outside the organization or system.

Another study conducted Pasha & Nelson (2021) is on the factors influencing innovation adoption by local governments. They chose to conduct the study on CompStat (Computer Statistics used by police as a performance management tool to monitors crime incidents at different levels and produce performance reports showing crime statistics by jurisdiction). The study mainly focuses on the influence of environmental stress on innovation adoption.

Their findings suggest that environmental stress such as violent crimes can lead to higher innovation adoption such as the CompStat by local governments. Other factors influencing innovation adoption were popularity and reputation of the innovation by the law enforcement agencies, public, and especially political systems. Also, the customization of the innovation to be compatible with the needs and culture of the organization and various stakeholders. Various other factors were identified in the study from previous research such as the organizational characteristics, environmental factors, and characteristics of the innovation (Pasha & Nelson, 2021).

Another modified theory of technology acceptance which is relevant to our field of study is the M-TAM mobile technology acceptance model which was developed by (Lindsay, Jackson, & Cooke, 2011) in response to the increasing implementation and acquisition of mobile technology in law enforcement in the UK. The adapted officer M-TAM (2.10) in one of the UK police enforce the Leicestershire Constabulary. To explain police officer's acceptance of mobile technologies the M-TAM model recognizes four categories; performance; security and reliability; management style; and cognitive acceptance. Performance category factors were data quality, officer efficiency, inputting, accessing, and sharing information, and functionality of the technologies. Security and reliability factors included battery life, network coverage, connectivity, and level of privacy. Management style's main factors are the level of training, technical support, officer involvement and information for mobile technologies. As for the cognitive acceptance the main factors are officer and public perception of technologies, peer influence and organizational culture (Lindsay, Jackson, and Cooke, 2011).

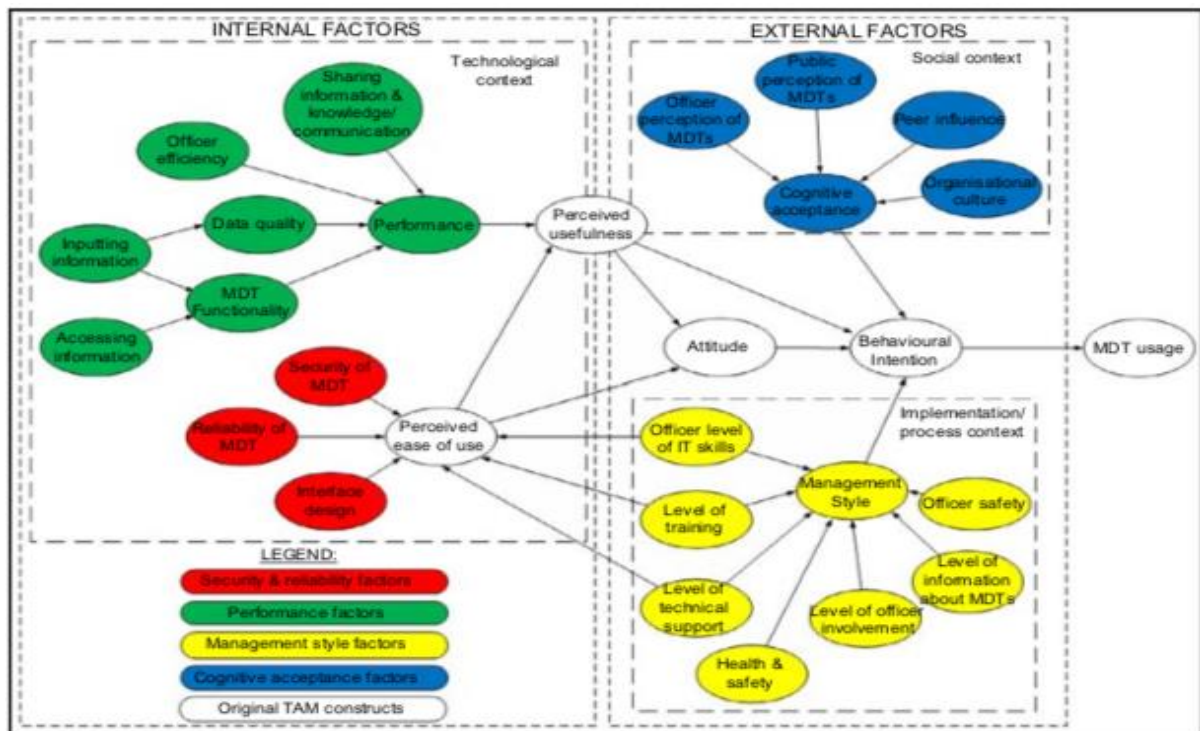


Figure 2. 15 Holistic officer mobile technologies acceptance model (M-TAM) (Lindsay, Jackson, and Cooke, 2011).

Lindsay, Jackson, and Cooke (2011) purport that the M-TAM is a high-level model which can be used in other law enforcement contexts. Other research has applied the Technology Acceptance Model (TAM) model in law enforcement but were concentrated on a specific law enforcement organization and did not specifically consider mobile technology adoption and if the model could be generalized to other contexts. Lindsay, Jackson, and Cooke (2014) conducted a further study to validate and enhance the M-TAM and to explore if the model is transferable to other UK police forces, and potentially worldwide.

Through their research they further modified the previous model by adding various factors. These factors are local supervision, senior management buy-in, and time to implement the project, which were included into the management style factors. Fit of the technology to the role and task have been put in the local context category. The study purports that the M-TAM is transferrable to other law enforcement forces with differing types of mobile devices in place. Also, that the model can be utilized as a valuable tool for law enforcement agencies and similar organizations around the world that are planning on mobilization of their technology implementation. The model

Environmental Enforcement Technology Adoption

should provide a wide range of factors needing attention for the successful mobilization of technology (Lindsay, Jackson, and Cooke, 2014).

Table 2. 4 M-TAM factors

Factor type	Context	Category	Factor
Internal	Technological	Operational Performance	Device Functionality
			Accessing information
			Inputting information
			Data quality
			Officer efficiency
			Sharing Information & knowledge/communication
		Security of MDT	
External	Social	Cognitive acceptance	Peer influence
			Organizational culture
			Public perception of MDT
			Officer perception of MDT
	Implementation/ process	Management style	Local supervision
			Level of training
			Level of officer involvement
			Level of information about MDT's
			Officer safety
			Health & safety
			Level of technical support
			Officer level of IT skills
			Time to implement project
			Senior management buy-in

Environmental Enforcement Technology Adoption

	Local	Fit of technology to role	
		Fit of technology to role	

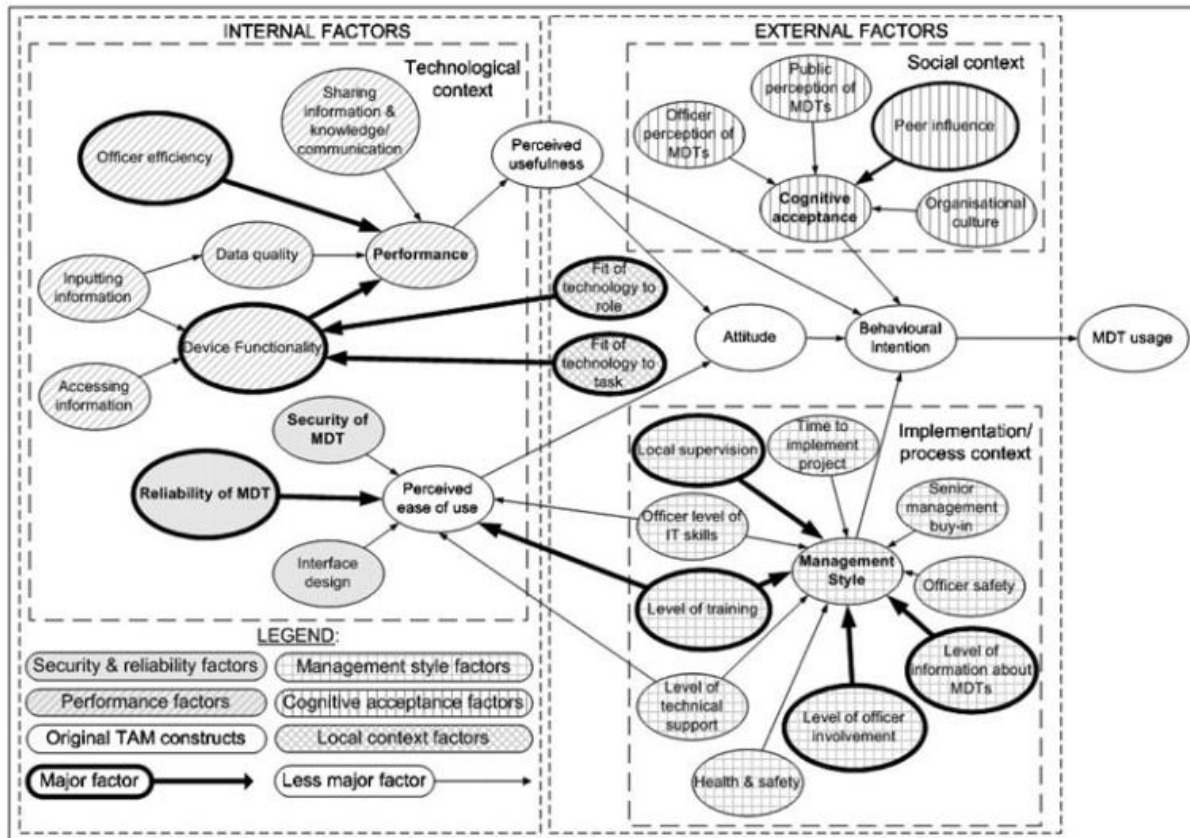


Figure 2. 16 Adapted M-TAM by Lindsay, Jackson, and Cooke (2014)

One modified technology acceptance model designed for environmental law enforcement was given by Sintov et al. (2019) in their paper titled “Fostering Adoption of Conservation Technologies: A Case Study with Wildlife Law Enforcement Rangers”. They conducted a case study on a new technology called PAWS designed to deter poachers and improve ranger patrol deployment in Indonesia. The study evaluated the impact of an educational program on the willingness of the rangers to adopt the technology. The study modified the technology acceptance model as seen in Figure 2.17 below.

Environmental Enforcement Technology Adoption

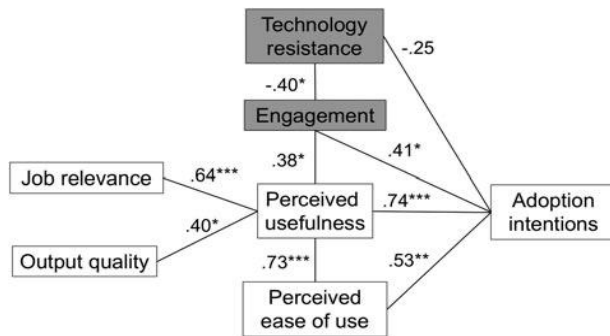


Figure 2. 17 Technology Acceptance Model variables (N. Sintov et al. 2019).

The following table presents the summary of the technology acceptance literature reviewed in this research regarding law enforcement.

Table 2. 5 Summary of technology acceptance literature in law enforcement

Theory	Field	Additional/important variables	Authors
Diffusion of Innovation	Social media/ police	<ul style="list-style-type: none"> • Role of the individual • Need 	Donne & Fortin, 2020
Diffusion of Innovation	Emergency Preparedness and Response	<ul style="list-style-type: none"> • Individual determinants • Organizational determinants • Contextual determinants 	Gulatee et al. 2020
TAM & UTAUT	Emergency Operation Centers	<ul style="list-style-type: none"> • Performance expectancy • Effort expectancy • Social influence • Information quality 	Prasanna & Huggins 2016
Diffusion of Innovation	Innovation adoption by local governments (CompStat)	<ul style="list-style-type: none"> • Environmental stress (ex. Violent crimes) • Popularity and reputation (agencies, public, and political system) • Compatibility to needs and culture 	Pasha & Nelson, 2021

Environmental Enforcement Technology Adoption

		<ul style="list-style-type: none"> • Organizational characteristics • Characteristics of innovation 	
TAM/ UTAUT	Understanding mobile technology acceptance law enforcement.	<ul style="list-style-type: none"> • Social context (Cognitive acceptance) • Implementation/process context (Management style) • Technological context (Performance) • Local context • Security & reliability 	Lindsay et al. 2014
TAM	Conservation technology adoption by wildlife law enforcement rangers	<ul style="list-style-type: none"> • Technology resistance • Engagement 	Sintov et al. 2019

2.6.2 Technology Acceptance in Mandatory Settings

Most technological application adoption and selection are conducted by top level management and is expected to be used by employees, especially in law enforcement organizations and entities. In some cases, this can result in failure or distribution of the implementation and use of the technologies by the employees if they are not accepted or resisted.

Literature on technology acceptance in mandatory settings is relatively low. Especially on theories such as TAM and TRA, which are initially utilized to understand technology acceptance in voluntary settings where the user may have no choice of using or choosing the technology. Later research attempted to resolve the issues of irrelevance of previous theories to non-volitant settings by adding factors that consider the mandatory setting implications on acceptance. Several studies have attempted to

better explain and predict technology acceptance in both voluntary and mandatory settings, such as the UTUAT, TAM, and TPB models.

The TPB model added the perceived behavioral control construct to attempt to explain acceptance in non-volitional settings. The perceived behavioral control is defined as “people’s perceptions of the ease or difficulty of performing the behavior of interest” (Ajzen, 1991). Further the construct was redefined by Ajzen (2002) to deal with the issues of unclarity and confusion with the factor of perceived behavioral control. Two components of the perceived behavioral control were suggested: Self efficacy, which refers to the perceptions of ease or difficulty of performing a behavior, and controllability, which refers to the extent to which the performance of the behavior is up to the actor (Ajzen, 2002).

The Theory of Planned Behavior was not without criticisms. Several studies have found that determinants of the theory are deficient in explaining and predicting the user’s behavioral intention (Ajzen & Fishbein, 2005). The perceived behavioral control value in a mandatory setting was tested and found to have minimal ability to explain acceptance and referred only to external and internal factors that might hinder use of the system, but not the mandatory nature of the technology used (Rawstorne et al. 2000). The Theory of Planned Behavior TPB only refers to volitional control but not voluntariness.

The UTAUT model added the moderating factor voluntariness of use, which moderates the influence of social factors on behavioral intention. Voluntariness of use is defined as the extent to which individuals believe that their use is perceived as voluntary, or free of will. Voluntariness has a substantial impact on explaining present consumption, but it has little impact on future intentions to continue using, according to Agarwal and Prasad (1997). They conclude that forced usage may be significant in influencing initial adoption decisions among users, but that users would eventually rely on more instrumental beliefs for their continuing usage based on their findings.

This temporal shift in attitudes impacting usage behavior is in line with previous findings (Venkatesh & Davis, 2000; Venkatesh et al. 2003). The social norms and behavioral intention connection use voluntariness as a moderating variable in technology adoption studies (Venkatesh et al. 2003; Venkatesh & Bala, 2008).

The TAM's ability to explain technology acceptance in mandatory settings was questioned by Brown et al (2002). They define the mandatory setting as "in which users are required to use a specific technology or system in order to keep and perform their jobs." Brown et al. (2002) posits that the TAM and its extensions in mandatory settings only consider the issue of necessity. They find that mandatoriness is much more complex and involves the extent to which a technology is necessary to perform task or job and the extent to which the application of the technology is integrated across users.

Brown et al. (2002) attempted to demonstrate that in a highly integrated environment where using the system is the only method to complete one's job, the TAM will be less effective than alternative models in explaining usage behavior. Their findings reveal a pattern of associations that differs from what is commonly reported in the literature. Three models were tested by Brown et al. (2002), Theory of Planned Behavior, the original Technology Acceptance Model, and the Technology Acceptance Model without the attitude construct.

TAM without attitude: The perceived ease of use was found to be the most influential factor influencing behavioral intention. The researchers find this result as misleading because the qualitative data showed that many individuals perceived the system as not easy to use.

Original TAM: The perceived usefulness was a significant predictor of attitude while neither PU nor attitude predicted behavioral intentions. The authors argue that in mandatory settings PU might better serve the goal of creating positive attitudes toward use rather than directly influencing intentions to use. Furthermore, the insignificant relationship between attitude and behavioral intention suggests that users' attitude toward using the system are not affecting their intentions to continue their use. Attitude was significantly influenced by perceived usefulness, although neither perceived usefulness nor attitude constructs predict behavioral intentions. Brown et al. (2002) propose that, in obligatory contexts, PU might be used to foster favorable attitudes toward usage rather than directly affecting intentions to use. Furthermore, the lack of a link between attitude and behavioral intention suggests that users' attitudes about utilizing the system have little impact on their intent to continue using it. As a result,

even if users have bad sentiments about using the system, they plan to keep using it because they have to, and they have no plans to leave the company.

TPB: Social norms and perceived behavioral control were most influential on behavioral intention of the tested models and explain 52 percent of the variance in behavioral intention.

According to Brown et al. (2002), the disparity between one's attitude and one's actual action causes greater dissonance, which can lead to unintended consequences. They go on to say that unfavorable views may cause users to doubt the motivations for introducing new technology, which can lead to the emergence of further roadblocks in the deployment process.

Other researchers found that behavioral intention was irrelevant to technology acceptance in mandatory settings (Linders, 2006). Linders (2006) focuses on mandatory innovations with IS, which is unlike theories and results in which voluntary use is considered. The Technology Acceptance Model was modified to better predict and explain technology acceptance in mandatory settings. The modified model excluded the Behavioral Intentions and Use since the research found those variables not to be useful in terms of measuring mandatory information system success. It was found that Attitude was the main determinant of IS success, followed by ease of use. Usefulness is the main determinant of attitude (Linders, 2006).

2.6.3 Critical observations and Gaps

Research objectives were identified and explained in Chapter One of this dissertation. The research gaps and questions are clarified below. As explained in the literature review (Chapter Two) scholars from different fields and with diverse interests recognize the important role of the technology adoption in the implementation and success of technology and its related domains. Many research studies have been conducted to explain the adoption and use of the technology adoption in law enforcement as shown in the literature review provided earlier in this chapter. However, a number of research gaps were identified in addition to those described below, including some of the critical observation from the previous research. The

Environmental Enforcement Technology Adoption

analysis and observations from the previous studies were conducted after rigorous and detailed review of these studies, and this includes identification, review, and evaluation of the previous studies. The following table (2.6) gives further details of the key study elements used for the analysis which include the research's title, author, methodology, objectives, gaps, analysis, samples, results, and future research. Majority of text was directly quoted from each original paper to ensure accuracy and proper interpretation of study elements for literature analysis.

Table 2. 6 Details of previous studies on technology adoption in law enforcement and mandatory settings

Title & Author	Methodology	Objectives	Gap	Analysis	Sample	Results	Future Studies
Technology Adoption in Law Enforcement							
Innovation and Policing: Factors Influencing the Adoption of Social Medias by Members of Quebec Police Organizations Donne & Fortin (2020)	The survey (Questionnaires) (1) an introductory section tried to determine what functions respondents performed in their organization (2) the second section consisted of questions on SM adoption, including how much time respondents devote to SM as part of their duties. (3) the third set of questions helped measure the respondents' perception of SM	to determine whether a model developed in research on innovation in organizations can be used to understand change that occurs in police organizations.	The literature on members of police organizations adopting new technology is generally descriptive and rarely explanatory.	linear regression	six different police organizations total: 177 participants 47 patrol officers 42 investigators 67 analysts 21 managers	SM adoption by members of Quebec police organizations can be partly explained by the factors suggested in the Diffusion of Innovation Theory as the findings in each model were significant. Moreover, each model followed the trends observed in the literature. Depending on the group of actors considered, the same variables are not always significant.	to assess adoption at the organizational level and to observe interrelation between organizational use and use in the field
Technology adoption for emergency preparedness and response in rural areas: identifying the main determinants	Systematic review	proposing a model of adoption and use of technology for emergency preparedness and response	while several models have aimed at explaining adoption and use of technology by individuals and organizations, very few of them have explicitly taken into account the specific	Systematic analysis	76 sources peer-reviewed articles, conferences, books, dissertations, and other reports from	Identification of relevant determinants of IT adoption and use in the EPR domain Three dimensions: individual, organizational, and contextual. In addition, it compares those EPR determinants with the determinants found in the more	develop a technology adoption and use model for EPR in rural areas

Environmental Enforcement Technology Adoption

Gulatee et al. (2020)		(EPR) in rural contexts	characteristics of the domain of emergency preparedness and response Furthermore, these models have not differentiated between urban and rural contexts.		years 2000 to 2019.	general literature on adoption and use of technology. Finally, the paper also highlights some unique characteristics of rural settings.	
Factors affecting the acceptance of information systems supporting emergency operations centres Prasanna & Huggins (2016)	The survey (Questionnaires)	examine how a range of technology acceptance factors could affect the acceptance of emergency operations centre information systems	Despite the recognition that information system acceptance is an important antecedent of effective emergency management, there has been comparatively very little research examining this aspect of technology acceptance.	structural equation modelling	383 end-users of four different emergency operations centre information systems	technology acceptance factors of performance expectancy, effort expectancy, social influence and information quality explained 65 percent of variance in symbolic adoption, which is a combination of mental acceptance and psychological attachment towards an information system. A number of moderating effects of age, gender, experience of use and domain experience were also identified. A mediating component, of performance expectancy, explained 49 percent of variance between facilitating conditions, information quality, effort expectancy, and resulting symbolic adoption	need to re-focus technology acceptance research on both mediating and moderating effects and the importance of considering domain specific factors.
The impact of general police officer outlooks on their attitudes toward body-worn cameras Kim et al. (2020)	The survey (Questionnaires)	examined whether the influence of negative or "concerning" policing attitudes toward body cameras is mediated by other variables, such as officer outlooks toward law enforcement, officers' perceptions of citizen cooperation or their opinions of the public.	A large share of the research focused on individual officer attitudes toward these new law enforcement tools. The scholarship, however, focused almost exclusively on their positive and negative perceptions of body cameras or correlations between those attitudes and general officer characteristics.	SEM, including both factor and path analyses	convenience sample of police officers in Buffalo and Rochester, New York. A total of 305 officers accessed the survey, but 45 did not provide any responses, and several others did not provide sufficient answers	Findings indicate that the relationship between experience and concerning perceptions of body cameras is mediated by distrust in citizens and perceived civilian cooperation. Further, an officer's outlooks regarding aggressive law enforcement tactics do not have a direct effect on concerning perceptions of body cameras, nor do they serve as a mediator between years of experience and concerning perceptions of body cameras.	studies of police acceptance or implementation of BWC should measure these concepts.
Predictors of police body-worn camera acceptance: digging deeper into officers' perceptions Todack & Gaub (2019)	The survey (Questionnaires)	examine individual-level factors related to police body-worn camera (BWC) acceptance.	Given the cross-sectional nature of the research to date, the reasons for the relationships observed between officer demographics and BWC acceptance are not clear. Moreover, the relationships between cultural attitudes, organizational justice and BWC acceptance have not been tested.	stepwise regression, beginning with a baseline model including only demographic characteristics and then adding each group of variables.	119 officers from one northwestern police agency a year after BWC deployment.	Supervisors, as well as officers who had worn BWCs longer, worked the most active patrol shifts, and viewed their supervisors as critical, reported more BWC acceptance. Other indicators of culture and organizational justice were not significant.	investigate officer BWC acceptance and resistance in other jurisdictions, drawing on a broader spectrum of predictors to investigate predictors of officer BWC acceptance in a variety of contexts
Drivers of Innovation: Environmental	The survey (Questionnaires)	to find out whether innovations are		event-history	362 respondents from city police departments		

Environmental Enforcement Technology Adoption

Stress and External Pressures Pasha & Nelson (2021)		more likely to be adopted by high-performing organizations or by organizations operating under stress		regression model	from the U.S. Uniform Crime Reporting (UCR) database		
Adapted technology acceptance model for mobile policing Lindsay et al. (2011)	qualitative, partially ethnographic design was followed to allow an in-depth exploration focus groups, interviews, observational “work-shadowing” and questionnaires.	to investigate the factors affecting officer acceptance of the MDTs and to reengineer a theoretical model that can be applied to a mobile policing context.	important to examine the factors affecting officer acceptance. There appears to be little understanding of the key factors	thematic analysis	Focus groups/interviews :total of 12 Observations: A total of 38 incidents were shadowed throughout the course of around 20 shifts.	In total, four main categories of officer acceptance factors were identified: officer performance, security/reliability, management style and cognitive acceptance. Evidence from the study showed a key shortfall in all three versions of the TAM in that they focus on the user perspective and did not confirm the broader organisational factors within the implementation and social contexts of mobile policing.	
Empirical evaluation of a technology acceptance model for mobile policing Lindsay et al. (2014)	Qualitative interviews	Validation of the mobile technology acceptance model (M-TAM) developed in a single police force.	Technology acceptance in policing is under-researched, yet mobile devices are widely implemented across UK police forces.	Thematic and content analysis	9 field experts (PM) from UK police force	that the M-TAM is transferrable to other UK police forces, and potentially worldwide. The influence of local supervision and fit of technology to roles and tasks are shown to be the most influential factors. Factors beyond the technology itself, such as the influence of peers and involvement of operational officers in technology investment decisions, must be considered to accommodate the strong cultural barriers in policing.	untested with regard to the implementation of mobile devices within other national cultures validity outside of the emergency services domain also remains an open area for future research
Fostering Adoption of Conservation Technologies: A Case Study with Wildlife Law Enforcement Rangers Sintov et al. (2019)	Survey (Questionnaire)	Evaluation of the impacts of an educational programme on the willingness of Indonesia-based rangers to adopt the tool (PAWS)	although some studies have focused on ranger experiences, and on the impacts of policing technologies on crime rates, few have addressed technology adoption among law enforcement personnel, and none among rangers	Spearman correlations	29 employees of the five primary groups responsible for protecting wildlife on Sumatra to participate in the programme	the findings of this case study stress the significance of accounting for and educating end users in disseminating conservation technologies, reinforcing the importance of accounting for human dimensions of conservation.	attempt to replicate these results using larger, multi-site samples and more advanced statistical techniques should use experimental designs and control groups with pre/post measures to discern causal processes, and should also include validity checks
Police perceptions of body-worn cameras (BWCs) by type of police agency Demir 2021	survey	compare police perceptions of BWCs in terms of officers' perceptions of BWCs acceptance (police support for BWCs, citizen support of BWCs, and comfort with the use of BWCs), the effect of BWCs on police (transparency,	Unlike the previous studies, the current study breaks new ground by examining state police officers' perceptions of BWCs and whether officers' perceptions of BWCs differ by type of police agency. Finally, unlike the previous studies, the current study also examines two additional outcomes	bivariate and multivariate analysis	131 police officers from the State Police (SP), City Police (CP), and University Police (UP)	that CP officers have the most positive views of BWCs, followed by UP officers, and SP officers. The multivariate analyses also showed that a significant difference was found between CP and SP officers for BWCs acceptance, effect of BWCs on police and citizens, and complaints, between CP and UP officers for effect of BWCs on citizens, while no significant difference was found between SP and UP officers.	To explore officers' perceptions in depth, the current quantitative study should be supplemented with qualitative studies. Future studies should be experimental, use random sampling for the selection of participants, and use qualitative methods such as interviews and focus groups with officers for in-depth exploration of officers' perspectives of BWCs and include the other explanatory

Environmental Enforcement Technology Adoption

		accountability, respectful treatment, use of force, and officer safety), the effect of BWCs on citizens ,officer activity, and complaints among different types of police agencies					variables and police departments. future studies should examine the differences across different type of police agencies in depth.
Information Technology to the Rescue? Explaining the Acceptance of Emergency Response Information Systems by Firefighters Weidunger et al. 2021	Mixed method Interviews and survey	propose a detailed, domain-specific acceptance model with factors that explain the acceptance of ERIS by firefighters	the conditions under which firefighters accept or reject such systems remain unclear. Existing theories explain the acceptance of information technologies only on a general level that does not consider the specific usage constraints existing in the firefighter domain.	Content and statistical analysis	82 domain experts 212 firefighters from Germany	a new acceptance model. Next to generic factors, it contains several domain-specific factors that determine a firefighter's intention to use an ERIS and the actual system usage. We found that firefighters' intention to use an ERIS is determined by several factors that characterize the quality of the system and that of the provided information. In particular, the flexibility, reliability, timeliness, and mobility of the system itself, as well as the accuracy, format, and currency of the provided information turned out to be important acceptance factors.	test the presented acceptance model in an international setting. To examine the generalizability of the presented acceptance model, future research could also explore if it is suitable to explain the acceptance of other FITs like drones, on-ground robots, or intelligent protective clothing. With the presented acceptance model and the measurement instrument, we also hope to provide a starting point for such endeavors.
Why geographic information systems in spatiotemporal crime analysis? Attitude of Kenyan police officers Baraka & Murimi, 2019	Mixed Structured questionnaire, interview guide and a focus group discussion	determine how crime is documented, mapped and analyzed in Kenya, and to assess Kenyan police officers' attitudes toward adoption of Geographic Information Systems (GIS) in spatiotemporal crime analysis	Kenyan police officers are however still using push-pins on paper-maps to analyze crime	The study used descriptive statistics, measures of central tendency, and measures of dispersion content analysis	120 police officers at the Kenya National Police Service (NPS) headquarters in Nairobi Only94 responded	although crime recording and spatial analysis were done manually, Kenyan police officers had an open mind towards adoption of GIS tools in spatiotemporal crime analysis <u>While TAM helps in assessing GIS acceptance status in crime analysis as a key concern of police practice, there is need to address theory as an integral focus of security scholars</u>	to have a larger sample comprising of police officers from all formations across Kenya to determine whether GIS usability perceptions can vary with reference to geographic space. conduct similar and/or related studies among all other security players like the National Intelligence Services (NIS), the Kenya Defense Forces (KDF) as well as private security providers. National security is a collaborative endeavor that calls for joint efforts from all stakeholders, and hence an all-inclusive study would provide a diverse and holistic perspective on GIS usability perceptions and allow generalization of research findings.
Mandatory technology adoption							
ISSUES IN PREDICTING AND EXPLAINING USAGE BEHAVIORS WITH THE TECHNOLOGY ACCEPTANCE MODEL AND	longitudinal study questionnaire s	identify the relevant issues necessary for applying the technology acceptance model and the theory of planned behavior to the	paucity of research that has considered the issues specific to predicting and explaining user behavior in these situations	Path analysis, based on regression equations	one organization (a hospital environment) in respect to one type of IS (a Patient Care Information System, PCIS), and one type of worker (nurses).	The results suggest that both the TAM and TPB predicted and explained two of the three behaviors (using care plans for planning care delivery and using care plans an educational tool). Their failure to predict Behavior 1 (updating the care plans as changes occur) is quite possibly	that this study be cross validated using a larger sample with a more even gender ratio and separate measures of user perceptions of voluntariness for each usage behavior

Environmental Enforcement Technology Adoption

<p>THE THEORY OF PLANNED BEHAVIOR WHEN USAGE IS MANDATORY</p> <p>Rawstone et al. 2000</p>		<p>prediction and explanation of mandated IS usage, and we assess the value of these models to the task.</p>			<p>61 nurses</p>	<p>associated with the formation of an intention.</p>	
<p>The Role of Innovation Characteristics and Perceived Voluntariness in the Acceptance of Information Technologies</p> <p>Agarwal & Prasad 1997</p>	<p>Cross-sectional</p> <p>Questionnaire</p>	<p>individual's perceptions about the characteristics of the target technology as explanatory and predictive variables for acceptance behavior, and present an empirical study examining the effects of these perceptions on two frequently used outcomes in the context of the innovation represented by the World Wide Web.</p>	<p>Diverse streams of research have attempted to explain and predict user acceptance of new information technologies</p>	<p>Regression analysis</p>	<p>73 business professionals enrolled in a part-time MBA program at a comprehensive university</p>	<p>results confirm, as hypothesized by prior research, that innovation characteristics do explain acceptance behavior. The results further reveal that the specific characteristics that are relevant for each acceptance outcome are different.</p> <p>The second research question asks if perceived voluntariness plays a role in technology acceptance. Results show that external pressure has an impact on adopters' acceptance behavior.</p>	<p>replication across different samples and across a range of different technologies.</p>
<p>Do I really have to? User acceptance of mandated technology</p> <p>Brown et al. 2002</p>	<p>Questionnaire (survey)</p>	<p>discuss our current understanding of technology acceptance, as well as the notion of mandated use.</p> <p>discuss a field study conducted in the banking industry to examine technology acceptance models in a mandated use environment.</p>	<p>Lack of research on technology acceptance in mandatory settings</p>	<p>PLS analysis</p>	<p>employees in the four most recently converted BHC bank affiliates. In total 195 surveys were distributed and 107 usable responses were received</p>	<p>differences in the underlying relationships of technology acceptance models in this mandatory use situation.</p>	<p>assessing necessity and interdependence, and their interaction. Likewise, additional measures of mandatoriness need to be developed to capture the complexity of the construct.</p>
<p>Using the Technology Acceptance Model in determining strategies for implementation of mandatory IS</p> <p>Linders 2006</p>	<p>Literature review</p>	<p>examines what the overall success determinants are, when an IS brought into a company. The focus will be on the differences when the use of this IS mandated from management to the users of the system, compared to voluntary use of the system.</p>	<p>Lack of research on technology acceptance in mandatory settings</p>	<p>N/A</p>	<p>N/A</p>		<p>N/A</p>

Environmental Enforcement Technology Adoption

<p>Technology Acceptance Model 3 and a Research Agenda on Interventions</p> <p>Venkatesh & Bala 2008</p>	<p>questionnaires</p>	<p>(i) develop a comprehensive nomological network (integrated model) of the determinants of individual level (IT) adoption and use; (ii) empirically test the proposed integrated model; and (iii) present a research agenda focused on potential pre- and postimplementation interventions that can enhance employees' adoption and use of IT</p>	<p>limited research in the IT implementation literature that deals with the role of interventions to aid managerial decision making. Particularly, there is a need to understand how various interventions can influence the known determinants of IT adoption and use.</p>	<p>PLS analysis</p>	<p>four different organizations implementing new IT</p> <p>156 responses</p>	<p>perceived ease of use, subjective norm, image, and result demonstrability were significant predictors of perceived usefulness at all time periods</p> <p>job relevance and output quality had an interactive effect on perceived usefulness such that with increasing output quality, the effect of job relevance on perceived usefulness was stronger.</p> <p>that experience moderated the effects of subjective norm on perceived usefulness such that the effect was weaker with increasing experience.</p> <p>the effect of image on subjective norm was significant at all points of measurements.</p> <p>the anchors—that is, computer self-efficacy, perceptions of external control, computer anxiety, and computer playfulness—were significant predictors of perceived ease of use at all points of measurement</p> <p>experience moderated the effect of computer anxiety on perceived ease of use such that the effect became weaker with increasing experience.</p> <p>none of the determinants of perceived usefulness had a significant effect on perceived ease of use.</p> <p>perceived usefulness was the strongest predictor of behavioral intention at all time periods</p> <p>behavioral intention was a significant predictor of use at all points of measurements</p>	<p>Further understand the role of interventions in IT adoption contexts</p>
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From the research, it was found that literature is widely available on the influence of technology and law enforcers experience on law enforcement strategies and performance'. Few have researched technology adoption factors and determinants of the field of law enforcement, especially from the perspective of enforcement personnel. When it comes to technology adoption among environmental enforcers, studies are even more scarce, in which only one of relevance was found in this field (Sintov et al. 2019). The unique characteristics of environmental enforcement requires additional studies when it comes to knowledge of technology adoption, especially when taking into account the human dimensions of environmental enforcers and the different settings and enforcement systems in which they operate.

Environmental Enforcement Technology Adoption

Several of the previous studies focused on filling gaps in literature when comes to technology adoption in domain-specific fields (Baraka & Murimi, 2018; Donne & Fortin, 2020; Gulatee et al. 2020; Lindsay et al. 2011; 2014; Prasanna & Huggins, 2016; Sintov et al. 2019; Weidunger et al. 2021). All the previous studies were focused on exploring or examining technology adoption in specific domains due to the unique challenges and characteristics of the various domains. For example, Weidunger et al. (2021) state that *“Existing theories explain the acceptance of information technologies only on a general level that does not consider the specific usage constraints existing in the firefighter domain.”*

Evidence from the literature on the theoretical gaps seems to point out a distinction between research context and the unique domain-specific fields in which their research was conducted. The domain-specific fields of the previously discussed studies were varied and were as follows: Four studies were on the domain of police (criminal law enforcement) which were (Baraka & Murimi, 2018; Donne & Fortin, 2020; Lindsay et al. 2011; 2014). Three studies were on Emergency Response, which were (Gulatee et al. 2020; Prasanna & Huggins, 2016; Weidunger et al. 2021). Only one study on environmental enforcement, which was (Sintov et al. 2019)

The majority of the research reviewed objectives were to examine technology adoption or certain constructs or determinants of technology adoption in the field of law enforcement, in which previous studies (although not enough, according to researchers) have been conducted. They were aiming to build on previous knowledge on technology adoption in their chosen law enforcement domain. This explains their methodology choice of their studies in which most are quantitative in nature. Although this seems to be the case few chose qualitative and mixed (two by the same researchers) and justify their choice by stating, “Although related research has adopted a quantitative, statistical approach, it was felt in order to meet the aim of the research more depth was necessary, therefore, a qualitative approach was adopted.” (Lindsay et al. 2011; 2014).

From previous understanding of the literature objectives and methodological choice, this research adopts a qualitative approach since it requires exploration of technology adoption in the barely studied domain of environmental enforcement. This

Environmental Enforcement Technology Adoption

choice of methodology was based on the exploratory nature of the research objectives, in which the research aimed to explore and develop technology adoption of users insights in the field of environmental enforcement. A few of the studies adopted a mixed methodology approach to explore scarcely researched technology adoption in unique fields (domain-specific research).

All the studies applied quantitative methods except for four studies that conducted mixed methodology or qualitative to explore technology adoption, which were by (Baraka & Murimi, 2019; Lindsay et al. 2011; 2014; Weidunger et al. 2021). The four studies all aimed at exploring technology acceptance in specific domains that have special and unique characteristics that influence acceptance in different manners. For example, Weidunger et al. (2021) propose a detailed, domain-specific acceptance model with factors that explain the acceptance of ERIS by firefighters, in which they purport that the domain of fire fighter is different than other domains and is considered a different field of study.

Knowledge from previous studies suggest that the previous models (traditional acceptance models such as TAM and modifications) concentrate on user perceptions only and do not take into account many of the external factors such as organizational, social, and environmental factors. Many of the previous studies try to examine and explore these factors in various technologies, domains, and contexts. Most of the studies conducted on technology adoption in law enforcement have applied the TAM model and the Diffusion of Innovation Theory, however, various scholars indicated an inadequacy of explanation of the traditional theory of the variances in adoption and especially when it comes to mandatory settings of technology adoption. Traditional model limitations were shown by previous studies and emphasize the need for these models to address additional factors, such as social and external factors.

While most of the reviewed studies are related to technology adoption in their fields, some of the studies deal with the influence of the technologies on the users or organizations rather than adoption of these technologies (Kim et al. 2020). Although these studies may seem irrelevant to the focus and purpose of this research, they provide added knowledge and understanding of some of the internal and external

factors that may have been overlooked in studies that concentrated on technology adoption exclusively.

Previous studies of technology adoption in law enforcement have researched and examined various factors that influence technology adoption but have not extensively examined the issue of mandatory setting technology adoption and use of the technologies. Most of the technologies in enforcement systems are mandatory, especially when it comes to the enforcers' use, although some of the studies deal with variation in the voluntariness of use of these technologies. Regarding the studies that examine mandatory setting technology adoption which are in various fields and domain, but not in law enforcement, discrepancies were found between some of the factors and constructs particularly in the Technology Acceptance Models. They suggest a weak explanatory power of the TAM in mandatory settings.

The main research gaps identified from the literature analysis were as follows:

1. Previous literature is widely available on the influence of technology and law enforcers' experience on law enforcement strategies and performance, however few have researched technology adoption factors and determinants of the field of environmental enforcement, especially from the perspective of the enforcement personnel when it comes to technology adoption among environmental enforcers.
2. Most of the studies conducted on technology adoption in law enforcement have applied the TAM model and the Diffusion of Innovation Theory, however various scholars indicated an inadequacy of explanation of the traditional theory of the variances in adoption especially when it comes to the adoption of technology in mandatory settings. Traditional model limitations were revealed by previous studies and emphasize the need for these models for additional factors such as social and external factors.
3. Previous studies of technology adoption in law enforcement have researched and examined various factors that influence technology adoption but have not

extensively examined the issue of mandatory setting technology adoption and use on the adoption and use of the technologies.

2.6.4 Research Questions

The above discussion shows that there is an increased need for further study to better understand users and identify the main characteristics that motivate users to embrace and employ environmental enforcement technologies, and that this information is notably lacking in the Kingdom of Bahrain. The author is interested in doing research to investigate the important elements that influence users' acceptance and usage of technology in environmental enforcement, with a focus on the Kingdom of Bahrain. To address the research gaps, the following research questions have been identified:

RQ 1: What is the nature of technology use in environmental compliance and enforcement in the Kingdom of Bahrain?

RQ 2: What factors influence technology adoption by users involved in environmental compliance and enforcement in the Kingdom of Bahrain?

RQ 3: How does a mandatory setting influence technology adoption by users involved in environmental compliance and enforcement in the Kingdom of Bahrain?

The below Figure 2.18 provides a summarized illustration of the research gaps, objectives and questions.

Environmental Enforcement Technology Adoption

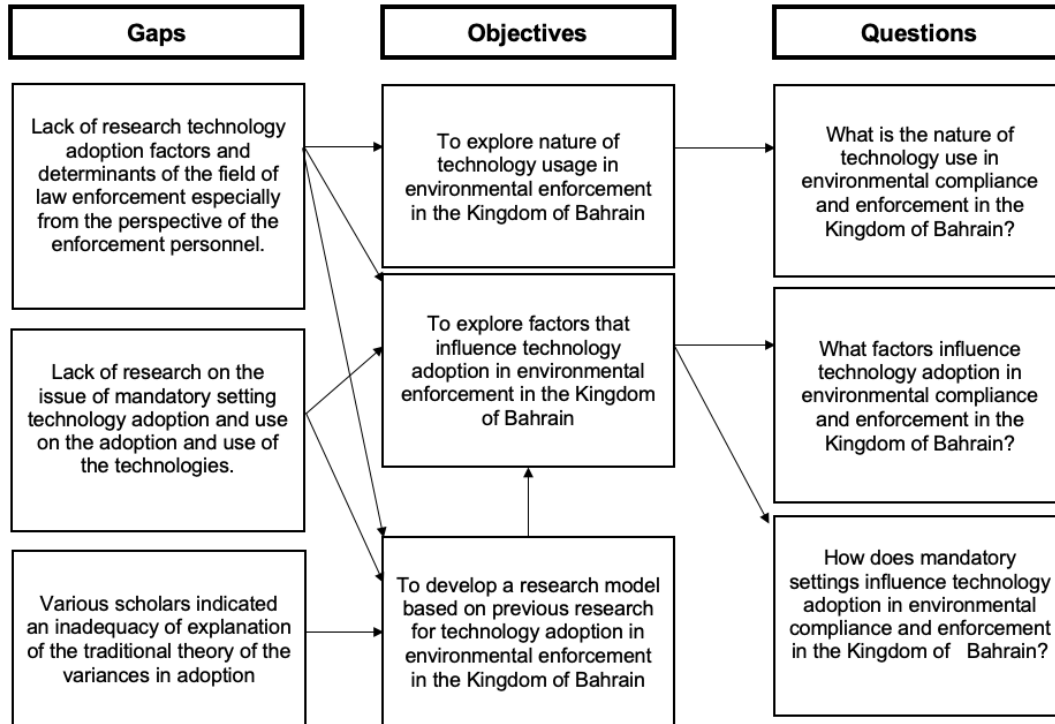


Figure 2. 18 Illustrated summary of the Gaps, Objectives and Questions of the research

Chapter 3 Research Context

This chapter will discuss the research context of this research. The structure of the chapter is as follows: 3.1 is an overview of the Kingdom of Bahrain's geography and environmental Issues. 3.2 will summarize some of the most prominent environmental initiatives in the Kingdom of Bahrain. 3.3 will describe the institutional governance of environmental protection in Bahrain. 3.4 will describe some of the technological applications implemented in the Bahrain Coast Guard. 3.5 will describe some of the most relevant technological applications in the Kingdom of Bahrain from various fields of law enforcement. 3.6 will be a summary of the chapter.

3.1 Kingdom of Bahrain's Geography and Environmental Issues

This section provides a brief overview of some of the Kingdom of Bahrain's geography and some of the environmental challenges it faces.

The Kingdom of Bahrain is an archipelago consisting of more than 84 natural and man-made islands. The kingdom has 33 natural islands and 36 small islands which are part the Hawar Islands. The Kingdom is located in the middle of the southern coast of the Arabian Gulf. Bahrain's land mass covers a total area of 769.6 km² with a total marine area (90.6%) of 7497.1 km² falling under the jurisdiction of the Kingdom (E-government authority, 2020). Its climate is arid and humid and is characterized by high temperature and low rainfall. The average summer and winter temperatures recorded during the period of 2009-2013 are 35.14°C and 18.82°C respectively. The annual rainfall noted during this period ranged between 20.2 to 98.9 mm (E-government authority, 2020).

The archipelago is located in the Gulf of Bahrain, a small strait on the Arabian Gulf's central southern shore. Bahrain's open shallow seas are characterized by difficult oceanographic conditions imposed by extremes in temperature and salinity (Ertemeijer et al. 2004; Zainal, 2009). Despite these natural stressors, the seabed is home to a rich and productive array of coastal and marine ecosystems, including mudflats, saltmarshes, mangrove swamps, coral reefs, algal beds, and seagrass meadows (Al-Zayani, 2009). Bahrain's marine environment supports an emerging

artisanal fishing fleet that landed 12215 metric tons in 2015. (General Directorate of Statistics, 2017). This fleet primarily supports finfish and crab fisheries, providing a vital source of protein to a total population of 1.4 million people (2016 census; General Directorate of Statistics, 2017). Despite ongoing economic diversification initiatives, the oil and gas sectors continue to play a major role in Bahrain's economy, with crude oil output reaching 17.76 million US barrels in 2016 (General Directorate of Statistics, 2017). The marine ecosystem is under threat from a variety of human-caused activities, including land reclamation, dredging, sewage and industrial discharges, overfishing, and oil exploration and exploitation. These activities have led to the deterioration of marine habitats especially sea grass, coral reefs and mangroves, and the reduction in fisheries and biodiversity (Khamis, 2010; K. Zainal et al. 2012).

Some of the top factors that affect the air quality in the Kingdom are energy production and conversion processes and the emissions of the petroleum and industrial sectors. Other issues harming the air quality are transportation, factories and the overlapping between industrial areas and some residential areas (General Directorate of Statistics, 2017).

Bahrain is facing an increasing shortage of natural freshwater as well as deterioration of the available water quality. The greatest challenges lie in the water demand for the agriculture sector and the accelerating demand on drinking water due to rapid urbanization, the expansion of tourism and industry sectors, and high consumption behaviors. This resulted in the decline of underground water levels and reduction in water quality mainly through salinization of these sources. This has led to the increase in production and distribution of desalinated drinking water and treatment, which resulted in an increase in wastewater and energy consumption (Erftemeijer et al. 2004).

Rapid urbanization causes rising demand for lands for housing and investment. This had led to a decline in cultivated areas and natural ecosystems. Many habitats and ecosystems have been lost and biodiversity has been decaying because of habitat loss and human disturbance.

Relevance to this study: The preceding section reveals that the Kingdom of Bahrain is under extreme environmental pressure from both natural (such as temperature extremes) and human (such as growing urbanization and overfishing). Even more so in the marine environment, which is enormous in compared to terrestrial land. The marine environment is critical to the Kingdom's economy and wellbeing, hence additional resources and effort are required to implement environmental regulations. Because of the need for methods to achieve effective environmental enforcement in the marine environment despite limited resources, this research looked into technological adoption as one answer. One of the reasons this context was chosen is the magnitude and importance of the maritime ecosystem, which necessitates technological solutions. The Kingdom of Bahrain is highly invested in technological solution and advancements to achieve its goals of sustainability and environmental protection.

3.2 Environmental Initiatives in the Kingdom of Bahrain

This section provides a brief overview of some of the Kingdom of Bahrain's main environmental initiatives to key environmental issues.

The Kingdom of Bahrain has various initiatives to ensure sustainability of the development process in multiple areas, which is echoed in the Constitution of the Kingdom, and to ensure the protection of the environment and to achieve a balance in the requirements of development, social and economic aspects, as well as in the vision and strategy of Bahrain Economic Vision 2030 and the National Strategic Master Plan 2030. Bahrain has established several institutions, agencies, and commissions involved in achieving sustainability in various dimensions through programs, policies, and strategies. Another initiative is the enactment of laws related to sustainable development applications that have become a requirement in economic, social, and political transitions to the international community. Furthermore, it has followed many multi-lateral conventions and compliance with its requirements - ensuring public awareness and national capacity-building in relevant areas.

The following section lists and describes several of the Kingdom's initiatives in the field environmental protection.

Energy:

Multiple government agencies have shown a growing interest in energy efficiency by implementing a range of policies, such as green policy, minimizing the use of products, facilities, chemicals that adversely affect the environment, and make efficient use of resources. The government has also developed a committee specializing in research into alternative energy-safe environments and promoting the adoption of these sources by government agencies, companies, residents, and people (E-government authority, 2020).

The Sustainable Energy Unit (SEU) was formed in November 2014 through a collaboration between the Ministry of Electricity and Water Affairs and the United Nations Development Program (UNDP). The Sustainable Energy Unit primary aims are to build a coherent and sustainable energy strategy in Bahrain and to promote renewable energy and energy efficiency. Additionally, the Unit seeks to solve legal, institutional, and capacity gaps in order to guarantee that Bahrain's energy industry is prepared to handle future challenges. The Sustainable Energy Unit is tasked with leading and promoting energy efficiency practices, transferring, and disseminating renewable energy technology, and developing relevant policies and regulatory frameworks in close collaboration with stakeholders and partners throughout the Kingdom of Bahrain.

Water:

In order to conserve water, the country thought it was appropriate to set up a council responsible for the protection, growth, and management of water resources, along with other administrative and regulatory procedures; thus, the Water Resources Council was set up, along with other main support initiatives. The water supply network is being upgraded and cutting-edge technology is being installed with the goal of reducing excess waste due to leakage, and a tariff system is being implemented to manage residential consumption (E-government authority, 2020).

Another initiative is treatment and reuse as water supply. The majority of the Kingdom of Bahrain's entire residential and industrial sectors are linked to the sewage network, which serves the majority of the population. Bahrain has 12 sewage

Environmental Enforcement Technology Adoption

treatment plants. The main facility is the Tubli sewage treatment plant, which recycles cleaned water for a variety of purposes, including agriculture and industrial operations.

Air Quality:

In order to conserve water, the country thought it was appropriate to set up a council responsible for the protection, growth, and management of water resources, along with other administrative and regulatory procedures; thus, the Water Resources Council was set up, along with other main support initiatives. Environmental Impact Assessments are also required for new construction projects in order to mitigate any adverse environmental consequences, with an existing mitigation strategy in place for those that are already in place. As a result, the SCE is now coordinating the development of an Air Quality Strategy in order to address current issues and improve pollution management at the source.

The Kingdom of Bahrain has taken a number of initiatives to contribute to global efforts, including adopting the United Nations Framework Convention on Climate Change, adoption of clean transportation projects, Promulgating Ministerial Decree (70) of 2015 on energy efficiency card for air conditioners, and development of a unique Green Building Code (General Directorate of Statistics, 2017).

Biodiversity:

In order to protect marine life and biodiversity of Bahrain, the nation has dedicated six areas to the creation of natural reserves, including five Marine Protected Areas: the Hawar Islands, the Gulf of Tubli, Dohat Arad, Mashtan Island, and Herr Bulthamah, and the Al-Areen Biodiversity Sanctuary (Naser, 2016). Bahrain is home to the world's biggest population of dugongs and is also home to the world's largest breeding colony of Socotra Cormorants. Additionally, it is home to two Ramsar-protected wetlands, one UNESCO natural world heritage site, and a handful of marine protected areas.

The Kingdom's government launched a two-year initiative in 2013 in conjunction with every major sector of Bahraini society with the goal of documenting and conserving the country's biodiversity for the first time in the country's history (General Directorate of Statistics, 2017).

Environmental Enforcement Technology Adoption

Bahrain's first implementable National Biodiversity Strategy and Action Plan - was established to boost livelihoods, safeguard the country's ecology, and assure food security in a country with less than 3% arable land. The approach aims to restore marine resources and fish stocks to safe and sustainable levels while also safeguarding agricultural areas from urbanization, which has become a rising issue in the quickly developing nation (General Directorate of Statistics, 2017).

UN Environment collaborated closely with the Bahraini government in 2016 to ensure that their National Biodiversity Strategy and Action Plan are aligned with the Sustainable Development Goals and other biodiversity-related conventions, including those on desertification and climate change, wetlands, and the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Land Use, Desertification and Coastal areas:

The Kingdom, through the Ministry of Municipalities Affairs and Urban Planning, and in cooperation with other ministries and institutions, is working on preparing detailed drawings for strategic structural plan for the Kingdom of Bahrain in 2030; based on several development requirements without compromising the environment and preserving its resources and development. For the purpose of allocating land for industries, housing development, oil and gas extraction and refining, cultural and recreational activities, agriculture, utility and telecommunications services, transportation hubs, road system development, and quarrying operations, a clearly defined management strategy has been developed (General Directorate of Statistics, 2017).

Among the many efforts to protect the coastal areas, the country has emphasized that during planning a project, and considering the projects' environmental effects; necessary studies to protect coastal areas are prepared prior to the approval of the proficient authorities. The country has also adopted the concept of integrated management of the coastal and marine environment in urban planning for strategic structural plan for Bahrain in 2030.

Chemical Substances and waste :

Many resolutions have been announced to address and control the chemical substances used in the country, such as placing control of substances that deplete the ozone layer, restriction and control on equipment and buildings containing asbestos, control on the import and use of banned and severely restricted chemicals, management of dangerous chemical materials, and the adoption of the Strategic Approach to International Chemicals Management (SAICM) (General Directorate of Statistics, 2017).

As part of the country's environment protection plan to control waste, the kingdom has adopted a national contingency plan for combating oil spills, the management of hazardous waste and healthcare waste, as well as adopting projects that address the need to recycle electronics.

The Waste Management Department of the Supreme Council for the Environment is responsible for managing waste generated by industry and hazardous waste generated by other sectors, as well as for disposing of waste in an environmentally safe manner, in accordance with domestic legislation and international agreements, and in accordance with the Kingdom of Bahrain's international commitments regarding environmental protection (SCE, Bahrain).

These efforts culminated in the Supreme Council for the Environment receiving the International Green Apple Award from the Green Organization in the United Kingdom in 2005. The prestigious award was presented to Bahrain's Public Commission for the Protection of Marine Resources, the Environment, and Wildlife in recognition of its initiative to establish the Haffira site for the disposal of industrial waste, as well as its initiative to provide a safe disposal space for hazardous waste.

Relevance to this study: The preceding section demonstrates significant environmental commitment and action. This is evident from the Kingdom of Bahrain's considerable initiative to improve environmental protection, including environmental compliance and enforcement. Numerous activities necessitate the implementation of technological solutions and applications, demonstrating a rising interest in adopting technological solutions for environmental protection and achieving sustainability objectives. This research explores the usage and adoption of technology in

environmental enforcement, which necessitates a research environment in which technology is widely adopted and implemented.

3.3 Institutional Governance of Environmental Protection in Bahrain

This section provides a brief overview of the institutional governance of environmental protection in the Kingdom of Bahrain, and some of the related bodies involved in this process.

The first governmental authority concerned with the protection of the environment in Bahrain was established by decree No. 7 of 1980, under the Ministry of Health, is the Environmental Protection Committee (EPC), later developing into The Environmental Affairs by the Legislative Decree No. 21 of 1996. The Environmental Affairs was reorganized under the Ministry of State for Municipalities Affairs and Environmental Affairs. Another governmental entity created for wildlife protection by the Legislative Decree No. 2 of 1995 called the National Committee for Wildlife Protection, which was further upgraded to the National Commission for Wildlife Protection. In an effort to integrate efforts and resources of the previous established organizations, they were merged to become the Public Commission for the Protection of Marine Resources, Environment and Wildlife (PCPMREW) in 2002 by the Legislative Decree No. 50 of 2002 and reorganized further by Legislative Decrees No. 10 and No. 43 of 2005. In 2012, the Legislative Decree No. 47 of 2012 established the Supreme Council for Environment (SCE). The Legislative Decree gives the SCE increased integration into all governmental and private sectors in the Kingdom and indicates that decisions of the Council are binding to all ministries, authorities, and institutions in the Kingdom (Naser, 2016).

Bahrain environmental compliance and enforcement systems are a multi-stakeholder systems, in which the SCE is the central authority responsible for legislation and implementation, as well as overseeing the actual compliance and enforcement process. Various government ministries and institutes have essential roles in the monitoring and implementation process of environmental compliance and enforcement in the Kingdom of Bahrain. Some of these are the Ministry of Interior, Ministry of Works, Municipalities, and Urban Planning, Ministry of Industry , Trade and

Tourism, and the Governates (Capital, Muharraq, Northern, and Southern). Other entities have been helpful in the monitoring and enforcement process such as the local NGO's.

One of The Ministry of Interior's directorates which is a major enforcer of environmental laws and regulations, including fisheries regulation is the Bahrain Coast Guard (BCG headquarters, 2020). This is especially the case, when it comes to the laws and regulations regarding the marine environment. Their relative higher technical and manpower capabilities are major factors affecting their enforcement capabilities in the marine environment. Their major role is the protection of territorial waters, including supporting environmental protection. The BCG has adopted technological solutions and support systems to help manage the territories under their jurisdiction, which is much greater geographically than terrestrial Bahrain. The next section will give more details on the technological approach adopted by the BCG.

Relevance to this study: the preceding section describes the institutional governance of environmental protection in the Kingdom. This illustrates the diverse nature of environmental protection and enforcement in the kingdom. This includes a statement that the BCG is the most well-equipped and resourced entity in these marine systems. This provides a population of experts in technological applications and environmental enforcement who will serve as the primary source of data for this study. Although not their primary mission, they are responsible for enforcing the majority of the laws and regulations of the Kingdom in the marine domain, including environmental laws. As this research requires an exploration of technology adoption in marine law enforcement, the BCG was selected as the primary source of data. While the other entities were selected as secondary data sources. In addition to the previous section's emphasis on the uniqueness of environmental enforcement systems, this study examined technology adoption as a unique and distinct field of law enforcement.

3.4 Bahrain Coast Guard Technological Application in Enforcement

This section will provide a brief overview of the current technological applications and their role in environmental compliance and enforcement in the Bahrain Coast Guard. As well as the short-term implementation processes. The source of all data for this section is the BCG headquarters (2020).

Environmental Enforcement Technology Adoption

The Bahrain Coast Guard have implemented several technologies and information systems to help enhance administrative and operational procedures and practices, including environmental law enforcement. They have an integrated system of sensors and data management and analysis tools to help deliver accurate, fast, and relevant data and analysis. They have a complex array of radars, cameras (short and long range and heat sensors) and tracking devices (AIS) which are mandatory by laws to be fixed on all vessels in the kingdom, from small fishing boats to commercial vessels. The latter sensors are connected and integrated by various systems and are fed to analectic systems such as the GSS to give further information to be used for planning and decision making. The application of these technologies in the coast guard have ranged from reporting of crime or violation to resource allocation and budgeting.

The Bahrain Coast Guard identifies the targets in territorial waters through the electronic geo-fence system, which was launched in 2011. The electronic geo-fence system consists of a coastal surveillance radar system, electro-optical camera systems, and an automatic identification system (AIS) for merchant ships, via which all ships whose tonnage exceeds 150 tons are bound by the laws of the International Maritime Organization (IMO). Targets are monitored through this system at the Maritime Operations Center under the command of the Coast Guard and its bases.

Also, the Coast Guard Command, out of its concern for the safety and souls of seagoers, is in the process of completing the electronic geo-fence system by installing automatic identification devices for small ships that sends an information package that includes the ship's location, information about the owner and contact numbers, and the devices themselves are equipped with a button to send a distress call in the absence of means of communication or in the event of an emergency occurrence at sea.

The electronic geo-fence system project was implemented as part of a strategic plan drawn up by the Coast Guard Commander in 2007, in order to promote the overall level of Coast Guard leadership in all its departments and divisions. The electronic geo-fence system project and the development of the radar system were among the most important projects that had to be decided upon because that is where the old system did not provide the required coastal coverage, did not have visual monitoring

Environmental Enforcement Technology Adoption

tools, and no operations center was equipped to accommodate the responsibilities of the Bahrain Coast Guard. Consequently, the Coast Guard command prepared a comprehensive study to assess the situation and put forward proposals to develop the radar system in order to achieve the electronic geo-fence system project, and this is what was achieved in 2011.

The security fence consists of a system of coastal surveillance radars, electro-optical camera systems, and an automatic identification system for commercial ships that are bound by it. All ships whose tonnage exceeds 150 tons according to the laws of the International Maritime Organization (IMO) are equipped with devices and electronic display and monitoring supplies that are monitored by a special maritime operations center under the leadership of the Coast Guard.

The electronic geo-fence system project was not completed at this time, as the system needed a monitoring system to be installed on all local ships registered with the Coast Guard command in order to impose maritime control over the Kingdom's territorial waters, which would contribute mainly to preserving the safety of lives and protecting the coasts of the Kingdom. The main reason for the failure to complete the system is that this is the lack of a technology commensurate with the technical requirements that have been prepared under the leadership of the Coast Guard, as the leadership has been studying how to complete this system by sending officers to various leading countries in the field of maritime navigation in order to benefit from their expertise and knowledge on the technology used in it.

The study period extended over a period of 3 years. In 2014, one of the leading companies in the field of monitoring navigational movement submitted a request to display its equipment to the Coast Guard leadership, so a special team was assigned to follow up the progress of the experiments work and make periodic reports and submit them to the officials in which they show the feasibility of the new system and the possibility of matching it with the electronic geo-fence system.

The trial period extended to 2015, when the radar system team led by the Coast Guard submitted the final reports on the progress of the experiments, with the recommendation to contract with the company to fulfill all the technical requirements

Environmental Enforcement Technology Adoption

and the effectiveness of the device during the period in which it was tested on coastguard boats for a period of more than 10 months. On August 19th 2015, a contract was signed with the company to install the devices on the boats registered with the Coast Guard Command and match them with the electronic geo-fence system.

The Coast Guard leadership has established a special team for the electronic geo-fence system project to oversee its maintenance and hold training courses. The team also conducts quality studies and research that keep pace with the steady technological development in the field of electronic monitoring and coastal monitoring and generates daily reports on the workflow in general. They also visit the radar towers to find out the extent of their readiness, as well as inspect the electro-optical cameras and maintain communication with the relevant companies for the operations of repairing, sending, and receiving devices. The BCG surveillance team conduct regular and continuous assessment of the technology systems effectiveness and future needs and requirement. This includes adopting specialized training and assimilation programs.

Also, due to the Coast Guard leadership's keenness to adhere to international standards and raise the level of competence, the technical team was trained to climb towers and obtain internationally recognized licenses that would allow them to climb communication towers to carry out installation and maintenance operations, as well as obtaining climbing licenses, authorizing the leadership to carry out training courses for climbing.

The electronic geo-fence system is considered a dynamic system that can be developed, changed, and added at any time whenever the situation needs to develop or enhance the ability of electronic monitoring, and this makes it not adhering to specific time conditions that must be replaced then the infrastructure that has been established to accommodate the electronic security fence system has been pre-prepared for future needs.

The electronic geo-fence system project team maintains all documents related to the system, whether technical, administrative, or legal, in archive files and organized in a specific order that makes it easy to extract any of them when needed. A parallel

Environmental Enforcement Technology Adoption

electronic archive has also been created that preserves everything related to the electronic geo-fence system from the first day of its implementation as a study into what it is now a reality, and specific employees have been allocated to maintain and protect these documents and to submit monthly reports on the contents and on what is added.

The initiative is unique in that every boat is fitted with a government issued identification transceiver coupled with a monitoring system that is specifically designed to deliver multiple benefits to all maritime stakeholders. The system fuses multiple sophisticated sensor systems such as radar, CCTV and AIS and uses state of the art data analytics to create a high resolution, high integrity data sets on the marine domain. Typically, maritime monitoring systems rely solely on radar which has limited range and does not identify vessels, and where identification transceivers are deployed, they are deployed on selected boats. Additionally, monitoring systems are normally focused on single specific applications such as search rescue, or security or environment monitoring.

The approach was to install specialist AIS Identification transceivers on every boat, each having integrated backup battery and anti-tamper functionality so that they are permanently installed. The monitoring system incorporates a range of functionality covering safety, security, and environment monitoring – with the use of new technologies such as Dynamic-3D visualization to enhance operator situational awareness. This ensures one national maritime monitoring system – a multiple stakeholders' approach.

The main benefit of this technology in the context of environmental compliance and enforcement is ensuring sustainable fishing activity and preventing illegal and unregulated fishing – both commercial and leisure. All fishing boats are accurately tracked and licensed. The system allows continuous monitoring of fishing activity, which in turn prevents illegal and unregulated fishing and, more positively, allows a co-operative approach to fishing activity considering fish stocks, movements, and environmental conditions. This ensures that the sensitive marine environment is protected through monitoring of vessel movement and activity, as well as providing evidence in cases of violations.

Relevance to this study : The preceding section indicates that the BCG is heavily invested in technological applications and has a well-established process for technological adoption. There are a wide variety of technological applications, the majority of which are integrated into a single system used by the majority of personnel involved in environmental enforcement. This research will explore the technology adoption of the adopted integrated system for the purpose of environmental enforcement. Data will be gathered on a relatively new technology that has been adopted and is currently being implemented. This provides a prime context for the study of technology adoption, given that this technology is also used or supportive of the enforcement processes of other entities. This section also illustrates the mandatory nature of the marine environment technology used by enforcers and the public sector. This research will also explore the effect of mandatory settings on environmental enforcement technology adoption.

3.5 Technology Applications in Enforcement in the Kingdom of Bahrain

This section provides other technology being implemented for enforcement of other fields than environmental protection which are relevant to the research in the Kingdom of Bahrain.

The Kingdom of Bahrain is increasingly applying IoT other technological innovations in governmental and nongovernmental fields to increase the efficiency and accuracy of services available for the public and government, including law and regulation enforcement. The ministry of interior has adopted a specialized version of the GIS called the GSS or Geographic Security system which is a comprehensive solution for public safety and law enforcement modified from advanced GIS technology providing location-awareness to national security (esrinea.com). The ministry of interior adopted this innovation to enhance public security enforcement, data sharing and circulation between departments, and response planning and management (MOI, Bahrain).

Environmental Enforcement Technology Adoption

The GSS is implemented in various departments and purposes. The main being emergency response, traffic management, mission planning, crime analysis, coastal surveillance, and task force management. The main benefits of these systems were ensuring efficient and effective resource management, enhanced response time and analysis capabilities, unified common operational picture (COP) for managers, integration between GIS software and other detection technologies such as cameras and radars, presorted procedures for incident handling, enhanced communication with mobile units, enhanced data sharing, integration with various government databases, real-time view of the current situation, enhanced management of day-to-day operations, critical infrastructure information, and location management (MOI, Bahrain).

Another e-government application, e-Traffic, is supplied by the General Directorate of Traffic and is available in Multiple languages. The application's goal is to make it possible for users to conduct transactions in an efficient and easy manner. One of the parts of the app that is a clear method of direct enforcement is the use of speed and traffic signal cameras, which is one of the program's primary features. The cameras are linked directly to the directorate, so there is no need for direct human involvement with the cameras. As soon as a violation of speed or traffic light is detected, a notification is sent to the violator with the specifics of the infraction, which may then be resolved in most situations inside the app's interface (payment). Consequently, there is no longer any requirement for direct human engagement in the processes of monitoring, reporting, and enforcement. Instead of using the usual technique, which requires time and human work, the data is provided immediately to the violation by email. When used in conjunction with IoT, this feature demonstrates how sensors linked through the Internet of Things may be a cost-effective approach to tackle monitoring and successfully punish infractions, shifting the focus of interactions from human-human to machine-machine interactions.

One suggested innovation that is presently being evaluated is crowdsourcing violation reporting, which aims to include the public in traffic enforcement by allowing them to report traffic offenses directly through the app. The proposed feature aims to provide a platform for reporting traffic offenses by utilizing smartphone cameras and GPS capabilities to identify and report them. The functionality is presently being

Environmental Enforcement Technology Adoption

evaluated owing to a number of obstacles, including funding constraints, privacy concerns, safety concerns, and legal concerns.

Another project involving artificial intelligence is being considered for use in law enforcement in the monarchy. Consider the current appraisal of face recognition technology' usefulness and usability in crime investigation and the capture of sought criminals or suspects, for example. Facial recognition innovations are used in conjunction with advanced cameras strategically positioned throughout the system to scan crowds and persons in order to detect, recognize, and identify suspects and offenders. Additionally, the technology features license plate recognition. As a result of a variety of challenges, including technological and privacy concerns, the project is currently in the review and planning stages.

One of the recent innovations is an e-government application called TAWASUL which is available for the public. The application is a mobile version of the National Suggestion and Complaint system which enables the public to submit their complaints, suggestions, and violations to any governmental entity at any time or place. The application uses the features available in the mobile devices such as camera and GPS to add value to the service. Users can submit complaint or suggestion and get feedback and are able to track the submissions progress. The potential for the application is for it to be utilized for monitoring and enforcement, especially in reporting violations. The current ways in which it is helping with enforcement and monitoring is clear in the options that are available for the users, which range from road maintenance to waste dumping violations.

The platform has given a transparent means of increasing collaborative approaches in efficient and effective reporting and detection of violations and effective ways of tracking the progress and evaluation of the outcomes. The app has the potential to increase monitoring and detection without the need to increase labor and cost of monitoring and inspection processes of the institute related to the complaint. It also increases transparency and emphasizes the role of the public. The tracking of the progression of the input, being complaint or suggestion, increases the assurance of action and is an effective way of evaluation and improvement of procedures.

Environmental Enforcement Technology Adoption

The general public has also discovered ways to participate in the environmental monitoring and enforcement procedures, which is a positive development. This is mostly accomplished through the use of social media platforms. In order to raise awareness and make the issue into a public opinion issue, the public must draw attention to the cause or violation through particular influencers or hashtags. When this happens, the authorities are typically intrigued and will take positive action.

One such situation occurred in the beginning of 2019. An endangered species of fish (sawfish) was caught and posted on social media by the violator. The image went nationally viral and when the image reached the fisheries who are responsible for the enforcement of illegal fishing investigated and caught the culprit. The culprit was fined and had other administrative actions taken against him. Despite the fact that this technique does not utilize official channels, many public concerns are reported and handled via the use of unofficial sites. The responsible entities are eager to take use of this transparent and real-time source of data, and the general public is more involved in the compliance and enforcement process as a result of the use of this type of data collection.

One of the latest applications of technology in the Kingdom of Bahrain has been an application to help combat and trace the spread of the COVID-19 pandemic in 2020 in the kingdom. The application called Be Aware tracks the location of the users at all times, which has helped contact tracing of active cases by giving precious tracking information on locations visited by an active case, and their contacts can be identified and tested. The app helps save time and resources during contact tracing. The app helps people be aware of their surrounding and gives alerts of active cases and gives transparent and real-time data to users. One of the features which is related to our research is the enforcement of home quarantine for recent travelers and suspected cases. The app, in combination with a real time tracking bracelet, provides real time location data on the people confined to home quarantine and alerts the authorities in case of any violations.

3.6 Summary

The maritime territory of Bahrain accounts for almost 90% of the country's total land area and is vital in terms of resources, particularly fisheries. These resources are under growing strain from both marine and terrestrial sources, including household and industrial operations that have had a significant impact on the marine environment, especially in coastal areas. Water desalination facilities, wastewater treatment plants, reclamation and dredging activities, pollution from dumping residues and wastes from diverse sources, and overfishing are all contributing to these pressures.

To ensure the long-term viability of development in a variety of areas, including environmental protection and attaining a balance between development, social, and economic considerations, the Kingdom of Bahrain has undertaken a number of initiatives, which have been echoed in the Kingdom's Constitution, and in the vision and strategy of Bahrain Economic Vision 2030 as well as in the National Strategic Master Plan 2030. By implementing programs, policies, and strategies, Bahrain has built a number of organizations, agencies, and commissions that are dedicated to attaining sustainability in a variety of dimensions throughout the country. One more endeavor is the introduction of legislation relating to sustainable development applications, which has become a requirement in countries making the transition from their national economies, social structures, and political systems to the international community. Apart from that, it has adhered to a large number of multilateral conventions and met all of their obligations, including raising public awareness and strengthening national capability in a variety of fields.

The Kingdom of Bahrain has a number of programs in place to address the growing environmental and health concerns. The commissioning of environmental compliance and enforcement systems is one of these activities. These are multi-stakeholder systems in which the SCE serves as the central authority for legislation, implementation, and oversight of the actual compliance and enforcement process. Various government agencies and institutions play critical roles in the Kingdom of Bahrain's environmental compliance and enforcement monitoring and implementation process (Naser, 2016). The Ministry of the Interior, the Ministry of Works,

Environmental Enforcement Technology Adoption

Municipalities, and Urban Planning, the Ministry of Industry, Trade, and Tourism, and the Governates.

The Bahrain Coast Guard is one of the Ministry of Interior's directorates that is responsible for enforcing environmental laws and regulations, including fisheries restrictions. This is particularly true when it comes to legislation and regulations pertaining to the maritime environment. Their relative superior technological and human skills have a significant impact on their marine enforcement capabilities. The main responsibility is to safeguard territorial water, as well as to help environmental conservation. The BCG has invested substantially in and embraced technical solutions and support systems to assist in the management of the regions under their control, which account for 90.6 percent of the entire area (E-government authority, 2020).

Bahrain's environmental system is multistakeholder in nature. Where the SCE serves as the central authority responsible for environmental protection and participates in legislative and regulatory efforts. Additionally, it is responsible for collaborating and coordinating with associated agencies responsible for environmental compliance and enforcement. This includes the BCG in the marine environment.

Environmental compliance and enforcement are made easier with this technology since it assures sustainable fishing activity while also discouraging illegal and uncontrolled fishing - both commercially and recreationally. All fishing vessels are tracked and licensed in real time with pinpoint accuracy. The system allows for continuous monitoring of fishing activity, as well as the prevention of illegal and uncontrolled fishing. More importantly, the system allows for a cooperative approach to fishing activity that takes into consideration fish populations, migration patterns, and environmental factors. By monitoring vessel movement and operations and providing evidence in the case of a violation, this helps to safeguard the delicate marine ecology that exists.

Chapter 4 Methodology

The purpose of chapter 4 is to introduce the research methods used for this qualitative study regarding technology use and adoption in the field of environmental enforcement in the Kingdom of Bahrain. This approach allowed an in-depth, real-world, and holistic understanding of the technology use and adoption in environmental enforcement in the marine environment in the Kingdom of Bahrain.

The study chose the domain of marine environmental compliance and enforcement since it represents the domain with the largest area of environmental enforcement compared to the terrestrial area and has the most technological usage in the field of environmental enforcement. The marine domain constitutes nearly 90% of the total area of the Kingdom as is essential and heavily used across various sectors. The BCG was chosen as the major source of data since it is one of the main implementers of environmental enforcement and is heavily invested in technological solutions. The study was conducted on various relevant stakeholders involved in environmental enforcement in the marine domain from the beginning of 2020 to mid 2021. Three data sources were used to ensure triangulation. The data sources were interviews (primary data source), onsite observations, and documents. The interviews were conducted online on relevant stakeholders involved in marine environmental compliance and enforcement using technology in the Kingdom of Bahrain.

The selected participants were from various backgrounds, experience, and roles in the environmental compliance and enforcement process. The primary participants were BCG personnel, and they totaled 12 interviews. Secondary participants are other stakeholders involved in the environment compliance and enforcement process and were 8 in total. The total participants of the interviews were 20 participants (more details presented in chapter 5). The research's qualitative methodology will be further described in this chapter and includes purposeful sampling, semi-structured interviews, and systematic data collection and analysis through the thematic analysis approach. Figure 4.1 illustrates linkage of various parts of the research methodology.

Environmental Enforcement Technology Adoption

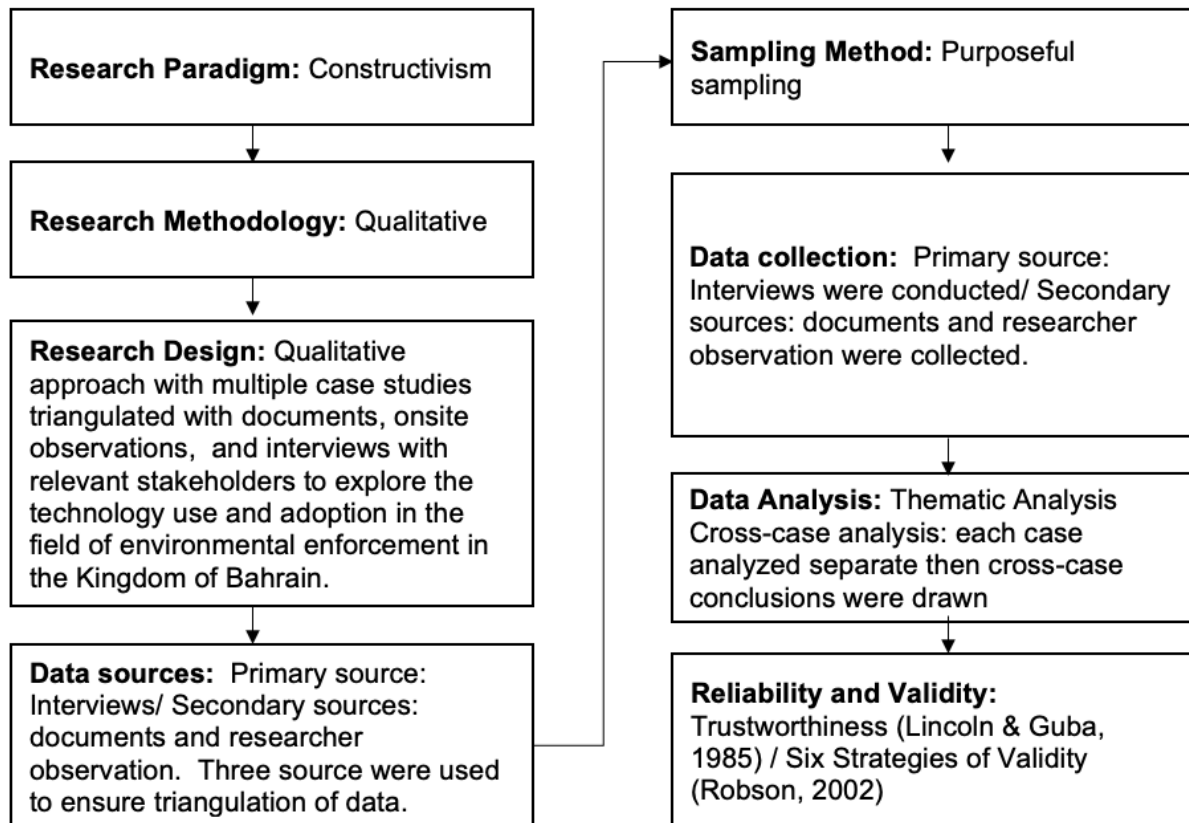


Figure 4. 1 Summary of various parts of research methodology

This chapter will discuss the research methodology used for this research. The structure of the chapter is as follows: 4.1 is an overview of the philosophical worldview of the research. 4.2 will describe the qualitative of the research. 4.3 describes the research design. 4.4 describes the research's participants and sampling. 4.5 is the researcher's role. 4.6 describes the data collection. 4.7 describes the data analysis procedure. 4.8 describes the steps taken by the researcher to achieve trustworthiness of research quality. The following section will describe the previously listed sections in further detail. 4.9 is the chapter's summary.

4.1 Philosophical worldview of the research

Creswell and Creswell (2017) state that "Worldviews as a general philosophical orientation about the world and the nature of research that a researcher brings mentors, and past research experiences. The types of beliefs held by individual researchers based on these factors will often lead to embracing a strong qualitative,

quantitative, or mixed methods approach in their research.” They gave four philosophical worldviews and their major elements summarized in Table 4-1.

Table 4. 1 Four Worldviews and their Elements (Creswell and Creswell, 2017)

Post positivism	Constructivism	Transformative	Pragmatism
Determination	Understanding	Political	Consequences of actions
Reductionism	Multiple participant meanings	Power and justice oriented	Problem-centered
Empirical observation and measurement	Social and historical construction	Collaborative	Pluralistic
Theory verification	Theory generation	Change-oriented	Real-world practice oriented

For this research the philosophical worldview will be constructive worldview. According to Creswell and Creswell (2017), constructivists believe that an individual’s understanding is acquired from the environment or the world they live in. Constructivists pay attention to the subjective nature of meaning-making and argues that intercultural differences and cultural memberships are socially constructed (Silverman, 2015). The understandings of the individuals emerge through discourse and interaction, and the focus of this worldview is on the process of interaction and what the participants achieve out of the experience in terms of new values, identities, and practices (Hua, 2015). This leads to multiple and varied meaning which makes the researcher search for the complexity of views, the researcher relies a lot on the participant’s views of the situation being researched. The question become broad and general for the participants to make meaning of the situation (Creswell and Creswell, 2017; Silverman, 2015). This worldview is more suitable to qualitative methodology and researchers begin by developing and modifying a theory, rather that starting with a theory.

This research focuses on the technology adoption of individuals involved environmental compliance and enforcement in the marine environment in the Kingdom

of Bahrain. The technology adoption process is distinctive. Adoption decisions were not made in a vacuum, but rather in complex real-world settings. To conduct a research study that investigates the factors that influence technology adoption, it is advantageous to employ a constructionist perspective. The discovery of meaning is not a universal fact. Individuals restricted by their own cultural rules develop meaning within complex social settings. Individual understandings and interpretations of reality are profoundly influenced by social interactions. Due to the fact that everyone has their own distinct social surroundings and cultural understandings, the actualized meaning will vary from person to person. Likewise, the judgments chosen based on these truths will be unique to each individual. What are the elements that drive technology adoption in environmental compliance and enforcement? is the fundamental issue of this study. Social interactions, cultural ideas, and the development of individual realities are most likely to be the answer.

Following the above, this research is rooted in the constructivism worldview in that the research will adopt a qualitative case study.

4.2 Qualitative Approach

This research chose a qualitative approach for several reasons. In general, qualitative research methods are especially useful in discovering the meaning that people give to events they experience (Creswell & Creswell, 2017; Silverman, 2015). The purpose of this study is to explore the technology use and adoption of individuals involved in environmental enforcement in the marine environment in the Kingdom of Bahrain. Moreover, qualitative approaches are used when the nature of research questions requires exploration (Stake, 1995). Qualitative research questions often begin with how, why, or what, to enable researcher to acquire an in-depth understanding of the situation in relation to the topic (Patton, 2002; Creswell & Creswell, 2017). This research explored the participants' experiences and perceptions on technology usage and adoption by asking its three main research questions, which are:

RQ 1: What is the nature of technology use in environmental compliance and enforcement in the Kingdom of Bahrain?

RQ 2: What factors influence technology adoption by users involved in environmental compliance and enforcement in the Kingdom of Bahrain?

RQ 3: How does a mandatory setting influence technology adoption by users involved in environmental compliance and enforcement in the Kingdom of Bahrain?

Another rationale is that qualitative approaches allow researchers to explore a phenomena, which can range from feelings to actual processes, that may not be achieved through other more conventional research methods such as the quantitative method (Corbin & Strauss, 2014). This research explored participants' experiences and perceptions on technology usage and technology adoption in environmental compliance and enforcement. Also, qualitative methods are appropriate approaches when studying phenomena in specific contexts and in their natural settings (Creswell & Creswell, 2017). The researcher studied individuals involved in environmental compliance and enforcement in the marine domain in the Kingdom of Bahrain in their natural setting (such as offices and patrols). The researcher's role is another rationale for choosing a qualitative approach. In qualitative methods, the researcher's role as an active participant in the study is emphasized (Creswell & Creswell, 2017). This was the case in this research, as the researcher was a primary instrument of data collection and analysis.

4.3 Research Design

This research adapted a qualitative approach with multiple case studies triangulated with documents, onsite observations, and interviews with various relevant stakeholders to explore the technology usage and technology adoption in the field of marine environmental enforcement in the Kingdom of Bahrain.

The research used this qualitative approach because it provides an in depth understanding, is open ended, and the results of this type of research methodology give insight and understanding of issues, can extend experiences, and increase knowledge to previously acquired knowledge (Dul and Hak, 2008; Hafiz, 2006; Tellis, 1998; Yin, 2018). This qualitative approach allows the researcher to uncover themes

and provide rich descriptions of the topic being studied (Creswell & Creswell, 2017). It also, allows focus on explanation and description of the phenomena rather than prediction and measurement of variables (Marriam and Tisdell, 2015).

This approach was chosen since it allows the researcher to focus on the understanding of the complicated connections between technology and environmental compliance and enforcement as well as connections between entities involved in environmental compliance and enforcement technology use, and technology adoption in context of the Kingdom of Bahrain. Further it allows focus on multiple viewpoints and allows variation in its methods (Dul and Hafiz, 2008; Tellis, 1998).

The overall rationale for choosing this qualitative approach is it allows the researcher to explore the phenomena of technology use and adoption in the field of environmental compliance and enforcement using several data sources (multiple case interviews, documents, and observation) (Yin, 2018). This method allowed the researcher to acquire a rich, holistic, and real-world perspective from the study to receive knowledge and understanding of the phenomena chosen to be studied. Since there were no predetermined sets of outcomes, the researcher adopted an exploratory qualitative study to answer its research questions (Yin, 2018).

Case study selection can vary since they can use single or multiple cases, it can be used for qualitative, mixed, or even be limited to quantitative methods to achieve the researcher's goals (Silverman, 2015; Yin, 2018). The research adopts a multiple-case study approach to achieve its objectives.

The research's rationale for selecting a multiple-case study is directly the result from the understanding of literal (predict similar results) and theoretical (predict contrasting results) replications (Yin, 2013). The research's approach aims to gain literal replications from the multiple cases which were three cases: cases are involved in the process of environmental compliance and enforcement in the marine environment using technology. The choice of a few cases is usually the more appropriate if literal replication is predicted (Yin, 2013), which is what the research predicted in the three cases, especially since all the cases are part of a multi-stakeholder system.

Environmental Enforcement Technology Adoption

Although the BCG is considered a supporting entity and not the central authority in environmental compliance and enforcement. the BCG was chosen as the main case since it is considered one of the major enforcers of environmental law in the marine environment and has the largest resources in terms of manpower, equipment, and technological infrastructure at its disposal. The study of these cases can give a better insight and understanding of the complex connections between the technology and technology adoption issues and provide a holistic, detailed, and in-depth description of the marine environmental compliance and enforcement in the Kingdom of Bahrain (Yin, 2018). The identification of the cases for this research were conducted in two steps: defining the case and bounding the case (Silverman, 2015; Yin, 2018). The researcher defined the cases as environmental enforcement in the marine environment and the main cases were the BCG, related stakeholders, and public entities. The case was bounded by their involvement in environmental compliance and enforcement in the marine environment using technology in the Kingdom of Bahrain.

In qualitative studies there several sources of data collection, such as interviews, researcher observations, participant observations, documentation, archival records, and physical artifacts (Creswell & Creswell, 2017; Silverman, 2015; Yin, 2018). Although not all methods have to be applied together. The study itself dictates which data collection methods need to be used to reach the understanding of the situation (Yin, 2018). Triangulation is the process of providing multiple sources of data to ensure the reliability of data (Silverman, 2015; Yin, 2018).

To achieve a rich, detailed, and triangulated understanding of technology's usage and its impact, and the factors that influence technology acceptance in environmental compliance and enforcement in the Kingdom of Bahrain, several data sources were collected (**each data source was described in more detail in later sections of this chapter**):

Interviews: Interviews were the primary source of data for this study. The interview data was collected from individuals in the BCG and its related stakeholders, who are involved in environmental compliance and enforcement by using technology in the Kingdom of Bahrain. The selected participants were from various backgrounds, experience, and roles in the environmental compliance and enforcement process. The

primary participants were BCG personnel, and they totaled 12 interviews. Secondary participants are other stakeholders involved in the marine environment compliance and enforcement process, which were 8 in total. The total participants of the interviews were 20 participants.

Observations: the observational data was collected from various departments and sections in the BCG in a time period of three months (initial plan was six months but was shortened due to COVID-19 pandemic restrictions). This included routine and unplanned site visits.

Documents: the documents included strategic reports, workflow plans, organizational charts, technology implementation strategies and implementation plans, and violation statistics collected from various relevant stakeholders.

Triangulation was ensured through three main data collection methods. The data collection was conducted in this case study methodology which were interviews, observations, and documents (Creswell & Creswell, 2017; Silverman, 2015; Yin, 2018). This was achieved through environmental enforcers online or phone face-to-face interviews (Appendix A), end-user interviews (involved in compliance assurance) (Appendix C), and archival records and observations collected during 2019-2021.

4.4 Participants

The Kingdom of Bahrain has many initiatives aimed at increasing environmental protection and sustainable development. Further, Bahrain is a signatory to many international treaties and agreements. This process has led to the development and coordination of many governmental and public institutions with the aim of increasing the effectiveness of environmental compliance and enforcement. This has also been achieved through the adoption of technological solutions by these entities to enhance their performance in this field.

Sampling technique and justification

The research selected the participants using purposeful sampling, which entails selecting participants based on specific criteria (Creswell & Creswell, 2017; Silverman, 2015; Yin, 2018). Purposeful sampling is a method that is frequently used

Environmental Enforcement Technology Adoption

in qualitative research because it emphasizes inclusion criteria in its sampling approach and plays a role in research that examines entities or processes rather than individuals. (Silverman, 2015). The research applied the purposeful sampling technique by selecting participants from the Kingdom of Bahrain that were involved in marine environmental compliance and enforcement while using technology and had at least 2 years' experience in this field.

Primary Participants (cases from BCG)

The Bahrain Coast Guard was chosen as the main source due to their status as a significant environmental enforcer in the Kingdom. Particularly in the marine environment domain, and their emphasis on technology integration and application in their procedures. The researcher interviewed one top manager, four middle managers, and seven key employees of the BCG which were involved in environmental compliance and enforcement. A total of 12 participants were selected who were involved in environmental compliance and enforcement. The chosen participants all have roles in environmental compliance and enforcement and use various technologies in their duties to implement environmental compliance and enforcement. The extent and types of technologies used vary between participants. Technological tools used differ between participants according to job descriptions and rank.

Secondary Participants (cases from related entities and public)

Further interviews were conducted with related stakeholders involved in environmental compliance and enforcement through technology. The secondary interviews were conducted to provide additional data from interviews and increase variation of participants. A total of eight interviews with stakeholders were conducted: One from the Directorate of Marine Resources (Fisheries), one from the Supreme Council of Environment, a scientific researcher, two commercial marine organizations, three fishermen/leisure. All the stakeholder participants were involved in different roles and degrees in the processes of environmental compliance and enforcement and utilized technology for this purpose.

Sample size and saturation

The total number of participants was 20 participants, 12 from BCG and eight related stakeholders. Each of the participants was provided a pseudonym to ensure privacy and confidentiality. The research derived the sample size from data saturation which is achieved when no additional knowledge or themes emerge from the participants (Creswell, 2013). This was achieved and confirmed in two stages in the research. The data saturation from the BCG participants was achieved by the 10th interview, and a further two interviews were conducted, and no additional information emerged. The next set of participants from the stakeholder reached data saturation by the 6th interview. Again, two more interviews were conducted with no additional information.

Although the issue of participants number in qualitative is debatable, several writers (Creswell, 2013; Yin, 2018) propose using at least 5 to 50 interview participants, with fewer people required when more than one interview is done per participant or when the group of interview participants is homogeneous, smaller sample pool, and data saturation fulfillment. Given that the participants' adoption and usage of technology varied, one interview was conducted with each participant, and 20 interviews were conducted in total out of the 27 who were willing to participate due to the achievement of data saturation. Decisions regarding interview selection were mostly influenced by the availability of interview times that matched those of the participant and the researcher and inclusion criteria was met (participants from the Kingdom of Bahrain that were involved in marine environmental compliance and enforcement while using technology and had more than 2 years' experience in this field).

4.5 Researcher Role

The researcher has been involved in environmental compliance and enforcement in the Kingdom of Bahrain for more than 15 years and has been part of different entities involved in environmental compliance and enforcement. The researcher's educational background consists of a Diploma in Police Science and Law, Bachelor of Science in Marine Biology, and a Master's in Business Administration.

The researcher was the main instrument in the data collection and had an active role throughout the research. The researcher has had much experience in interviewing people, especially job interviews conducted for personnel recruitment in his organization. Although the research has had prior relationship with people in the field of environmental compliance and enforcement, the research tried to vary between entities and department from which participants were chosen to reduce the influence on participants and bias.

4.6 Data Collection

The data collection for this qualitative study was collected in two phases. Secondary data was first collected through researcher observation and archival data. Then the primary data was collected through the interviews to further understand technology use and adoption in environmental compliance and enforcement in the marine environment.

Secondary Data Collection

The sources of the studies secondary data are observations and archival data which were collected from December 2019 to February 2020 (Initial time was decreased due to COVID-19 pandemic) from the Bahrain Coast Guard and its related entities.

Observations:

The field observations enabled the researcher to collect valuable and meaningful information from participants in their natural settings (Yin, 2018). This additional data resulting from the observations provided a new layer of understanding to the research and gave further credibility to those themes that emerged and substantiated the findings (Patton, 2002).

Observation provides an increased understanding of the research and is used for triangulation (Yin, 2018). For this research the observations were collected from

Environmental Enforcement Technology Adoption

three sections of the BCG and its personnel. The sections were the Maritime Operations Center, which is the centralized control room that is responsible for surveillance, monitoring, and coordination of BCG patrols and in some cases between BCG and other related entities in the field. The second was the actual patrols and their commanding officers, and finally, the supporting offices that are also involved in environmental compliance and enforcement, such as the legal affairs. Observation site visits were conducted 3-4 times a week for three months. The intended period of observation was longer but had to be cut short due to COVID-19 pandemic restrictions and protocols.

The researcher had an active member role in which the researcher had more of a central role in the chosen setting and had some interactions with the members in addition to his observations. Although the researcher presence was clear, the researcher was careful in not to interfere or influence any of the activities taking place, and interference was restricted to inquiries in order to receive further understanding on some activities from members. The aim of the researcher was to report the activities, processes, and opinions of members in the targeted settings. A sample of the observations format can be found in (Appendix I)

Documents:

To gain increased understanding of the participants and the research context, the researcher gathered and examined many varied artifacts and documents related to environmental compliance and enforcement and technology use. These included organization mandates, strategic reports, workflow plans, organizational charts, history of the organization, technology implementation strategies and implementation plans, as well as violation statistics and processes, and others.

The data was obtained through close contact with Bahrain Coast Guard personnel and its related entities due to the fact the researcher is or was a part of these organizations. This information gives the researcher a better understanding of the current technology use and adoption in environmental compliance and enforcement in the Kingdom. The data also gives the researcher a preliminary background on the organization structure, culture, procedures, and processes. After

examining the collected documents, the research filtered out and excluded irrelevant documents, especially in regard to the relevancy of the documents to the research questions and objectives (Merriam, 1998). This data source was also used for the data triangulation process of the research.

Primary Data Collection (Semi-structured Interviews)

Interviews are a primary source of case study evidence since most qualitative studies deal with human matters and activities. They are also targeted and insightful, since they can focus directly on study topics and provide personal views and explanations (Creswell & Creswell, 2017; Silverman, 2015; Yin, 2018). The source of primary data for the research was the semi-structured interviews which requires understanding of research aim, rapport with participants, and some degree of probing (Silverman, 2015). The interviews were conducted on Bahrain Coast Guard employees and individuals from related entities that participate in and have a direct or indirect role in environmental compliance and enforcement in the marine environment. The individuals should to some degree utilize technology in their goal to achieve environmental compliance and enforcement.

Interview development

Hill et al. (2005) suggest designing an interview protocol consisting of eight to ten questions with probes that may be completed in one hour. Additionally, the study suggests doing at least two pilot interviews to assess the questions. During the proposal for the interview protocol, the researcher and two members of the doctorate advisory team assessed the interview questions. This set of thirteen interview questions included a variety of investigations. The addition of two questions to the protocol was suggested by the researcher's PhD advisor. The interview questions were developed to meet and reflect the research questions. Further three pilot interviews were conducted to ensure clarity and applicability of developed questions. After pilot interviews no alterations were conducted.

Interview protocol

The interviews were conducted from afar through online platforms or by phone and lasted between 20 to 40 minutes. The initial research interview method was face-to-face interviews in offices, but due to the required precautions and social distancing protocols in place at the time, the method was changed to online platforms and phone interviews. The interviews were initiated with an introduction of the researcher's personal background and the study's aim and confidentiality issues. The respondents were encouraged to share their knowledge and opinions on the questions in the interview as well as to elaborate on any relevant knowledge. The interviews were conducted in either English or Arabic to accommodate the participants needs and comfort to ensure the best expression of ideas and opinions by participants.

The interviews were transcribed by hand and were not recorded by voice or video. This is due to organizational protocol and regulation which prohibit the use of such methods of documentation. The Bahrain Coast Guard is part of the Ministry of Interior which is considered a military organization. The use of voice and video recording require strict protocol and permission. The initial documented answers and comments were sent by email or other electronic communications such as WhatsApp to the participants to be reviewed at the end of each interview to ensure validation of content of the documentation of the answers and comments. This gave the respondent a choice to review, alter, and enhance the information provided and it was altered accordingly by the researcher before the end of the interview.

Before the actual interviews were conducted with the participants, two main steps were taken. First, the chosen participants were contacted and received a brief summary of the researcher's and research's background and objectives. This was done by electronically sending Invitation to Participation Letters (Appendix E), which were sent either by email or through other platforms such as MMS or social media platforms. Once the individuals agreed to participate, they were sent Consent Forms (Appendix G) that were filled and sent back to research. Once the consent forms were signed and sent back, the researcher coordinated with the participant to organize an online interview time and date, as well as to arrange the most appropriate electronic platform to conduct interviews. Most of the interviews were through audio applications

(phone or WhatsApp) and some video through Microsoft Teams and other platforms. Both the Invitation to Participate and Consent Forms had Arabic versions (Appendix F; Appendix H)

4.7 Data Analysis Procedure (Thematic Analysis)

Data from the interviews were transcribed directly during the interviews since the interviews were documented by hand and did not utilize any recording devices. After the interviews were transcribed, the interview answers were returned to the participant for their final approval and confirmation of the information transcribed in the interview. The interviewee was provided with an opportunity to go over their statements to confirm and clarify any mistakes or misinterpretations. The process of transcribing and finalizing the answers of the interviewees provided an understanding of each interview separately before the analysis process began. This process lasted approximately four months, with some delays occurring due to the COVID-19 pandemic disruptions discussed in the beginning of the Data collection section.

Thematic analysis rationale

The study adopted the analytical approach of Thematic Analysis because it *“provides a flexible research tool, which can potentially provide a rich and detailed, yet complex account of data.”* (Braun & Clarke, 2006). The research adopts a theoretical approach since the research coding is specific and directly related to the research questions of the study. The levels at which the themes are identified are at a semantic level in which the themes were derived from direct or explicit meanings of the data (Braun & Clarke, 2012; Guest et al., 2011).

The thematic analysis allows inductive and deductive analysis of data which was needed in this research since the analysis was conducted from themes and codes from the data itself and also prior research theories developed and was transposed onto the data (Braun & Clarke, 2006; Braun & Clarke, 2012; Guest et al., 2011). This process was attained by first transcribing and reviewing to identify patterns, then summarized in reports, and finally interpreted.

The research adopted the six phases or steps of thematic analysis method provided by Braun & Clarke (2006). Further elaboration and information on the manner and procedures on the six-phase thematic analysis method were acquired and implemented from several studies (Braun & Clarke, 2012; Guest et al., 2011; Maguire et al., 2017; Nowel et al., 2017). The steps begin after the interviews ended and all the data have been transcribed. The data was transcribed with attention to details and was checked for accuracy. The secondary data was also analyzed through the same methods as the interviews. Details of the researchers process of thematic analysis through the six-step thematic analysis are as follows:

- 1- **Familiarizing yourself with your data:** This phase provides the essential orientation of the raw data and understanding of the main ideas of the data. The first step in this phase was the transfer of data transcribed by hand from the interviews to electronic format since there were no audio or video recording of the interviews. This step provided preliminary understanding of the raw data collected from the interview. Next the interview transcription was read thoroughly and repeatedly to identify significant quotes and ideas that are significant and relevant to the research, as well as points which may be considered less crucial but significant to the research objectives. The research initially used annotations on the interview transcription and further utilized an initial coding chart to identify significant quotes or testimonies that appear to be relevant.
- 2- **Generating initial codes:** After the researcher was familiarized with the collected data, the relevant data that was identified as significant and relevant was grouped according to similarity and patterns (initial coding process). The initial coding of the data commenced through the systematic coding of relevant data and points of interest across the whole data set. There are three main types of data codes and are as follows:
 - Descriptive codes: data that are more direct and require minimal interpretation.
 - Interpretive codes: codes which require some degree of interpretation to be fully understood.

Environmental Enforcement Technology Adoption

- Inferential codes: data that are both informative and suggestive of casual interactions

For this research the codes were a combination of all three code types, the main being descriptive codes since they were drawn from concepts acquired from relevant technology acceptance theories and previous literature. The acquired knowledge and understanding from relevant literature and theories allowed the researcher to better contextualized the research issues and understand participants perspectives and realities. In attempting to further understand the classification process, the data (such as codes and phrases) were grouped according to relevance to research questions and objectives.

- 3- **Searching for themes:** After the initial coding process was concluded, the different codes were compared and contrasted and organized into initial themes, which were relatively many at this point of the analysis process. The themes are categories that serve synoptic and accurate representation of the relevant attributes provided by the participants to the context of the research. The codes are grouped together according to pattern and similarity. This phase of the analysis was conducted in several steps. First, the coding generated in the previous phase was read through and revised to verify the data accuracy. Next, the correlation of the codes with the statements and their relevance with research objectives were assessed. Lastly, the main step of identifying themes through grouping of codes according to similarities and patterns and reviewing the themes to identify further subthemes was taken. The initial thematic map was developed which included seven main themes.
- 4- **Reviewing themes:** To ensure the best comprehensive description of the issues of the research, the themes were systematically reviewed for similarities and merged similar ones into one another. The review entailed confirmation that the elements' names or categories are accurate and precise (themes, subthemes, or codes) and that they accurately represent the data. Also, the themes were revised to ensure the themes are clear, understandable, and properly represent the links between the elements of the theme, subtheme, and codes and that they are logical and hierarchically linked. After the review of the factors discussed previously, fewer themes were adopted because of the

merging of themes of similar context and ideas or because of irrelevant representation of data elements that are irrelevant to the research objectives. The Themes at this stage were four Themes.

- 5- **Defining and naming themes:** This phase was initially conducted through similar steps as the previous phase, but the themes were reviewed in a definitive manner. For example, the themes were reviewed to ensure clarity and relevance of theme names and relationships with data elements and research objectives. Then the researcher further refined the themes identified in the previous step and generated clear names and definitions for each theme. Although the number of themes did not change in this phase, they were clearly defined and organized in a matter that eases the final interpretation and analysis. The finalized thematic map was developed in (Appendix J).

Four main themes were developed from the thematic analysis which were relevant to the research questions and the hierarchical order of the research. Each of the themes had several subthemes adopted through both deductive and inductive approaches from the analysis of the interview data complimenting the main themes. The main themes and their subthemes are as follows:

Table 4. 2 Conceptual framework outlining the main themes and sub-themes from participant interviews

Main Themes	Sub-themes
1. Technology usage	a. Technology b. Task c. Role d. Benefits
2. Applicability of M-TAM	a. Technological context b. Social context c. Implementation/process context d. Local context
3. Stakeholders' context	a. Strength and commitment b. Knowledge and awareness c. Clarity and unity

Environmental Enforcement Technology Adoption

	d. Integration of technology
4. Mandatory Settings	a. Extent of Use b. Degree of Necessity

6- **Producing the report:** the report was produced and written providing the findings of the data after analysis.

Cross-case analysis

In case study research five analytic techniques are usually used which are explanation building, timeseries analysis, pattern matching, logic models, and cross-case synthesis (Yin, 2018). Since this research conducted a multiple-case study, cross-case synthesis was adopted as its analytical technique. According to Yin (2018) cross-case synthesis treats each case as a separate study and later the findings are gathered across the separate cases. In this research each case was analyzed separately to address the research questions. The researcher explored each of the cases technology use and adoption for the purpose of environmental compliance and enforcement. Each of the cases were also analyzed separately and stored in the research database under the title of case studies. After the cases were analyzed separately, the research conducted a cross-case synthesis in order to determine if there were common themes, or explanations, to answer the research questions. This was accomplished by comparing the experiences of environmental compliance and enforcement entities utilizing cross-case memos and individual case analysis.

The individual case analyses were utilized to compare the categories, or answers to study questions, across and within each case. The responses to study questions were subsequently synthesized across environmental compliance and enforcement entities. Through cross-case analysis, the researcher was able to present a summary of the experiences of various environmental compliance and enforcement entities in balancing dual tasks. This multiple-case study gives an in-depth description of the distinct experiences of selected environmental compliance and enforcement entities

as well as the parallels between their experiences. Each case's research questions were answered separately, then analyzed collectively. This cross-case analysis compared both the distinctive and similar experiences of environmental compliance and enforcement entities.

4.8 Reliability and Validity of the Research

This section will describe the steps and strategies taken to ensure reliability and validity of the research. The two main procedures are the concept of trustworthiness by Lincoln & Guba (1985) and the Six strategies of Robson (2002). The details of these procedures will be described further in the following sections.

4.8.1 Trustworthiness

The research quality is measured by the reliability and validity of the research design and data analysis. In qualitative research, the term trustworthiness is used to judge the research quality rather than the terms reliability and validity, which are used in quantitative research (Lincoln & Guba, 1985). Trustworthiness is linked to credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985; Nowel et al. 2017; Silverman, 2015). Other more recent studies have given further factors to ensure quality of qualitative research, this study adopted the original factors given by Lincoln & Guba (1985) because it is widely recognized and accepted (Nowel et al. 2017). To achieve each of the previous results, various techniques and strategies related to research approach need to be implemented. The following sections will discuss the steps taken to ensure credibility, transferability, dependability, and confirmability.

Credibility

The credibility of the qualitative research is dependent on various factors. These include the data collection and analysis techniques and methods, credibility of the participants, and the credibility of the researcher (Lincoln & Guba, 1985). The researcher's credibility is of significant importance since he/she is the primary instrument of data collection and data analysis (Patton, 1990).

Credibility of Data

The credibility of data and procedures is essential in ensuring high quality research. Yin (2018) attributes proper implementation of the four principles method, especially in a case study that should help deal with the issue of construct validity and evidence reliability. The four principles given by Yin (2018) are as follows:

1. Use of multiple sources of evidence
2. Creation of a case study database (increases the reliability of entire case study)
3. Maintain a chain of evidence (increase the construct validity of the information in a case study)
4. Exercise care when using data from social media sources

The research took into consideration the four principles to enhance the validity and reliability of evidence of the study. The following section will elaborate on the steps implemented to attempt to address the previous issues.

The use of multiple sources of evidence were achieved by attaining evidence through the sources. The sources of evidence were interviews, observations, and archival data. Interviews were the primary source of data while observations and archival data were secondary data sources. Triangulation using the three previously stated evidence sources applied in the research was used to enhance the quality of the evidence and the overall research quality. Data triangulation helps to strengthen the construct validity of the case study (Yin, 2018).

The second and third principle were addressed through the creation of a case study database and maintaining a chain of evidence. The database gives easy and orderly access to data for the study for the researcher and others if needed. The database was divided into two main sections: primary and secondary data. Most of the data collection was documented by handwritten notes which were later transcribed to computer written documents and stored according to data types. The files were dated and filed according to chain of evidence. The hand-written notes were further scanned and filed in a separate folder specialized for this purpose which was also

divided into two sections: primary and secondary data. This process helps increase reliability of the evidence and to ease access and retrieval of data. The chain of evidence was maintained through the storing of the data according to date and the sequence in which the data was collected. The fourth principle was not addressed in our study since there was no gathering of data from social media sources.

As for the data analysis's credibility, the research adopted the guidelines and steps provided by Braun and Clarke in 2006 which provide clarity to the processes and procedures to thematic analysis, which is the method utilized in this research. The means in which the researcher addressed each of these steps was mentioned in section of Data Analysis Procedure. The researcher further confirmed the quality and validity of the method by checking that the steps are as per criteria for proper thematic analysis provided by various studies (Braun & Clarke, 2012; Guest et al., 2011; Maguire et al., 2017; Nowel et al., 2017).

Credibility of the Researcher

The researcher has been involved in and is experienced in the field of environmental compliance and enforcement in the Kingdom of Bahrain for more than 15 years. The researcher's education background is also related to the researched issue since he has a scientific and management-based background. Also, the researcher has previous experience in conducting interviews and understanding participants perceptions. The researcher has been actively involved and responsible for technology adoption and implementation strategies and projects, including environmental compliance and enforcement. Therefore, the researcher is familiar with issues regarding environmental compliance and enforcement and technological issues in this field.

Credibility of Participants

In order to ensure credibility of the participants, the researcher has set specific criteria for them. The main criteria is the involvement of the participant in environmental compliance and enforcement in the marine environment through the use of technology. Also, a procedure taken in the research to ensure credibility of the participants is the variation in participant roles and backgrounds. The primary

participants were chosen from the BCG, but others were chosen from related entities, including the public, who are involved in environmental compliance and enforcement in the marine environment. This enabled the researcher to receive focused, varied, and unprejudiced answers to questions.

Transferability

Transferability is the extent to which the findings and conclusion of the qualitative research are transferable to other participants and contexts (Nowel et al. 2017). Two main procedures that facilitate transferability are providing thick descriptions of context and research process and purposeful sampling (Bitsch, 2005). This research uses the technique of purposeful sampling and is describe in previous sections. The research also described in detail the research context in Chapter 1 and 3 and also described in detail the research process through the various stages from research design to the data analysis procedure.

Dependability

Dependability is achieved through ensuring the research design and process is clear, logical, traceable, and properly documented, readers should be able to examine the research process, to be able to judge the dependability of the research (Lincoln and Guba, 1985; Nowel et al. 2017). The research process is described in detail in previous sections of this chapter; research design section, data collection including interview protocol section, and data analysis procedure of thematic analysis section.

Confirmability

Confirmability is established after all the previous discussed qualities (credibility, transferability, and dependability) are achieved (Lincoln and Guba, 1985). To achieve confirmability the researcher should clearly show how the findings and interpretations were derived from the data collected (Nowel et al. 2017). In this research the three markers needed to achieve confirmability were discussed in the previous sections. The sections regarding research design, data collection, and data procedure for this chapter describe the methods used by the researcher as well as the reason these methods were chosen.

4.8.2 Six Strategy Validity

To establish validity of the research further steps were taken. Validity in qualitative research is frequently discussed in terms of three prevalent risks to validity in qualitative studies: researcher bias, reactivity, and respondent bias. (Lincoln and Guba, 1985).

Any unfavorable effect of the researcher's knowledge, or assumptions, of the study, including the influence of the researcher's assumptions on the design, analysis, or even sampling technique, is referred to as researcher bias. Reactivity, on the other hand, refers to the researcher's potential effect on the investigated setting and persons. Respondent bias is defined as a circumstance in which respondents do not provide honest replies for whatever reason, such as considering a particular issue as a danger or being ready to please the researcher with comments they feel are desired.

In this research Robson (2002)'s suggested six strategies which aim to address the previously stated threats to validity were adopted and implemented. The six strategies were namely: prolonged involvement, triangulation, peer debriefing, member checking, negative case analysis and maintaining an audit trail. Each of the strategies (Robson, 2002) and their procedures in this research will be briefly explained and presented in this section.

Prolonged involvement

Relates to the amount of time the researcher was involved in the study, including contact with the environment and the persons under examination. Being a member of this group, or even a friend to your participants, may be a huge benefit and a factor that both raises the degree of trust between you, the researcher, and the participants and reduces the risks of reactivity and response bias. However, it may represent a risk in the form of researcher bias resulting from your and the participants' probable assumptions of resemblance and presuppositions about some common experiences (Robson, 2002).

In this research this was achieved through the researcher's long involvement in the field on marine environmental compliance and enforcement across all the

entities and many of the individuals involved in this field. This is especially the case in the BCG in which the research has very long involvement in the organization and its individuals which are is the main source of data for both the primary and secondary sources of data. To reduce the risk of research bias that may arise from this long involvement with the participants the researcher was very careful not show any predetermined assumptions and to not have any influence on the participants. It was made very clear to the participant that the research has not predetermined outcomes and assumptions on the topic and that the research is aimed at exploring a previous insufficiently research field of technology adoption.

This was also conducted during the data collection by researcher observations, in which the research was very careful not to influence any of the procedures and decision in the chosen site, and not to ask question that considered as leading the observed individuals and entities to certain assumptions.

Triangulation

May relate to data triangulation through the use of multiple data collection, triangulation of methods by using mixed methods approach, and theory triangulation through the comparison of various theories and perspectives with developing theory of research, or through drawing from various fields of research.

In this research the triangulation of the three data sources, which were interviews, documents, and researcher observations, was conducted to ensure the validity of the data and findings. Another fulfillment of this strategy is that many of the findings were further supported and drawn from previous studies from relevant field (such studies on technology adoption in criminal law enforcement). For example one of the themes that was developed was Applicability of M-TAM which was developed during the analysis of the data which showed big similarities in findings to the previously reviewed model devised by Lindsay et al. (2014). The findings were compared and found to be supported by their study on mobile technology acceptance in the field of law enforcement (UK police).

Peer debriefing

Which is the sharing, discussing, and receiving of feedback from peers and others, including experts. Examples are discussion and presentation of findings of research with both internal and external individuals and in various events, such as conferences. The aim of this process is to receive critique, feedback, and suggestions to further enhance research. This input can be crucial to limit and prevent the researcher bias.

This strategy was attained through the participation of the researcher of this study at various stages in several conferences, in which both criticism and feedback were received and taken into account in the development of the research. Examples of these events were the ICGER 2021 conference and the *Industrial Revolution & Business Management: 11th Annual PwR Doctoral Symposium (PWRDS)2020*. The researcher also received feedback from various sources at various stages, these included colleagues, peers, and academic expert from outside organizations.

Member checking

Is the testing by the participants of the developing findings in with the aim of enhancing the validity of the findings through various means. Three main tools are used to achieve this strategy:

1. Regular contact with the participants throughout the period of the data collection and analysis and verifying certain interpretations and themes resulting from the analysis of the data. This method is used to control the influence of the researcher's assumption and understanding on the developing findings.

In this research, the researcher had frequent contact with the participants and discussed various input of the interviews with the participants to ensure all the input by participants are clear and not misinterpreted. For example, after the all the interviews were conduct , discussion of the construct of intention to use was misused by many of the participants in which discussion later revealed that

they actual meant the extent to which to will use the technology or to which potential.

2. Another tool is a validation interview or a follow-up interview. These interviews are used to validate research findings and verification of applicability to individual participants. This method was not adopted in this research, although the other methods in this strategy were adopted.
3. Revision of interview transcripts by the participants and receiving feedback such as comments and corrections. This step was conducted after each and every interview in which the research sends each transcript to the participants to ensure the text of the transcript and clear and properly present the comments and views of the participant.

Negative case analysis

Is the analysis of cases or collections of data acquired from a single participant, that do not fit the patterns emerging from the rest of the data. When a developing explanation of a phenomena the researcher is examining does not appear to apply to one or a small number of participants, the researcher should pursue a different line of inquiry to determine the cause of this discrepancy. Although the researcher may be tempted to disregard these out of dread of more work, the researcher should make it a practice to investigate them thoroughly, since negative case analysis, especially when paired with member verification, is an effective method for decreasing researcher bias.

Although in this research this was rarely the case, there were some instances in which the research did receive data that is different that most of findings. For example the previously discussed discrepancy attained on intention to use in which one of the participants that intention to use does not apply to their field. This led the researcher to reevaluate the construct and through discussion with participants and further data analysis it was revealed that the intention to use was misunderstood by majority of participant. It was later discovered that they actually means the amount or extent of actual use.

Audit trail

Monitoring and documenting all research-related activities and data, such as interview and observation data, notes, and the coding procedure. The researcher had all the data sources and processes archived and organized in chronological order. The researcher is able to clear trace the process and return to any of the data and activities at any time.

4.9 Summary

The study adapted a qualitative approach with multiple case studies triangulated with documents, onsite observations, and interviews with various relevant stakeholders to explore the technology usage and technology adoption in the field of marine environmental enforcement in the Kingdom of Bahrain. To allow deeper insight of the desired topic while allowing topics of importance to emerge the study used open-ended interviews. The topics were technology use and adoption in the field of environmental compliance and enforcement, in the Kingdom of Bahrain. The adoption of research's qualitative methodology was described in the previous sections and included purposeful sampling, semi-structured interviews, and systematic data collection and analysis through the thematic analysis and cross-case synthesis approach (Braun and Clarke, 2006, Yin, 2018).

Chapter 5 Data Analysis, Findings, and Discussion

This chapter presents the findings and discussion of the qualitative analysis of this research. It will be organized as follows: 5.1 will give the background information. 5.2 through 5.6 will present the themes discovered and 5.7 will be the discussion of findings. 5.8 will be the summary and the main findings of the research.

5.1 Background Information

Invitations were sent either electronically or by telephone to 32 participants. Out of the 32 invitations, five declined to participate because of difficulty of availability or not matching criteria of the interview. Only 20 interviews were conducted, although 27 accepted the invitation to participate in the interviews, and this was due to data saturation, which was achieved by the 19th interview. A further two interviews were conducted to confirm data saturation. After the data saturation was confirmed, the data collection from interviews of the BCG personnel and related stakeholders involved in environmental compliance and enforcement in the marine environment was stopped and the analysis process was initiated.

Of the total of 12 participants from the BCG; one is top management (Director level), four are middle management (Division Heads), and seven are key employees (Officers) involved with environmental compliance and enforcement in the BCG who utilize technology for this purpose. As for the responsibilities of the participants, four were involved in the Maritime Operations Center, five were involved in direct patrols (either sea or land patrols), one in Legal Affairs, and one in training (one of the participants was involved in both patrols and the maritime operations center). Six of the participants had over 15 years of experience, five had over 10 years of experience, and one had over five years of experience. As for the age of the participants, one participant was over 40, nine were over 30, and two were over 20. The education background of the participants was seven with Master's Degrees, four with Undergraduate degrees, and one with a Diploma. Of the 12 participants, five utilized integrated technologies, five separated, and two utilized both categories of technologies.

Environmental Enforcement Technology Adoption

Of the total eight participants from the related stakeholders; one was from the Directorate of Marine Resources (Fisheries), one from the Supreme Council of Environment, one was Scientific Researcher, two from commercial marine organizations, and three were fishermen (for leisure).

Table 5. 1 Demographic data for the interview participants

Cases: BCG						
CASE	JOB TITLE	RESPONSIBILITY	EXPERIENCE	RANKING	EDUCATION	AGE
1	DIRECTOR	PATROL	15+	TOP	MASTERS	30s
2	DIVISION HEAD	OPS	10+	MIDDLE	UNDERGRAD	30s
3	OFFICER	OPS/ PATROL	10+	KEY EMPLOYEE	MASTERS	30s
4	OFFICER	LEGAL	10+	KEY EMPLOYEE	MASTERS	30s
5	DIVISION HEAD	TRAINING	15+	MIDDLE	MASTERS	30s
6	OFFICER	OPS	15+	KEY EMPLOYEE	MASTERS	30s
7	OFFICER	PATROL	10+	KEY EMPLOYEE	MASTERS	30s
8	OFFICER	PATROL	5+	KEY EMPLOYEE	UNDERGRAD	20s
9	OFFICER	OPS	15+	KEY EMPLOYEE	UNDERGRAD	30s
10	DIVISION HEAD	PATROL	15+	MIDDLE	UNDERGRAD	40s
11	DIVISION HEAD	OPS	15+	MIDDLE	MASTERS	30s
12	OFFICER	OPS	10+	KEY EMPLOYEE	DIPLOMA	20s
Cases: Related entities / Public						
CASE	JOB TITLE	SECTOR	EXPERIENCE	RANKING	EDUCATION	AGE

Environmental Enforcement Technology Adoption

13	DIRECTOR	FISHERIES	15+	TOP	MASTERS	30s
14	DIVISION HEAD	SUPREME COUNCIL OF ENVIRONMENT	15+	MIDDLE	MASTERS	30s
15	PhD RESEARCHER	N/A	20+	N/A	PhD	40s
16	DIRECTOR	COMMERCIAL	15+	TOP	MASTERS	40s
17	DIRECTOR	COMMERCIAL	15+	TOP	UNDERGRAD	30s
18	N/A	LEISURE/ FISHERMEN	20+	N/A	UNDERGRAD	30s
19	N/A	LEISURE/ FISHERMEN	30+	N/A	N/A	50s
20	N/A	LEISURE/ FISHERMEN	30+	N/A	N/A	50s

TABLE KEY:

AGE:	20s = 20-29	30s = 30-39	40s = 40-49	50s = 50-59
EXPERIENCE:	5+, 10+, 15+, AND 20+ YEARS			
RESPONSIBILITIES:	OPS = MARITIME OPERATIONS CENTER	LEGAL = LEGAL AFFAIRS		
	TRAINING = MARITIME TRAINING WING	PATROL = FIELD PATROL		
* The categories were shown in relatively broad-spectrum to ensure the confidentiality and privacy of the participants identity, since the population size is relatively small and limited to one organization. Increased details of the participants can easily lead to identification of the participants.				

5.2 Theme 1: Technology Usage

The technology used and its type for any purpose is determined by various factors, ranging from feasibility to performance. From the analysis of the data on technology used in the BCG and related stakeholders for the purpose of environmental compliance and enforcement in the marine environment, two categories of technologies were identified and categorized for the purpose of the study as separated and integrated technologies. The research identifies separated technologies as technologies utilized separately and are more basic. The integrated technologies were identified as more complex systems that integrate the technologies together in

one system. The local context of fit to task and role were found to be a very essential factor influencing device functionality and influence the usage.

Various technologies and applications were identified to be utilized for the purpose of environmental compliance and enforcement in the marine environment. Although these technologies were exclusively meant for use for environmental compliance and enforcement since the main task of the BCG is protection of the kingdom's territorial water from all crimes and violations. Environmental compliance and enforcement is a secondary or supportive duty of the BCG. This is one of the factors leading to the increased variation and effectiveness of the use of technology for environmental compliance and enforcement in the marine environment compared to entities whose duties exclusively entail environmental compliance and enforcement, such as the Fisheries Directorate and the SCE.

The BCG were found to utilize more technologies that are relatively more integrated and complex due to their wide range of duties and requirements which are not exclusively related to environmental laws and regulations. Their main duty is ensuring the safety and security of the Kingdom's territorial waters. The following table list the identified technologies used by the BCG and related stakeholders for environmental compliance and enforcement.

Table 5. 2 Summary of Technology Used for Environmental Compliance and Enforcement by the BCG and related stakeholders

Technology	Summary
Call Center	Hotline that receives calls 24/7 in order to answer people's queries and requests.
RADAR	Used by operators to constantly detect, track, and monitor the activity of all vessels inside Bahraini territorial waters.
Camera	Industrial grade specialist day & night Coastal surveillance cameras which helps visual identification of vessels and events and provides visual capabilities to the system and aids in surveillance as well rescue missions.

Environmental Enforcement Technology Adoption

AIS	Free of cost AIS identifiers (vessel identification transmitters) to all registered vessels in Bahrain. These enable precise and continuous identification and GPS location of vessels – continuously with updates every few minutes. This has helped the fishermen and vessel owners to keep a track of their vessel as well equipping them with a vital SOS capability to request for help during times of distress at sea.
VHF Radios	Used for communicating with vessels to provide all kinds of assistance.
GIS/GSS	Geographic information system has a database of all cases and violations. It helps identify areas of environmental importance, sensitivity, and violations.
Wireless Communication Devices	For communication with patrols (land and marine) for information sharing and transfer and quick response.
GPS	Global Positioning System used for navigation and positioning
OIS 104 (google)	IT software available to personnel oil spill response that issued for monitoring oil tanker activity including fuel discharge and load.
Web-Based Models	Electronic platforms Specifically designed to help monitor and predict levels and direction of pollutants such as, dispersal of suspended solids Water (Total Suspended Solids) resulting from dredging operations and oil spills.
Marine Traffic Apps	Applications which provide real-time data on movements of ships and the current location of ships and details of vessels.
Social Media Apps	Such as Instagram and Twitter to receive updates and information on laws and regulations

Environmental Enforcement Technology Adoption

The separated technologies that were used for environmental compliance and enforcement were found to be the GPS, radars, AIS devices, cameras, and mobile apps.

The integrated technology used in the BCG was the Bahrain Coastal Surveillance System, which is an integrated system of GPS, Cameras, Radars, and AIS integrated through IT software.

Two main determinants of technology used and their category are the participants environmental roles and responsibilities. Each of these factors was a determining factor in type of technology as well as complexity of technology used.

5.2.1 Task

For the purpose of this research, responsibility is defined as the departments the participant is attached to or responsible for and its work environment. This factor was strongly linked to the technology utilized for the purpose of environmental compliance and enforcement. Personnel who were serving in the Maritime Operations Center utilized the Bahrain Coastal Surveillance System, which is the integrated system used for compliance assurance and enforcement (Cases 2, 3, 9, 11, and 12). The personnel in patrols or responsible for patrols utilized separated technologies such as GPS, radars, cameras, and GSS software (Cases 1, 3, 7, 8, and 10). As for the personnel in support offices, the technology varied. In training, separated technologies were used (Case 6), while legal affairs utilized both types of technology (Case 5).

This was also found to be similar from the perspective of the related stakeholders. The entities which were part of the enforcement process whose tasks entailed direct patrols utilized separated technologies to complete their tasks such as GPS, AIS, and IT software which are not integrated (Cases 13 and 14). The same applies to individuals and entities who were directly involved in ensuring compliance of their operations and vessels (Cases 15, 16,17,18,19, and 20).

The variation in technology used was found to be linked to the personnel's work environment as well as responsibility (task). The personnel whose tasks entailed being in field enforcement and linked to direct or manual enforcement utilized more basic and singular technologies such as the GPS and radars fitted on their patrol vessels or vehicles. The reason for this is that they are directed and managed by the Maritime Operations Center which has the whole picture and is responsible for the whole marine area, while the patrols are in charge or limited to smaller specialized areas. Also, the environment in which the patrols operate make it more difficult and less practical to utilize complex systems. For example, some patrol boats are located in relatively far-off locations where internet and other communication systems cannot be received and utilized.

5.2.2 Role

Although the BCG has a supportive role in the Environmental Protection process, they have a major and essential role in environmental compliance and enforcement in the marine environment. Interview data shows variation in the degree in which participants view the magnitude of their role in environmental compliance and enforcement. Most of the interviewees find that they are a major and essential part of environmental compliance and enforcement in the marine environment. At the same time there is a clear understanding that their role is a supportive role and not their main responsibility.

“Important role in supporting the specialized entities in charge of environmental protection through enforcing all marine related environmental laws and regulations” (Case 7)

The extent of involvement in the environmental compliance and enforcement process and job description is a major determinant of the type and specific technology utilized. Personnel who are directly responsible or involved in environmental compliance and enforcement in the field utilize more segregated technologies such as GPS, radars, and cameras, while Ops Center personal and supporting offices, which have several roles in environmental compliance and enforcement, use more

integrated systems and IT software such as the integrated surveillance systems and GIS.

As for the related entities which have a primary role of ensuring environmental compliance and enforcement, the technologies utilized were directly linked and specialized for that purpose. The SCE and the Marine Resources Directorate utilize technologies that are separated and similar to the technologies used by patrol personnel in the BCG, however they need to collaborate and coordinate with other entities if needed to obtain further detailed data.

Enforcement:

Another significant role of the BCG and related stakeholders in environmental compliance and enforcement was identified as direct enforcement. The enforcement role was viewed by the interviewees as the actual enforcement of environmental laws through surveillance and reporting of direct violations of the environmental law. The actions varied from actual apprehension and taking violators to court to identifying violations and reporting to the authorities responsible (such as SCE and Fisheries) after securing the scene and gathering evidence.

“Enforcement of fisheries and environmental laws prevention and apprehension of violators.” (Case 3)

“These patrol boats are tasked to enforce all laws in Bahraini Waters and that includes environmental laws.” (Case 1)

Technology utilized for the purpose of direct enforcement of the environmental laws and regulations were similar to the ones utilized by during the monitoring process. The main difference is in how the result of these technology are used. The data provided by these technologies is not just used to plan and identify, the data is used to build cases and investigate further into the violation and take further action.

Planning and decision making are an essential part of the monitoring and enforcement processes of the BCG in environmental compliance and enforcement.

Environmental Enforcement Technology Adoption

Data from the interviews have shown that planning and decision making is attained by statistics and analysis of data provide by integrated and IT technologies, such as identifying areas of increased sensitivity and illegal activities or hotspots. This helps monitoring and patrol efficiency. The technology used are IT software (GSS) and data from other technologies (integrated monitoring system) to display the information needed for proper planning and decision making.

“GSS: Geographic Security system – This system has a database of all cases and violations. It helps us identify areas which have environmental violations so we can focus on.” (Case 1)

“Also used for statistics which are used to identify hotspots and repeat offenders.” (Case 3)

Monitoring:

Interview data shows monitoring as the one of the most key roles of the BCG and related stakeholders in environmental compliance and enforcement, whether it be on the field through patrols, or in offices through the Operations Center, legal division, or supporting offices. All of them seem to use technology as the major and essential tool to achieve their goal of monitoring the marine environment for potential violations and pollution. This also applied along the job rankings scale with most personnel of different ranks found monitoring to be their biggest role in environmental compliance and enforcement.

“Compliance assurance through monitoring Bahrain waters through ops and direct patrols.”(Case 3)

“I have a major role in environmental compliance and enforcement in monitoring violations” (Case 6)

“Our operation center is working 24/7 to monitor the territorial water boundaries as well as restricted zones for any unlawful activity, including illegal fishing and environmental issues.” (Case 2)

Environmental Enforcement Technology Adoption

Technology used for the monitoring role varied according to job description and ranking. Personnel who serve in direct operations of environmental compliance and enforcement such as officers in charge of patrol operations and patrol officers, utilize more basic technologies such GPS and radars that are equipped on the patrols. These technological tools serve the purpose of detection and location identification of potential violators of environmental laws and regulations. Interviewee replies regarding technology utilized for the purpose of environmental compliance and enforcement that indicate the technologies and role in monitoring were as follows:

“Call Center: We have a dedicated hotline that receives calls 24/7 in order to answer people’s queries and requests. RADAR: A network of RADARs are used by our operators to constantly detect, track, and monitor the activity of all vessels inside Bahraini territorial waters. Camera: Bahrain Coastguard is equipped with Industrial grade specialist day & night Coastal surveillance cameras which helps visual identification of vessels and events and provides visual capabilities to the system and aids in surveillance as well rescue missions. AIS: In 2015, Bahrain Coastguard in compliance with international standards started providing free of cost AIS identifiers (vessel identification transmitters) to all registered vessels in Bahrain. These enable precise and continuous identification and GPS location of vessels continuously with updates every few minutes. This has helped the fishermen and vessel owners to keep a track of their vessel as well equipping them with a vital SOS capability to request for help during times of distress at sea.” (Case 2)

“When violations at sea are detected, the presence of ships near the area is confirmed by an integrated system using radar, cameras, and tracking devices to monitor ships and their movements.” (Case 6)

When it comes to related entities of the Directorate of Marine Resources and the Supreme Council of Environment, the technologies used for the role of monitoring are also separated but are more specialized for the purpose of environmental monitoring. One of these technologies used is web-based models, which are dedicated electronic platforms for monitoring and predicting location and distribution of pollutants, such as oil spills.

Environmental Enforcement Technology Adoption

“A Web-based model is also used, which is an electronic platform specifically designed to help predict the levels and direction of the spread of Total Suspended Solids resulting from drilling operations using offshore rigs. This platform is a microcosm model similar to other mathematical modeling software used in the organization for forecasting the dynamics of oil spill models such as Oil MAP and GNOME, for example.” (Case 14)

Personnel serving in the Operations Center and supporting offices utilize more sophisticated and integrated technologies. The main technology is the integrated system which allows for bigger scope and accurate monitoring system of detection, location, and vessel identification (including BCG patrol vessels). The system integrates cameras (long and short range), radars, AIS, and software that make it possible to accurately identify position and vessel information and can even identify activity of the vessels such as dredging or fishing. The IT software facilitates the integration process and provides further information for monitoring, such as the vessel's owner, permits, and registration validity.

“Patrols: Radar and GPS used to monitor and identify targets and potentials violators as well as use of these techs as evidence of violation. While Ops: use of ops integrated monitoring system which includes cameras, radars, AIS, and information systems which is used to monitor, identify, and apprehend violations. Also used for statistics which are used to identify hot spots and repeat offenders.” (Case 3)

Coordination and Collaboration

Data from interviews identified coordination as another role of the BCG in environmental compliance and enforcement, this was found to be the case when suspicious activities or violations were detected, and further action was needed. The main entities identified for coordination were the SCE, fisheries, and the Public Prosecution. The personnel working in the OPS and supporting offices having the bigger role in this process.

Environmental Enforcement Technology Adoption

“Many joint meetings are held with different environmental authorities to discuss about issues related to protecting sea life and how Coastguard can play its role in helping and improving it.” (Case 2)

“Monitoring violations and passing them on to bodies with environmental jurisdiction.” (Case 6)

Although coordination with other related entities is a role of the BCG and related entities, the utilization of technology is relatively low and basic during this process. The technologies used are general communication technologies and software or IT technologies, which are used to display information and data gathered from the field or that can be used as evidence or proof of misconduct. The technologies used are not directly linked to the process of coordination and collaboration with other entities but provide data and information that helps with the process.

Although there are no technological applications directly shared by the related entities other than the AIS devices which fitted on all vessels, some information can be shared by official request from related entities. The reason for this is the BCG technologies are used for a larger purpose of protecting the territorial waters of the kingdom including environmental aspects. Some of the data provided by the technologies can be confidential and cannot be made available to all entities.

“We collaborate with these entities if needed including receiving supporting data from their technologies.” (Case 13)

Awareness

The BCG have a role in public awareness which includes the importance of protecting the environment, increasing knowledge of environmental laws and regulations, and procedures that required. This role was found to apply to both the personnel on patrols and in offices.

Environmental Enforcement Technology Adoption

“Civilians and boat owners are continuously updated about the developments in the sea with regards to fishing areas, no go zones, fishing seasons, curfew hours and other safety instructions through all media channels.” (Case 2)

“Making seafarers aware of the need to preserve the environment.” (Case 6)

For the purpose of awareness in general, the technologies used were communication and surveillance technologies. The communication technologies ranged from call centers to VHF radios and the surveillance was through the AIS devices which give the BCG and the vessel owners real time GPS location and tracking capabilities. The communication technologies are used to inform the public and the seafarers of any possible violations and sites they should avoid and changes in rules and regulation. As for the identification devices (AIS) they are used to keep the vessels informed of their locations and possible infringement into illegal areas, such as marine protected areas.

“Call Center: We have a dedicated hotline that receives calls 24/7 in order to answer people’s queries and requests. VHF Radios: Another entity that is an essentials part of our operation center which are used for communicating with vessels to provide all kinds of assistance.” (Case 2)

Case 2 also states

“AIS identifiers (vessel identification transmitters) to all registered vessels in Bahrain. These enable precise and continuous identification and GPS location of vessels continuously with updates every few minutes. This has helped the fishermen and vessel owners to keep a track of their vessel as well equipping them with a vital SOS capability to request for help during times of distress at sea.” (Case 2)

The role of awareness is also crucial to the entities and individuals who are tasked with self-compliance. The continuous and real-time sources of information provided by the regulators through various platforms is essential to ensure compliance by these entities. Commercial organizations, fishermen, and other seafarers rely

Environmental Enforcement Technology Adoption

heavily on the availability of information and updates through various methods, such as social media platforms and official sites to ensure they are aware of the latest changes and obligations required to ensure self-compliance during their operations.

“Mobile application such as social media to keep updated and in some cases as a violation reporting method.” (Case 18)

Legal Process

The legal process of environmental compliance and enforcement was also found to be an essential role of the BCG and related entities. The legal processes taken by different responsibilities range from monitoring and gathering evidence to actual action such as administrative actions or transfer to the public prosecution depending on violation. The main part of patrols and Ops personnel is surveillance and identification of violations, gathering evidence, and securing the crime scene. The personnel of legal affairs are tasked with the receiving and organizing of violation reports and investigation. Depending on the nature of the violations, cases might be transferred to the Public Prosecution or have administrative penalties and actions. They are tasked also with execution of criminal judgement orders.

The type of technology utilized for the legal role varies according to responsibility. Patrol personnel utilize separated technologies available to vessels for identification of violations, violator identities, and location. This data is crucial to the legal process as it is the initial stage in which this data is used as evidence of the violation or infringement of the environmental laws. Many of the interviewees expressed the that the provision of tangible evidence by the technology is of the upmost importance to their role in environmental enforcement.

“Help us see what vessels if vessels are violating any environmental laws. It also helps with the legal process when the video is given to prosecution as evidence.” (Case 1)

Environmental Enforcement Technology Adoption

The Ops and legal affairs utilize integrated technologies with more IT software applications. Which are used to gather and organize as well as to transfer data and cases to related departments and entities, such as the Public Prosecution.

“Data from integrated system, AIS, GPS, Cameras, and radars for the propose of evidence to back the legal processes (evidence). IT software NAJEM and GIS for coordination and receiving violation reports and transferring of information and documents from and to the related entities, such as the Public Prosecution.” (Case 4)

Self-Compliance

With regards to the entities and individuals that have the role of self-compliance assurance, the results show a clear concern by these individuals to ensure compliance with environmental laws and regulations. They use several technologies to help ensure their operations are adherent to environmental regulations. The more complex and bigger the operations the more technologies are used. For example, small leisure and fishing vessels use simple technologies that help them to adhere to laws and regulations and mostly by mandatory technologies fitted on vessels such as the AIS devices that track vessel movements.

“GPS, AIS, and Fish finder(sonar) to identify location of restricted and sensitive areas and comply their regulations.” (Case 18)

While commercial fleets have more technologies that are utilized to ensure compliance such as gas and oil leakage sensors. The commercial fleets also have increased requirements to adhere to.

“Various navigation technologies such as GPS, radars, and AIS devices and in bigger vessels NAVTEXT which provides increased data and warnings such as metrological information. These devices ensure we are within designated and safe areas and routes to prevent any violation of environmental regulation or environmental damage.” (Case 17)

These entities also constantly keep updated on changes in laws and regulation by the regulatory organizations. One technology used for this purpose is social media applications, especially information on official sites or platforms.

“Mobile application such as social media to keep updated and in some cases as a violation reporting method.” (Case 18)

5.2.3 Benefits

Data from the interview verifies four main identified benefits of technological implementation in the environmental compliance and enforcement processes. They were found to be comfort, speed, accuracy, cost, transparency, and others. The following section will discuss each separately:

Speed

The data from the interviews show that technology has greatly affected the speed of transactions and processes of environmental compliance and enforcement in the BCG and their related stakeholders. It has affected the speed of transactions including the exchange and data quality which have become more real time. All the participants agree that speed has an impact on technology usage in environmental compliance and enforcement (cases 1-20). The speed of transactions has also resulted in reduced costs, effort, and time needed for environmental compliance enforcement processes.

“It has greatly affected the speed of information exchange and the speed of monitoring.” (Case 6)

“The time of information transfer has been decreased.” (Case 3)

“Very much, it has had a large impact making the monitoring process faster. Because the tools and processes have become more integrated which saves time.” (Case 7)

Accuracy

The use of technology by the BCG and related stakeholders has greatly impacted the accuracy of environmental compliance enforcement processes and outcomes. All the participants agree that accuracy was impacted because of the technology. The main area in which accuracy was increased is in the data provided for environmental enforcement and compliance purposes (cases 1-20).

“Accuracy has also increased, the data is Realtime and accurate, especially through the availability of several technologies to confirm data accuracy.” (Case 4)

“The information displayed is more accurate” (Case 5)

Transparency

Increased transparency resulted from the implementation of technology applications in environmental compliance and enforcement. Although this is the case, transparency is an effect of the increased speed and accuracy of data as well. All the participants find transparency has increased due to the use of technology, except for case 6, who indicated the transparency is unaffected by the use of technology. The reason for increased transparency is the accuracy and security of data, as the data cannot be altered or interfered with and can be shared and used by various parties.

“The integrated system has resulted in more accurate and transparent information.” (Case 7)

“Transparency increased since the information is in Realtime and secured in the available system which enable or decreases human error and interference.” (Case 4)

“The systems we use store all data and actions in an un-editable memory and therefore everything is completely transparent at all times.” (Case 2)

Environmental Enforcement Technology Adoption

The others either stated differently, as they find that transparency remained the same as before the use of these technologies or did not address the issue of transparency in their answers.

“I feel the transparency has not been affected very much, information was transparent even without the technology.” (Case 6)

The factor of transparency appears to be less impacted by the use of technology, although still enhanced. It also seems to be a secondary impact of the technology because other factors are part of the reasons the transparency has been affected and increased.

Cost

Cost was found to be a secondary impact of the use of technology in the environmental compliance and enforcement process. The initial cost of acquiring and implementing technology can be an expensive investment. The components of necessity and the end result, as well as the tradeoff between the cost, benefits, and longevity of these benefits are essential factors in effective technology acquisition and acceptance in the field of law enforcement and especially environmental law enforcement. The issue of the initial costs of acquiring or implementing technology is a major concern for decision makers and management in the field of environmental compliance and enforcement. All the participants find high cost to be justifiable in the long run because of the utilization of technology (cases 1-20).

“Whilst a single system is high in cost, the investment provides benefits for over 10 years, it generates many benefits, which are applicable to many stakeholders and so in fact the cost when spread across all of these components is quite low versus the benefits.” (Case 2)

The initial costs of acquiring technology can be high, but in the long term it saves resources such as money, manpower, equipment, and maintenance used in environmental compliance and enforcement. An example of this is through less manual monitoring and enforcement processes, such as the patrol boats which can require maintenance and manpower as well as fuel. The technology has affected this

Environmental Enforcement Technology Adoption

process while providing accurate and real time data which enables the patrols to concentrate in certain areas and not randomly patrol large areas of the sea and coasts without knowing where the targets are or where the hotspots are.

“It has reduced the cost of operating direct patrols since patrols have a lesser role in monitoring than before.” (Case 7)

“This has lowered the cost, manpower, and time for patrol boats, since they do not have to patrol and search vast areas for targets or violation as before.” (Case 3)

“Targets of Interest are identified from far away and sometime the violation are recorded by cameras; then our patrol are dispatched for enforcement. Thus, we do not need as much patrol boats. We do not use as much fuel.” (Case 1)

Other Factors Impacted

Various other factors were impacted by the use and implementation of technology and environmental compliance and enforcement processes. Knowledge and understanding of processes and purpose as well as technical skills have been increased by the use of these technologies in environmental compliance and enforcement. Enforcers have more knowledge of the tasks and duties and the way to accomplish them through technology than in the past when they maybe were only forced to follow orders, sometimes without understanding the purpose or what exactly needs to be done. This has increased professionalism in tackling their responsibilities and duties they are tasked with. This has resulted in increased efficiency of transactions and the end result of ensuring compliance and enforcement of environmental laws.

“Technological skills and knowledge of the enforcers have also increased with increased use of these techs.” (Case 3)

Another impact of technology is increased security of data and information which results in less probability of human interference and malpractice and increases transparency.

“Security (Data is secure and unchangeable)” (Case 4)

5.3 Theme 2: Applicability of M-TAM

Technology acceptance or user acceptance is an important factor determining the success of technology applications in the field of environmental compliance and enforcement as was found from the data collected from the interviews in the BCG and related stakeholders for the purpose of environment environmental compliance and enforcement. Many factors were found to influence technology acceptance from the perspective of the users of the technology for environmental compliance and enforcement. During the analysis of the data of the research it became apparent that many of the findings and codes we similar to many of the constructs of the previous models reviewed in the conceptual framework, especially the M-TAM model devised by knowledge gained from Lindsay et al. 2014. This led to the naming of current theme of the Applicability of M-TAM. **Although the model was not used to explore the technology adoption in the various case studies of this research, similarities arouse during the analysis of the data, which led to the naming of this theme.**

The M-TAM is a technology acceptance model developed for the use of law enforcement (police) in the UK. Its original constructs were found to be transferable and applicable to the research context by the data collected which will be shown in the following section by each of their main constructs and their relation to the original TAM model constructs.

5.3.1 Technological Context

Performance Influence on Perceived Usefulness

The data from the interviews show a clear link between performance and technology acceptance through the influence of performance on perceived usefulness. Most of the personnel working in the BCG for the purpose of environmental compliance and enforcement find the end result of the technology makes their job easier and faster.

“Because of the end result it has made the process of environmental compliance and enforcement easier and more accurate.” (Case 7)

“It helps reduce time and effort in environmental enforcement, which makes my job easier.” (Case 6)

“Because of the results. Technology made environmental enforcement much more effective” (Case 1)

From this it is found that the main issue affecting the performance construct found in environmental enforcement in the BCG is the device functionality and specifically the fit to role and task of the technology. The end-result of the use of this technology was found to be the main factor affecting the perceived usefulness of the technologies utilized which affected the user’s acceptance of these technologies. The research therefore verifies that the performance construct is a valid and crucial construct affecting perceived usefulness in technology acceptance in environmental compliance and enforcement.

Sharing Information & Knowledge Communication

Information sharing and communication were found to influence operational performance. Most technologies’ usage for environmental enforcement had communication and data sharing attributes within the BCG and with related entities. This increased the user’s perception of the technology’s performance. This attribute

Environmental Enforcement Technology Adoption

was essential to ensure circulation of information and accurate and transparent processes.

“Data from integrated system, AIS, GPS, Cameras, and radars for the propose of evidence to back the legal processes (evidence). IT software NAJEM and GIS for coordination and receiving violation reports and transferring of information and documents from and to the related entities, such as the Public Prosecution. This essential to our task” (Case 4)
Enforcer Efficiency

The level of was found to influence the performance of the technology used for environmental compliance and enforcement. The higher the enforcer’s efficiency is, the higher the performance. Without sufficient efficiency of enforcers, the performance cannot adequately be achieved. The data analysis finds this factor to be applicable in the context of the research.

“Speed in understanding the marine domain is essential so that action can be taken at the earliest possible moment.” (Case 2)

Data Quality

From the data analysis, data quality was also found applicable in its influence on performance of the technology, and the influence of data input and access had influence on the data quality. Current technology application in the BCG has a large amount of data which requires increased data access, input, storage, and analysis capabilities in order to make proper and efficient use of the information to ensure data quality and, in turn good performance, of the technologies. Also, the data management was found to influence the technologies’ functionality. Without proper data management capabilities, the technology cannot function adequately.

“Well, the speed of receiving data has increased effectively. But when such huge amount of data is streamed into our servers it requires a lot of effort to analyze and sort out information received from different sensors. I would also add a comment that quality of data is key and that new sensor systems being adopted generate massive amounts of data, and it’s important that this is

continuously processed and analyzed in real time, so that you have a real time 'picture' and understanding.” (Case 2)

Technology Reliability, Security, and Design Influence on Perceived Ease of Use

The 3 main factors found to influence the perceived ease of use were reliability, security, and interface design. They affect the perceived ease of use of technology in the field of environmental compliance and enforcement. Trust seems to be one of the main factors affecting the perceived ease of use environmental enforcement using technology.

Interface Design:

The interface design should be understandable and easy to use, the data from the interviews shows the interface design influences the perceived ease of use of the technology in the environmental compliance and enforcement process.

“Simplicity of using it and friendliness is important” (Case 5)

“Must firstly involve minimum user interaction and inconvenience” (Case 2)

Security and Reliability:

Security and reliability are also found to have an influence on the perceived ease of use offer technology in the field of environmental compliance enforcement. Security and reliability seemed to come in the form of trust of the enforcers in the data's security and reliability.

“It is essential that the technology being adopted is trusted and trust comes from understanding” (Case 2)

“Security and reliability are also a factor, Data should be safe” (Case 4)

Environmental Enforcement Technology Adoption

Several factors influence the perceived security and reliability of the technology use. Two important factors are the technology's ability to be updated and ensured back-up plans in cases of technology failure. Rapid advancements and clear and substantial impacts of technology on the effectiveness and efficiency of environmental compliance and enforcement processes and results has led to an increasing dependency on these technologies by the enforcers of environmental law. This dependency has increased the risk of deficiencies in environmental compliance and enforcement in the case of system or technology failure and interruption. One interesting point raised by one of the interviewees is that even though he is currently comfortable, he is worried about the future comfort levels because of the astronomically fast rate at which technology is changing and the possibility of failure or destruction of the technology. He feels that more effort should be invested in back up plans and not be totally dependent on the technologies alone.

“Technologies changing at an astonishing pace and constant being modified and changed this I feel may need much more knowledge, training, education, and dedication of time. I also feel we should have some sort of backup for scenarios where technology can be disabled, some sort of backup plan.” (Case 3)

Clear back-up systems or procedures are essential to ensure minimal disruption and delay in the processes and procedures in the case of failure or disruption of these technologies. This should include training on protocols which were implemented in the past, or more basic technologies that are easier to substitute and can be depended on until technical issues are resolved and dealt with. This also requires specialized personnel to deal with security and other technical issues, which must be monitored, tested, and updated regularly.

“BCG is looking at systems where advanced AI predict events and thus enable preventative action to be taken – effectively we move so fast we overtake future events with our action.” (Case 2)

5.3.2 Social Context

Cognitive Acceptance Influence on Extent of Use

Cognitive acceptance was also verified as a factor affecting the extent of use of technologies by environmental law enforcers. The most prominent factors within the cognitive acceptance construct that influence usage from the data collected in the interviews were found to be organizational culture and enforcer perception of the technology. Organizational culture included age and level of education of the enforcers in the BCG responsible for environmental compliance and enforcement using technology. Personnel of older age and less education were found to have less intention of using the technology. The reason for this seems to be the lack of technical or technological skills and resulting from long-term habits in which they do not accept any form of technology and are used to older ways. This is also considered to be part of the enforcers' perception that varies in individuals.

“Because of the ease of use, but people from different background and age groups may find some difficulty, such as older personnel not used to utilization of technology.” (Case4)

The degree of accountability of the enforcers using the technology seems to affect the usage intention. The more accountability may cause some users to be very cautious and unwilling to use the technology because of the fear of making mistakes and being held accountable for them.

“Accountability of the enforcer: This may sometimes discourage the user from using a technology.” (Case3)

The public perception as well was found to influence cognitive acceptance's influence on the extent of use of the technology for environmental compliance and enforcement.

5.3.3 Implementation/ Process Context

Management Style Influence on Extent of Use and Perceived Ease of Use

The management style construct includes a wide variety of internal factors ranging from training, time to implementation, and management buy ins. This construct is verified to influence both the usage intention and the perceived ease of use of technology for the purpose of environmental compliance and enforcement by the BCG personnel. The management style construct was found to be an essential factor influencing technology acceptance, especially after adopting the technology, and these factors have to be researched and studied thoroughly before adoption or acquiring any technology.

Level of Training and IT Skills

Level of training and technical skills are the main factors influencing the perceived ease of use from the perspective of the management style. Higher levels of training and technical skills in the personnel involved in using technology for the purpose of environmental compliance and enforcement results in increased perceived ease of use. This will make using the technology simpler and require less effort for the users.

“Training ranging from basic to advance is a must depending on users’ role and usage.” (Case 5)

The other factors in the M-TAM model regarding the management style that influenced the usage intention were also verified from data collected in the interviews. The most prominent factors other than training level and technical skills were understanding of the technology which includes the technology itself and its benefits, technical support, and time to implement.

Time to Implement Project

Time to implement is another factor found to be applicable to the research’s context in which the data shows that more time should be spent on research and

Environmental Enforcement Technology Adoption

evaluation of proposals in order to acquire and select the suitable technology for the chosen role and task required.

“The most important aspect of adopting a technology is to invest 70% of your time on research and testing the tech whereas the remaining 30% should be used to analyze other requirements.” (Case 2)

This is essential to ensure a precise and swift implementation plan to ensure optimum adoption implementation. Delayed implementation may result in lower use of technology by users.

Time to Implement Influences Perceived Ease of Use

The original M-TAM model finds that time to implement a project influences management style, which in turn influences usage. Data from this research further finds that the time to implement influences the Perceived Ease of Use in which the longer it takes to implement a technological application, the more the users will perceive the effort and time needed to use and apply the technology.

Level of Information About Technology

The level of information was found to be an influencer of usage through knowledge and understanding of the attributes, purpose, and potential of technologies in enhancing processes. This was found to influence not only usage directly but also the perceived ease of use construct.

“Knowledge of the benefits of technology not understanding the advantages of using the technology can affect technology acceptance.” (Case 7)

Level of Technical Support

Technical support was also found to be applicable from the data gathered in the research. Technical support is essential to ensure users increased usage and perception of ease of use of the technology.

“Technical support round the clock is important” (Case 5)

5.3.4 Local Context

Fit to Task and Role Influence on Device Functionality (Performance)

The applicability of this construct was clear from the exploration of the current technologies used in the Kingdom of Bahrain in the BCG and its related entities. The details of the findings of the data analysis are discussed in further detail in the previous section 5.1. The two main determinants of technology use and degree of use were role and task.

5.4 Theme 3: Stakeholder Context

The legal construct is a unique factor influencing technology acceptance in the field of environmental compliance and enforcement. Several factors under the legal environment have been identified through extensive literature review on the shortcomings of environmental compliance and enforcement. These constructs were explored in this research and its influence on the extent of use of technology was investigated for the purpose of environmental compliance and enforcement in the marine environment.

The constructs and accompanying factors were obtained from the literature review on the shortcomings of environmental enforcement. The research attempts to find correlation of these factors with the theory of technology acceptance and find what factors in the legal environment affect it, and to what extent the technology is used. The four devised constructs after analysis under the legal environment were 1) the legal system's strength and seriousness in dealing with environmental protection issues; 2) The knowledge and clarity of legislation; 3) Clarity and unity of procedures and technologies; and 4) Integration of technologies into legal process and systems.

During the analysis of the legal context factors, a broader context and set of factors became evident, being the stakeholder context. The stakeholder context attained from the analysis included the related entities involved in the environmental compliance and enforcement process in the Kingdom of Bahrain. This was a result of the analysis of collected data which portrays a multistakeholder environmental enforcement system. The legal factors were part of the broader stakeholder context discovered in the research. The data from the research regarding the stakeholder's context in general shows it has high the extent of usage in environmental compliance and enforcement in the marine environment.

The primary reason for this is that it ensures that users of environmental compliance and enforcement technology have an understanding of the benefits and implications of their decisions, even after the crime or violation has been transferred to other connected institutions, such as the public prosecution. Furthermore, it assigns a level of satisfaction or dissatisfaction to the result, which effects the technical adoption of the technology used for this purpose by reducing the use of the technology used for this purpose. Once again, need appears to be a factor in the stakeholder environment, as evidenced by the fact that legislation and legal systems that demand the use of technology to complete the process encourage the use of technology by enforcement officers.

The Stakeholder's environment also provides some clarity and unification of process influencing the usage; technology use becomes clearer and organized. One extremely influential factor found from the data is the tangibility of evidence by the information provided by the technology, this factor has a very strong influence on the enforcer's extent of use of the technology used for environmental compliance and enforcement. The latter factors will be clarified further in this section when giving the results for each factor.

5.4.1 The Strength and Commitment Influence on the Extent of Use

The environmental enforcement (all related entities including legal system) system's strength and commitment in dealing with environmental issues especially

Environmental Enforcement Technology Adoption

environmental crime and violations was found to greatly influence the users of technology's extent of use for the purpose of environmental compliance and enforcement. Data from the interviews show there is a clear link between extent of use and the commitment and strength of the enforcement system in dealing with environmental issues.

The main aspect in which the enforcement systems, especially the legal system's strength and seriousness, influences the extent of use is through the end result of the violation that has been acquired; the stronger conviction or penalty given, the higher the usage intention is of enforcement personnel tasked with environmental compliance and enforcement as well as the entities and individuals responsible for self-compliance. Dissatisfaction with the end result may make the enforcer feel that the technology is a waste of time, effort, and money which affects usage. Also, weak legal systems influence self-compliance entities to adhere to obligations required by technology and the adoption of specialized technologies for this purpose which can be costly in some cases.

“Very high, the legal system strength and seriousness in the prosecution process gives the users (enforcers) technology for environmental enforcement increased trust and satisfaction in the benefits of the technology used for this purpose. The stronger the end-result in court the more the intention to use the technology.” (Case 4)

As for participants who are responsible for self-compliance, they also agreed with the importance of having a strong and serious legal system. They also show that this factor strongly influences usage of technologies for the purpose of environmental compliance.

“No doubt that the more serious is the willingness to enforce environmental compliance, the wider the application of technologies. I think incorporating the use of technology as an obligatory requirement in the relevant national legislation shall assist in maximizing the application of technology to monitor environmental compliance. In this regard, Bahrain has as a good

Environmental Enforcement Technology Adoption

successful case study of imposing the fixing of AIS on all non-military vessels as a legally-binding requirement.” (Case 15)

“The seriousness and the strength of a legal system will ensure that all users implement technologies to comply with the law. Intention to violate the law will vanish and there will be seriousness in adopting to the laws.” (Case 16)

It was also found to be the influential factor, especially by management and decision makers, with regards to choosing the appropriate and legitimate technology that is in correlation with the legal system requirements.

“The legal environment / framework is the defacto guide for our activities. It is therefore very important for us and is a fundamental guide to our decision making in regard to technology. For example, we must be careful to remain within privacy laws at all times whilst achieving compliance with the applicable rules for environmental protection and conservation.” (Case 2)

5.4.2 The Knowledge and Clarity of Legislation’s Influence on Extent of Use

The degree of knowledge of the legislation by the enforcers, the public, and related entities, as well as the degree of ambiguity of the legislation itself was found to greatly influence the usage of the available technological tool by environmental enforcers. Increased knowledge and understanding of the legislation influence the usage of enforcers because of increased understanding of what exactly is required from the technology to fulfill the legal process in accordance with the current legislation.

This provides the enforcer with increased satisfaction and understanding with the end-result and what is required to attain the most effective and satisfying end result by using the technology. Unambiguous or clear legislation also influences the usage of enforcers for the same reason the increased knowledge of the legislation, in that the enforcers using the technology know exactly for what purpose to use the technology at hand.

Environmental Enforcement Technology Adoption

“Very much, the knowledge of legislation specially by the users of the technology give them a sense of purpose and understanding of how, why, when, what, and where to use the technology. Ambiguity means not knowing and understanding the purpose of using the technology and how to implement but clear legislation does the opposite.” (Case 4)

Knowledge and understanding of the public of the legislation also was found to influence the enforcers' use of the technology because it makes their task less time and effort consuming. If the public understand the legislation and its requirement, especially when it comes to the technology at hand, the enforcers will need less effort and time to explain why and what is required for the public.

“The public knowledge also increases the acceptance of the technology by the enforcer because it makes his job easier especially when it comes to explaining what is required to the public.” (Case 3)

“Understanding of the legislation and regulations especially when it comes to the use of technology for compliance gives the user increased intention on using the technology and clear understanding of its purpose. The technology is only helpful if the user understands what is needed and how he can achieve and why. He will be confident and more willing to use it to help achieve his goals.” (Case 17)

Another way that the knowledge and ambiguity of legislation fix the enforcers usage intention is by increasing the sense of being protected but also makes them accountable when using the technology for the purpose of environmental compliance and enforcement. When the legislation is clear and understood by the enforcers, they will know how to protect themselves and present proper evidence and requirements from the technology.

“If the legal regulations are put in a way the protects users and punishing people misusing the technologies in a very clear way to the user, it will increase user's acceptance of using technologies.” (Case 5)

5.4.3 Clarity and Unity Between Related Entities Influence on Extent of Use.

The data analysis of the factors of having a clear environmental authority and collaboration and coordination between related entities were considered to be separate factors influencing the enforcers extent of use in different manners and magnitudes. Data from the interviews found that the two factors influenced the usage in the same way and same degree. Most of the participants had either the same answers on how these factors influenced the usage or referred to the previous answers regarding the two factors. When asked about the influence of collaboration and coordination of related entities the participant asked to refer to the same answer to question about the influence of having a clear authority on usage.

“It has a big impact for the same reasons as having a clear authority which I stated in question 9.” **(Case 7)**

After examination and analysis of the secondary data and the interview data, the two factors were found to have the same general extent of influence on the usage of technology in environmental compliance and enforcement. Although some of the participants find some variation in the extent of influence, in general the extent was found to be very high for both factors. Also, the way in which it influences the usage is similar. The influence on usage was found to be by providing clear, concise, and unified processes and procedures for the use of the technology to achieve the requirements for the end results of ensuring compliance and enforcement.

This provides the enforcers with a sense of a unified team and clear and unified strategy and process of ensuring compliance and enforcement with related entities which will ensure effectiveness of achieving their goals and increase their sense of satisfaction because of clarity in procedures and transparency of data and outcomes.

From the findings of the previous section the research verified the two factors as relevant influencers of extent of use in environmental compliance and enforcement personnel. The two factors were merged and formed as one construct of the legal

Environmental Enforcement Technology Adoption

environment which will be named “clear and unified processes” for the purpose of this study.

Clear and unified processes and procedure between related entities and departments, including end-users such as the fishermen, for the use technology for environmental compliance and enforcement has significant influence on the extent of use of enforcers of environmental laws and regulations. This factor affects the enforcers intention because of the increased sense of having a unified goal of protecting the environment through tools that provide transparent, accurate, and fast results. The extent of clarity and unity of the procedures between stakeholders, especially when it comes to the procedures of using the technology, is strongly linked to the extent of use of these technologies for environmental compliance and enforcement.

“Means having clear processes and procedures for the use of the technology for the purpose of environmental enforcement. This eases the using the technology and increases the sense of working in one team.” (Case 4)

All participants (Cases 1 to 20) agree on the high extent to which the clarity and unity influences the extent of use. For example, a unified system and platform in which the technologies operate, and data is accepted is highly influential to the usage, since it will result in less confusion and effort when it comes to submitting and monitoring the data, especially in field like environmental compliance and enforcement, which is the case in the Kingdom of Bahrain. This will also increase deterrence to commit violations by perpetrators because of the transparent and traceable data and increased surveillance and monitoring.

“By making the processes and procedures clear and understandable. the employees use of the technology will be serious, monitored and with standardized procedures with the authority itself, resulting in increased acceptance of the technology used.” (Case 6)

The regulated individuals and entities also find that having clear and unified technologies and procedures to be highly influential on their extent of use. One unique

factor especially to the commercial sector is the need to achieve better reputation and having closer ties with the regulatory entities.

“Commercial sectors are always trying to achieve close and transparent relations with authorities to ensure compliance and improve companies reputation, if the entities are collaborative with each other and have unified and clear goals especially ones that are achieved by technology the users will be more intent on using them.” (Case 17)

The unification of the technologies and their procedures across the whole enforcement chain results in faster and more accurate data sharing and access. As well as transparent and easy communication channels between the individuals and entities involved in environmental enforcement. This aids in ensuring ease and accurate flow of information in an integrated manner and continuous advancement and development of the technologies and their procedures in attempt to achieve their main goal of compliance assurance.

“The use of technology by compliance and environmental enforcement officials is one of the most important elements of linking between the various entities and institutions and an important element that would ensure the speed and durability of the procedures taken and the speed of law enforcement, which ultimately leads to strengthening the principles of integration in the institutional work system, which would cast a positive shadow on the intention of the compliance and environmental enforcement officials to use technology in general.” (Case 14)

5.4.4 Integration of Technology Influence on the Extent of Use.

Integration of the technology use for the purpose of environmental compliance and enforcement into the legal process has been shown to have a great influence on the extent of use of enforcers of these technologies. This has been shown in two main aspects from the thematic analysis of the interview data: necessity of using technology to complete tasks (including legal process) and the tangibility of evidence. The

Environmental Enforcement Technology Adoption

integration and acceptance of the data output in the legal process by the BCG and related entities is crucial influencer on the extent of use of environmental enforcers.

Throughout the analysis of the data of the interviews, the issues of tangibility of evidence and authorization of the technology used and making its use mandatory to complete the tasks was reoccurring. This was found to be an essential factor throughout the environmental compliance and enforcement process while utilizing technology for the initial steps, such as monitoring, to the final process, such as the prosecution by the Public Prosecution.

The amount of time utilizing technology for the purpose of environmental compliance and enforcement is very high. Most of the interviewees said that they use technology nearly all the time in order to fulfill their duties in environmental compliance and enforcement. The reason for this is that it has impacted on their procedures and has also become a necessity to perform their duties. The interview data purports that even with minimal user acceptance, necessity has made it a mandatory part of their processes, they cannot complete the tasks and duties appointed to them without using technologies currently being implemented in the BCG. They utilize the technology in most of the procedures and processes involved in environmental compliance and enforcement.

“The marine domain is very complex, with thousands of movements every day. The use of technology is now and essential and important part of our daily routine and enables us to enhance every part of our daily operations.” (Case 2)

“Nearly all the time, in every transaction and process some form of technology is utilized it has become a necessity.” (Case 3)

“All the time. Most targets committing environmental violations are first identified by radars, AIS, or Cameras.” (Case 1)

“Very often, it has become a necessity in the environmental compliance and enforcement process.” (Case 7)

Environmental Enforcement Technology Adoption

The second factor identified in the integration of the technologies in all compliance and enforcement processes, including the legal process, is tangibility as evidence. The extent to which the technologies' output and data is accepted and authorized in the legal system, especially in Public Prosecution, influences the usage of these technologies by the enforcers of environmental laws. This is especially true when it comes to the tangibility of the output data as evidence in these processes, particularly in legal processes.

The tangibility of evidence from the data is extremely essential and important for the enforcers of environmental laws. This seems to come up in most interviews in various aspects regarding the accuracy of evidence. The tangibility of evidence has become more accurate from the technology used for the purpose of environmental compliance and enforcement because it has become possible to pinpoint the exact positions and identifications of the violators as well as give visual and audio proof of the violation from recording data from the system or from cameras and other sources such as the AIS tracking device.

“In all our legal cases, Coast guard has provided reports, evidence of all sorts that were collected by our sensors and have been provided to relevant authorities as well as in the Court of Law.” (Case 2)

The data quality becomes an important factor to the authorization of the technologies data throughout the environmental compliance and enforcement process. This requires continuous monitoring and updating of the technologies, especially if the essence of data analysis and storage is also affected. That needs to be taken into account, as the accuracy increases, and further steps are needed to ensure the accuracy is maintained with increased regularity.

“Accuracy has always been an integral aspect of our research and development process. Throughout our surveys and POCs we have always at technologies that would enhance our accuracy of targets and so far, we have been pretty good at selecting sensors and technologies that are providing us with high accuracy results. Again, data quality and quality data processing are key points.” (Case 2)

5.5 Theme 4: Mandatory Setting

As discussed in previous sections of the research, the intent to use and the consequent actual use were found to not explain technology use in mandatory settings. Attitude towards the technology does not influence the intention to use since the technology is mandated to the user and therefore inapplicable to mandatory settings (Brown et al. 2002; Linders, 2006). The data analysis finds that the attitude and other factors influence the extent to which a technology will be used.

Although some of the participants used the phrase usage intention, the intention was found to not be applicable to the technologies studied in this research due to them being mandatory and necessary for tasks. The term was used in the answer due to the format of the interview questions which asks the influence on various factors on usage intention. The participants perception and understanding of usage intention is the degree of actual use of the technology.

“The user attitude will not necessarily affect the usage intention since the technology has become essential to complete our tasks which is mandatory and not a matter of choice or preference. But it will affect the way or amount of use” (Case 8)

Although the user does not have the choice or ability to intend to use, their attitude can have further implications, such as to resist or not use the technology to its full potential (Brown et al. 2002). If the users have a positive attitude towards the mandatory technology, they will use it to its maximum capacity and potential to reap the benefits of using the technology.

“It has a big effect because if enforcers do not accept the technology, they will not use it to its full ability, and if it is not used to its full ability, it won't be as effective.” (Case 1)

From the above findings the research's proposed construct of extent of use was found to have the capability of predicting and explaining technology use in mandatory settings. For this research the extent of use was developed and chosen since it is

more applicable to mandatory settings than the intent to use which is not possible because of an unavailability of the option to choose or use the technology. Positive attitudes and the other external variables influence the extent of use intention in that the user intends to use the technology to its full potential.

5.5.1 Degree of Necessity

Although the research initially proposed the inclusion of the voluntariness of use as a moderator of technology use. The findings from the data show another relationship than originally proposed. The degree of necessity, which refers to the extent to which the technology at hand is mandatory or necessary to complete tasks, was found to be a direct determinant and influencer of the extent of use of the technology or innovation.

Despite the technology used for environmental compliance and enforcement in the research domain was mandatory, the degree of necessity varies. One crucial factor found to influence the extent of usage is the necessity or need of using technology to complete the task at hand. The influence of necessity was also found to be a factor affecting technology use in mandatory settings by Brown et al. (2002), in which they found, along with necessity, the integration of the system across the process affected technology use in mandatory settings.

The data analysis clearly shows that necessity of using the technology to complete tasks strongly influences the extent of use of environmental enforcers. This factor has been repeated often and emphasized in the data collected from the interviews. Examples of this evidence is found the interview questions regarding time and comfort of using the technologies, which shows that this factor influences the user's extent of use.

Making use of technology a necessity to complete tasks by management and the organization strongly affects user's extent of use of the technology in the processes of environmental compliance and enforcement. The attitude of the users was found not to influence the user intention since the use of technology is mandatory and necessary

and their tasks cannot be completed or accepted unless it is completed through the technologies required.

5.7 Discussion

This section will present the discussion of the findings of the research. Each Theme's findings will be discussed separately.

Theme 1: Technology usage

The findings on current technology utilization in environmental compliance and enforcement in the Kingdom of Bahrain are presented in the first section of the theme. The technology employed by the BCG and its associated stakeholders was the primary focus of the discussion. The key findings were that there were two major kinds of technologies now being used for the purpose of environmental compliance and enforcement in the Kingdom of Bahrain, which were identified in the study. They could be classified as either separate technologies or as integrated technologies.

Separate technologies are those that are employed independently of other technologies or systems. Whereas integrated technologies are those that are integrated into a larger and more complicated system. The separated technologies were more fundamental in nature and are widely available to the majority of enforcers and the general public. Individuals who used distinct technologies for the aim of enforcement typically received them from their organizations. However, public and commercial entities generally relied on staff or privately funded technologies, with the exception of the BCG-provided and mandatory AIS equipment. The integrated systems are complicated and integrate a variety of technologies, including some of the separated technologies. They are exclusively employed by enforcement bodies.

The bulk of technologies were either directly related to one another or were in some way related to an integrated system. This has been demonstrated to be an effective technique of boosting the overall performance and effectiveness of technologies, as numerous studies on technology utilization in the field of law

Environmental Enforcement Technology Adoption

enforcement, especially environmental law, have demonstrated (Abreu et al. 2018; Allena, 2020; Andoni et al.2019; Herweijer et al. 2018; Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020; Visser & Hanich, 2018; Xu et al. 2019).

Many of the previous studies find the integration of various forms of technologies into a single and unified platform to enhance to accuracy, acceptability, and effectiveness data management (Andoni et al.2019; Herweijer et al. 2018; Kouhizadeh & Sarkis, 2018; Mahyuni et al. 2020; Xu et al. 2019). This provides a rich source of data for both implementers and decision makers in the field of law enforcement. This is essential in the current rapid increase in technology advancement, to ensure the large number of technologies and data are managed properly and efficiently (Abreu et al. 2018; Allena, 2020) .

This was demonstrated to be particularly true when data management systems were implemented. The BCG's technology integration was intricate and spanning multiple data management platforms. The concept of integrating and merging numerous technologies into a single system results in quantifiable and accessible data that can be used for planning, decision-making, and execution, which is consistent with the findings of numerous research. (Borum, 2020; Gargiulo et al. 2016; Larsen, 1999; Martinelli & Moroni, 2018).

The reason for the BCG's more complicated technology systems in comparison to its associated institutions is the BCG's broader scope of responsibility. The BCG's primary responsibility is not environmental enforcement. Their primary mission is to safeguard the Kingdom's territorial waterways from any dangers and crimes. This includes enforcing environmental rules and regulations, which the BCG regards as a secondary function. The BCG's vast marine regions and duties have necessitated increased investment and implementation of complicated technical solutions in order to meet its efficiency and effectiveness targets and goals. This desire to improve effectiveness results in numerous entities adopting innovations to accomplish their goals and aspirations, particularly those with a broader range of responsibilities and obligations (Borum, 2020; Gargiulo et al. 2016, UNEP,2019).

Environmental Enforcement Technology Adoption

The other main finding is that there were two main determinants of the technology being utilized for the purpose of environmental compliance and enforcement in the Kingdom of Bahrain. They were the task characteristics and the role of the user. For example, the tasks that required field work used technologies which were more basic and durable, patrol personnel used technologies that are used separately like vessel GPS and radars since their work environment is limited in space and connectivity. This is the case with long range patrol mission where connectivity and maneuverability are a big concern for personnel and operators. Tasks and roles that require direct collaboration and coordination, including related entities, required specialized technologies such as data management and communication systems. The data from the technology is later relayed to the operations where the data is then incorporated into the integrated system.

As for the role of the user, the technology used is also chosen according to this factor. For example, users involved in the legal process require the use of more sophisticated and complex systems to receive authentic and reliable data to ensure proper prosecution and procedures, while people involved in awareness may require basic and minimal technology potential to complete their job. This finding further supports the conclusion that integration is critical and important for the acquisition of realistic and holistic data for decision-making and efficient operations.

Previous research by Goodhue & Thompson (1995) also finds the influence of task characteristics and technology characteristics on the performance and utilization of technologies in general. Their Task-Technology Fit theory purports that the technologies characteristics should be suitable for the task characteristics required (Goodhue & Thompson, 1995). This knowledge is essential to ensure appropriate technology tailoring and adoption for any field and task, including environmental compliance and enforcement.

Previous research on technology in law enforcement support these findings in which the task characteristics and role have significant influence on technology use (Glicksman et al. 2017; Goodhue & Thompson, 1995; Omand, Bartlett, & Miller, 2012; Steele, 2018; Wang, 2012). The Lindsay et al. (2014) model of mobile technology acceptance finds that fit to task and role are major influencers of device functionality

of the technology. Which was found to be relevant and appropriate assumption in this research's context and domain.

The research identified several benefits of the current technology being used on the environmental compliance and enforcement processes, the main benefits being increased speed, accuracy, transparency, and lowering costs and effort. These benefits are an indicator of a successful adoption process of technology in the BCG. This resulted in the increase of benefits and indication of satisfaction with the technology by the users both in the BCG and its related stakeholders.

The previously described benefits of technology use in compliance and enforcement in the Kingdom of Bahrain were also discovered in other research on the benefits of technology adoption and use in law enforcement. With the bulk of research identifying numerous benefits associated with the progress and attainment of more effective and efficient results and outcomes on their processes and goals (Albers et al. 2017; Castell et al. 2014; English et al. 2018; Glicksman et al. 2017; Hojageldiyev, 2019; Lum et al. 2017; Morabito, 2017; Munoz et al. 2019)

While numerous studies have demonstrated the benefits of technology usage in law enforcement, they have also found some limitations and concerns that may restrict the effectiveness of technology use in law enforcement (Glicksman et al. 2017; Onoda & Young, 2017; Lum et al. 2017; Munoz et al. 2019; Zhang et al. 2021). The constraints appeared to have an effect on not only technology adoption but also on the entire law enforcement process if not considered and addressed (Lum et al. 2017). This research did not directly evaluate and examine the effect of technological limits on technology adoption but did explore the effect of low levels of benefit on technology acceptance.

Planning and assessment are critical components of ensuring the success and efficiency of any new technology purchase and deployment. Planning for technology application is critical and should include careful thought of the specific manner in which new and existing technologies can be developed, implemented, and used at all organizational levels to achieve goals for increased efficiency and good management (Lum et al. 2017).

This aspect of successful planning and management of the BCG's technology application appears to account for the favorable results in terms of beneficial results and user comprehension of advantages. The BCG offers comprehensive strategy plans and detailed action plans for technology adoption, which include all aspects of adoption, including evaluation, selection, implementation, and progress.

It is necessary to understand and handle concerns and limits regarding the use of technology in law enforcement prior to enacting legislation and policies that effectively address such concerns and constraints. To assure the technologies' efficacy and to minimize the risk of adverse outcomes from these limits, the process of reviewing and regulating these issues should be constant and consistent (Glicksman et al. 2017; Onoda & Young, 2017; Lum et al. 2017; Munoz et al. 2019).

Theme 2: Applicability of M-TAM

The findings show similarity of the M-TAM developed by Lindsay et al. (2014), showed its relevance to the enforcement domain of this research and was modified to fit the field of environmental compliance and enforcement in the Kingdom of Bahrain, and it is applicable to general technology rather than mobile technology specifically. The findings of this research show the applicability and transferability of the model and its constructs to the context of this research, in which most of the constructs and their relationships were found to be similar and applicable.

The data analysis clearly demonstrated the M-TAM's relevance and transferability to the field of environmental compliance and enforcement, particularly in the Kingdom of Bahrain. The key reason for this is the similarity in context of Lindsay et al. (2014)'s prior research and the context of current investigation. Both were carried out in law enforcement agencies, with the main difference being the type of enforcement. The M-TAM was designed for criminal law enforcement (Lindsay et al. 2014), while this study focuses on environmental law enforcement. Both need broad enforcement techniques and procedures, although they differ in a few particular areas.

Environmental Enforcement Technology Adoption

The M-TAM's extensive covering of the numerous variables and criteria used to explain and forecast technology adoption in various prior theories and explored disciplines has also resulted in the model's high transferability and acceptability. Another reason is that the chosen participants in both research have comparable organizational structures and missions. The majority of participants in both research are members of the interior ministry, although they work in distinct locations and fields.

The study demonstrates that the model is adaptable and transferrable to the use of general technology, not simply mobile technologies, as Lindsay et al. claimed in their initial study (2011). The major explanation for this appears to be connected to the environment in which the participants in this research function, as well as the nature of the currently utilized technology. The participants work in the maritime area, and many of them work in the field (for example on patrol vessels). Their work environment and requirements typically need device and technology mobility and connectivity. As a consequence, the model's mobile technology acceptance knowledge was applicable in environmental law enforcement in the maritime environment. Similarity in technology qualities and specifications, particularly mobility, may have influenced the determination of application of the M-TAM.

Despite the fact that this resemblance was identified, one surprising result was that this applicability was revealed in participants who did not directly use mobile technology. The model appears to apply to stationary technology as well as data management systems. This appears to be due to the indirect usage of mobile technologies, which eventually merge into these stationary systems.

Although the original constructs were applicable, some modifications were conducted to tailor the model to the research context; the main modification being the replacement of the behavioral intention with the extent of use construct to fit the research technology use setting which is mandatory (Brown et al. 2002; Linders, 2006). The original constructs of the TAM were found to be applicable and had significant influence especially on the attitude towards the use of technology (Venkatesh & Bala, 2013; Venkatesh & Davis, 2000; Venkatesh, Morris, Davis, & Davis, 2003). The perceived usefulness and perceived ease of use had significant influence on the attitudes of the users, further the perceived usefulness had direct

influence of the extent of use of the technology (Venkatesh & Bala, 2013; Venkatesh & Davis, 2000).

As for the external factors of social context, implementation, and process context they were found to have influence on the extent of use of the technology by users. These external factors were found to be determinants of technology adoption and acceptance by other studies conducted on technology in law enforcement (Donne & Fortin, 2020; Gulatee et al. 2020; Kim et al. 2020; Prasanna & Huggins 2016). For example, Gulatee et al. (2020) find organizational determinants that are factors beyond the employees themselves have significant influence on the adoption of technology in law enforcement settings. The management style construct of this research has similar implication on technology acceptance. As for the social context of this research, other researchers have found similar influence of social factors in the domain of law enforcement such as Prasanna & Huggins (2016).

The local context which includes fit to task and role were found to have a strong influence on the perceived usefulness. Although the relationship was not directly linked to the perceived usefulness, it was linked to the device functionality and performance output of the technology. This was also found in previous research by Goodhue & Thompson (1995) where the task-technology fit model finds the fit to influence the performance impact of the technology at hand. The previous findings gave further evidence to the applicability of the constructs of the model to general technology use rather than only mobile technology.

As was initially inferred by the research and previous studies that developed the model (Lindsay et al. 2014), the M-TAM seemed to be a relevant model that can be applied and transferred to this research's context and field. The Similarity in law enforcement systems may explain this transferability. Although the systems operate in different domains and regions, the common responsibility of enforcement is similar in nature. Especially in the research's case of the environmental enforcement in the marine environment in the Kingdom.

Theme 3: Stakeholder's Context

The findings regarding the influence of the stakeholder's environment was discovered after the analysis of the proposed legal environment factors. The analysis revealed a broader context of influence from the initial proposed legal environment. The Stakeholders environment was found to have direct influence on the extent of use of the technology for the purpose of environmental compliance and enforcement in the Kingdom of Bahrain.

The stakeholder's environment can vary from region to region and between organizations. This is especially true in cases where environmental compliance and enforcement is dependent on several entities with similar goals of compliance and enforcement, as is the case in the Kingdom of Bahrain. The environmental enforcement systems in the Kingdom of Bahrain operate through multi stakeholder systems.

This provides an insight into the influence of the environment of the stakeholders on the extent of use of technologies for environmental enforcement and compliance. Any single entity part of this system cannot operate and achieve their tasks without proper collaboration and coordination with the related stakeholders. This issue may affect the technologies use due to lack of required results if system are not organized to facilitate multistakeholder processes. For example, insufficient integration of technologies may result in effort and time mismanagement and consequent dissatisfaction of users of technology's results. Prior research, such as Lum et al., has underlined the relevance of effective results and outcomes from the usage of technology (2017).

Contextual determinants of technology adoption in law enforcement in which the factor is outside the employee and organization itself has been found to be a determining factor (Gulatee et al. 2020). In this research, four factors were found to be part of the stakeholder's environment that had influence on the extent of use of the technology in the context of the study:

1. The system's strength and commitment

Having sufficient capacity and commitment within the enforcement system is critical for ensuring adequate achievement of enforcement goals and targets in any field, but particularly in environmental law enforcement, where levels of commitment and intuitive capacities differ significantly across nations and regions due to a variety of factors such as funding and political commitment (UNEP, 2019). The findings of this study lend support to the same general assumptions about the overall effectiveness of environmental law enforcement. This issue is also shown to have a substantial impact on the adoption of technology for environmental compliance and enforcement in the Kingdom of Bahrain, according to the findings of the research.

Despite the fact that the legal system was first postulated and analyzed independently in the research, the analysis demonstrated that this component has an impact on the greater context of the stakeholder's operational environment. In multi-stakeholder enforcement systems, such as those in the Kingdom of Bahrain, the strength and dedication of the legal system have been proven to be extremely important characteristics. Unless they have the support and assistance of a strong and committed legal system, stakeholders will be unable to work successfully or achieve their aim of effective enforcement on their own. Similar findings were suggested by previous research of the importance of cooperation among governments, the private sector, and the individual citizens (Giles et al., 2021; Milmanda & Garay, 2020).

The nature of the Kingdom of Bahrain's environmental enforcement procedures serves as the foundation for the conclusions reached in this study, which are as follows: The environmental enforcement system in the Kingdom is multi-stakeholder, with the Public Prosecution in charge of the vast majority of legal actions and convictions against polluters. A considerable influence on the operation and usage of technology by relevant entities is exerted by the strength of their legal systems. Due to the inefficiency and lack of commitment of the legal system, for example, enforcers may be unable to motivate themselves to work efficiently and spend time and resources in technology adoption since they may regard this as a waste of their time and resources.

Environmental Enforcement Technology Adoption

The findings illustrate not just the influence of the strength and dedication of the legal system on how far a technology is used, but also the influence of the strength and commitment of all stakeholders on the amount to which a technology is employed. None of the involved entities will be able to achieve adequate technology adoption unless the entire system is sufficiently capable and committed to improving the effectiveness of environmental compliance and enforcement, thereby increasing the demand for and desire for others involved in environmental enforcement to adopt and use technologies to improve process and goal achievement, and thereby increasing the demand and desire for others involved in environmental enforcement to adopt and use technologies to improve process and goal achievement.

2. The knowledge and clarity of legislation

Numerous study discovered that a lack of understanding of environmental rules and regulations was a significant factor contributing to insufficient environmental enforcement and compliance (Ijaiya & Joseph, 2014; B. J. Preston Chief Judge, 2013; Nemesio , 2014). This prior knowledge reinforces and justifies the findings of this theme. While the findings are not directly related to technology use, they appear to give critical evidence to support the remainder of the findings and discussion on this issue.

Findings from the research on the influence of stakeholders' environments on technology acceptance and use indicate that the level of expertise and knowledge of the legislation possessed by environmental enforcers, the general public, and all other stakeholders, as well as the level of clarity of the legislation itself, all have a significant impact on environmental enforcers' use of available technological tools in their work. Increasing people's education and awareness of the law has an impact on the use of enforcers because it allows them to gain a better understanding of what exactly is required of technology in order to carry out the legal process in accordance with current legislation.

This raises the enforcer's satisfaction and understanding of the ultimate goal, as well as what is required to achieve the most effective and satisfactory end result possible through the use of technology. Uniform or clear laws and regulations also

Environmental Enforcement Technology Adoption

increases the desire of law enforcement officers to use technology for the same reason that greater knowledge of the law does (Nemesio , 2014). Environmental law enforcement officers who use technology understand exactly why they are doing so.

The huge and diverse range of multi-stakeholders involved in Bahrain's environmental law enforcement process appears to be the driving force behind these conclusions. Numerous associated entities have responsibilities other than environmental enforcement, and in other cases, environmental enforcement is merely a secondary duty.

As a result of their numerous new tasks and expectations, participants were able to identify this phenomenon. Because of this, the amount of training and effort required to get familiar with and comprehend the legislation that falls within their jurisdiction or mandate could significantly grow. For example, due to time and competence restrictions, enforcers who are accountable for a broad range of obligations may be unable to recognize and know all of the applicable regulations. In some cases, this may limit their performance and willingness in a variety of areas, including the use of available technology, because they may not grasp the purpose and requirements of technology in order to comply with regulatory standards.

Furthermore, it was revealed that the public's awareness and understanding of the law has an impact on the law enforcement officers use of technology because it simplifies their job and saves them time and energy. Enforcement officers will spend less time and effort explaining why and what the public is required to do if the public understands the statute and its obligations, which will be especially important in light of current technology available. Enforcement officers reported that they were satisfied and at ease when interacting with entities and individuals who understood legislation and regulation properly, which helped to increase the time and effort opportunities for more effective and efficient technology use, according to the findings.

Another way that knowledge and ambiguity in legislation impacts enforcers' usage is by increasing their sense of protection while simultaneously holding them accountable when using technology to ensure environmental compliance and enforcement is a positive experience. When law enforcement officers have clear and

understood regulations, they will be able to defend themselves and present proper documentation and requirements from technological advancements. The understanding of the protection of using the technology that is supported by legislation led to increased use of technology for environmental enforcement. Also the public who understand and comprehend the legislation seems to feel protected and use the technology to its full potential.

3. Having clear and unified technologies and procedures between related entities.

After conducting a data analysis on the impact of the two initial factors of having a clear environmental authority and collaboration and coordination between related entities on the extent to which technology is used in environmental compliance and enforcement in the Kingdom, it was discovered that the two factors influenced usage in the same way and to the same extent. The majority of participants either repeated their responses regarding how these factors influenced usage or referred to their previous responses regarding the two factors. When asked about the effect of collaboration and coordination amongst related entities, the participant referred to the same response to the previous question concerning the effect of having a clear authority on usage.

Following an examination and analysis of the data collected, it was concluded that the two aspects have a similar overall impact on the use of technology in environmental compliance and enforcement as each other. Despite the fact that some individuals saw some variation in the extent of influence, the extent of influence for both factors was found to be relatively high in the vast majority of cases.

Following the accumulation of this knowledge, it was decided to construct the sub-theme of process and technology clarity and unification. In order to achieve this result, researchers discovered that the way in which it influences utilization is the same for each. Providing clear, simple, and standard policies and procedures for the use of technology to meet the end goals of ensuring compliance and enforcement was determined to be the most effective method of influencing usage.

Environmental Enforcement Technology Adoption

This creates a sense of unity among enforcers and a clear and unified strategy and process for ensuring compliance and enforcement with related entities, ensuring their effectiveness in achieving their goals and increasing their sense of satisfaction as a result of clear procedures and transparency of data and outcomes.

As was the case with prior conclusions about the stakeholder environment, this issue included comparable arguments for the multi-stakeholder enforcement system. The multi-stakeholder structure of environmental enforcement appears to explain why the findings of a strong influence of clear and uniform processes and technologies between stakeholders on technology adoption are significant.

All participants concur on the need of clarity and uniformity in determining the extent of use. For instance, a unified system and platform through which technologies operate and data is accepted has a significant impact on usage, as it results in less confusion and effort when it comes to submitting and monitoring data, particularly in fields such as environmental compliance and enforcement, as is the case in the Kingdom of Bahrain. This will also serve as a deterrent for perpetrators to commit infractions, as the transparent and traceable data, as well as greater surveillance and monitoring, will serve as a deterrent.

Clear and uniform protocols and procedures for the use of technology for environmental compliance and enforcement among related entities and departments have a substantial impact on the extent to which environmental law and regulatory enforcers use technology.

Although previous research do not explore the direct influence clear and uniform protocols and procedures for the use of technology. They explored the influence of the clarity of mandates and centralization of environmental authorities on the process of environmental enforcement as a whole (Ijaiya & Joseph, 2014; Komaki & Fluharty, 2020; Popa et al. 2019). While some researchers find centralization of environmental institutes effective others find a more decentralization approach is more effective (Zhang 2017). These finds seem to provide basic approval for the findings of this research on the issue of influence of clarity and unity of protocols and

Environmental Enforcement Technology Adoption

procedures for the use of technology among related entities in environmental compliance and enforcement.

This factor has an effect on the tools that enforcers utilize since there is a greater sense of working toward a common objective of safeguarding the environment using tools that are visible, accurate, and timely. The degree to which processes amongst stakeholders are clear and consistent, particularly when it comes to the rules for utilizing technology, is inextricably tied to the amount to which these technologies are used for environmental compliance and enforcement.

Additionally, regulated individuals and commercial entities feel that having clear unified technologies and procedures has a significant impact on the amount to which they employ them. One characteristic that distinguishes the business sector, in particular, is the requirement for improved reputation and stronger ties with regulatory bodies. This need compels regulated entities to comply not merely to avoid sanctions, but also to improve their reputations, which can be commercially beneficial.

Data interchange and access has become more efficient and accurate as a result of the integration of technology and its accompanying procedures throughout the enforcement chain. Also needed are channels of communication that are transparent and easily accessible to both persons and organizations involved in environmental enforcement and compliance. Achieving this allows for the continuous improvement and development of technologies and their related procedures in order to achieve their primary goal of compliance assurance, as well as the integration of information flow.

Effective data circulation and management across stakeholders was also found to influence the environmental enforcement process as a whole by previous research (Nemesio, 2014; Preston, 2013; UNEP, 2019). According to prior research, information should be transparent and accessible to all stakeholders, including the general public. This can help ensure accountability for all parties involved and strengthen the institutions' integrity, which should result in enhanced trust and public participation (Koontz & Newig, 2014; Nemesio, 2014; Preston, 2013). This finding seems to further support the knowledge gained on the issue of clarity and unity of

protocols and procedures for the use of technology for environmental compliance and enforcement among related entities and departments.

4. Integration of technology across stakeholders.

It has been demonstrated that the integration of technology across all relevant entities for the purpose of environmental compliance and enforcement has a significant impact on the extent to which these technologies are used (Brown et al. 2002). This concept was discovered to be critical in the acceptance of the technologies by the people who utilize them. The key reason for this, as determined by the research, is the requirement for acceptable, transparent, and concrete data and procedures, particularly when it comes to the final consequence of infractions and criminal prosecutions. Because of the nature of the Kingdom's multistakeholder system, any flaws or inattentive procedures or measures by any of the involved entities may result in insufficient results due to the structure of the system.

Assurances of efficacy of processes and outcomes of technology use are critical to the acceptance of these technologies by the general public and enforcement entities. An important factor influencing the extent to which environmental enforcers are used is how well the BCG and related entities integrate and accept the data output by the legal procedure in which it is used.

The research identified two major elements that determine how technologies are integrated and thus the extent to which they are used. The first was the requirement that all stakeholders use the technology. The amount of effort spent utilizing technology for environmental compliance and enforcement is quite extensive. The majority of interviewees stated that they use technology almost exclusively to carry out their environmental compliance and enforcement responsibilities. This is because technology has altered their practices and has also become a requirement for them to accomplish their tasks.

According to the interview data, even with little user acceptance, necessity has forced it into their operations, and they are unable to fulfill the tasks and obligations assigned to them without utilizing the technologies now implemented in marine

Environmental Enforcement Technology Adoption

environmental enforcement. They incorporate technology into the majority of their environmental compliance and enforcement procedures and operations.

The preceding findings show that it is critical for all stakeholders to mandate the usage of the same technologies and to integrate them across the concerned entities. This helps conserve resources such as time and effort by providing a clear understanding of the present state and procedures of other entities. Additionally, this assists in avoiding confusion and conflict among stakeholders. This was demonstrated to have an effect on the extent to which users employ technology, in the sense that they have knowledge and access to the technologies in use and are aware of the precise status and additional required procedures. This sense of obtaining accurate, transparent, and efficient information encourages them to expand their reliance on technology to carry out their responsibilities.

Throughout the study of the interview data, the concerns of tangibility of evidence and authorizing and mandating the use of technology to fulfill tasks recurred. This was determined to be a critical aspect throughout the environmental compliance and enforcement process, from the first stages of monitoring to the last stages of indictment by the Public Prosecution. The extent to which the technologies' output and data are acknowledged and sanctioned by the legal system, particularly by the Public Prosecution, has an effect on the intention of environmental law enforcers to use these technologies. This is particularly true when it comes to the tangibility of the output data used as evidence in certain processes, most notably legal ones.

Previous study on environmental enforcement lends more weight to the argument that the tangibility of data generated through technology has an influence on law enforcement. One discovery that demonstrates the critical nature of data tangibility, particularly in the legal system, is the critical role of specialist courts in environmental enforcement and protection (Glicksman et al. 2019; Milmanda & Garay, 2020; Nemesio, 2014). For example, Nemesio (2014) concludes that the availability of specialized environmental courts with a thorough understanding of environmental laws and the consequences of environmental crime and degradation enables effective compliance enforcement through strong deterrence of environmental crimes and violations.

The tangibility of evidence derived from data is critical for environmental law enforcers. This appears to come up in the majority of interviews when discussing various facets of evidence's accuracy. The tangibility of evidence has improved as a result of the technology used for environmental compliance and enforcement, as it is now possible to pinpoint the exact locations and identifications of violators, as well as provide visual and audio proof of the violation, using data recorded from the system or from cameras and other sources such as the AIS tracking device.

The data quality becomes critical during the environmental compliance and enforcement process (Giles et al., 2021; Milmanda & Garay, 2020; Preston, 2013). This necessitates regular monitoring and updating of systems, all the more so when the very nature of data analysis and storage is impacted. This must be considered as accuracy grows, and further procedures must be taken to guarantee that precision is maintained with increased regularity.

The above factors were found to influence the extent of use of technology for environmental compliance and enforcement in the Kingdom of Bahrain. These factors were also found to be factors that hinder environmental compliance and enforcement in a broader context. Not only do they impact the acceptance of the technology used, but also can hinder the whole enforcement process leading to inadequate satisfaction of entities and individuals involved in compliance and enforcement. For example, it can lead to low job satisfaction of enforcers because of increased effort and inadequate results of environmental protection in general (Giles et al., 2021; Komaki & Fluharty, 2020; Milmanda & Garay, 2020; Nemesio, 2014).

Theme 4: Mandatory settings

The findings on technology acceptance in mandatory settings made significant contributions to our understanding of this issue. The settings for technology use in this research were determined to be mandatory, as the technology used by the BCG and related stakeholders is mandatory for users and is required for the completion of their tasks, processes, and procedures, although in some cases, such as with self-compliance involved individuals, they are voluntary.

Environmental Enforcement Technology Adoption

The mandatory nature of technology in this research gave an excellent opportunity to explore and attempt to get further expertise and knowledge about the subject. There is a dearth of literature on technology acceptability in required situations. Particular emphasis is placed on theories such as TAM and TRA, which were first used to analyze technology acceptance in voluntary circumstances where the user may not have a choice about the technology's usage or selection.

Later study sought to address the issue of earlier theories being irrelevant in non-volitant contexts by including elements that evaluate the consequences of required settings on acceptance. Numerous research, such as the UTUAT, TAM, and TPB models, have sought to better explain and forecast technology adoption in voluntary and required contexts (Agarwad & Prasad, 1997; Brown et al. 2002; Linders, 2006; Rawstrone et al. 2000).

According to the findings of this research, established technology acceptance models, such as the Technology Acceptance Model, do not sufficiently predict and explain technology usage in required contexts. This is in line with past research in this field (Agarwad & Prasad, 1997; Brown et al. 2002; Linders, 2006; Rawstrone et al. 2000). There are several factors involved, including the M-Tam and the recommended improvements from this research to explain technology acceptability in required situations.

To attempt to explain the impact of the amount to which technology usage is voluntary, the study initially considered including a voluntariness moderator from the UTAUT (Venkatesh et al. 2003). The researchers concluded that the degree of voluntariness was meaningless because all of the technologies under consideration were entirely necessary and had no degree of voluntariness. The first proposed concept of extent of usage intention to utilize appeared to be meaningless in required circumstances, as well.

Other investigations discovered that the aim to use technology in required contexts has no relationship to its adoption (Linders, 2006). For instance, Linders (2006) focuses on mandated improvements in information systems, as opposed to

theories and outcomes that address voluntary use. Modifications were made to the Technology Acceptance Model in order to anticipate and explain technology adoption in mandated situations more accurately. The Behavioral Intentions and Use variables were removed from the updated model since the research discovered that they were not relevant in determining the success of obligatory information systems. It was discovered that the major factor of IS success was one's attitude, which was followed by the ease with which the system was used. The key factor influencing attitude is usefulness (Linders, 2006).

The extent of use was the only concept developed to attempt to address the issue of technology acceptability in required situations. The findings indicate the extent of use, which is related to the degree to which the technology will be employed. The Technology Acceptance Model is insufficient for forecasting and explaining technology adoption in compulsory situations. Although attitude and other variables influenced the amount to which the technology was used, they had no effect on the intention to use the technology because it is necessary, and users have no option. In the required setting of the study domain, we eliminated the intention construct and replaced it with the extent of usage, which may be impacted by another aspect in the model, such as attitude toward the technology.

From the analysis of the data collected, in particular on the issue of intent to use and extent of intention to use. The research deduced that the phrase intention to use was expressed in the interviews, actually means actual use. This understanding was reached when analyzing findings on the purpose and the extent of use of the current technologies and impacts. The participants expressed the view that they have no choice of using the technology and that they are necessary in completing their tasks and mandates. The same was found in regard to other related entities, including the public and private entities. The phrase intention to use was an expression of the extent of actual use of the technology. The technologies in the study were all mandatory and necessary to utilize.

Brown et al. (2002) conducted one of the studies that cast doubt on The TAM's capacity to explain technology acceptance in mandatory contexts. They describe a mandated setting as "one in which users are forced to utilize a certain technology or

system in order to maintain and execute their duties." According to Brown et al. (2002), the TAM and its expansions in required contexts address just the question of need. They discover that mandatoriness is a far more sophisticated concept that encompasses the degree to which a technology is required to execute a task or job and the degree to which the technology's application is integrated across people.

Brown et al. (2002) sought to demonstrate that in a fully integrated environment in which utilizing the system is the only way to perform a task, the TAM is less successful at describing use behavior than alternative theories. Their data suggest an association pattern that is not consistent with what is frequently stated in the literature.

As per Brown et al. (2002), discrepancy between one's attitude and actual behavior increases, which might result in unexpected consequences. They continue by stating that negative perceptions may encourage users to question the motives for adopting new technology, resulting in the formation of additional hurdles during the adoption process. Although attitude and other characteristics had an effect on the amount to which the technology was used, they had no effect on the intention to use the technology since it is required and users do not have a choice whether to use it or not, as Brown et al. (2002) shown. As a result, the research concludes that the intention construct is irrelevant to technology acceptance in the required context of the research domain and substitutes the level of usage for the intention, which may be impacted by another model feature such as attitude toward the technology.

Another conclusion is that the need of utilizing technology to accomplish the user's activities and goals has a direct effect on the amount to which the technology is used, a finding that Brown et al. also discovered (2002). The degree of need was discovered to be a contextual variable that varies depending on the organization's strategy and external environment. The requirement of utilizing technology to complete activities and accomplish goals clearly influenced the amount to which technology was utilized (Brown et al. 2002).

This is obvious in the data, since the majority of participants stated that technology is required to do their activity. The degree of necessity seemed to better explain technology acceptance in mandatory settings than voluntariness moderator

from previous models. Since the use is mandatory there will be no degree of voluntariness. Rather the users will be compelled to utilize the technology farther if the use is necessary to complete their tasks and goals.

The majority of technical applications are adopted and selected by senior management with the expectation that they would be used by personnel, particularly in law enforcement organizations and institutions. This might result in the failure or dispersal of the technologies' deployment and use by employees if they are not welcomed or opposed. This is critical when decision makers and implementers want to integrate technology into their enforcement systems. Making technology a needed and necessary tool can assist in increasing usage and, as a result, technological acceptability.

5.8 Main Findings

This section will present the conceptual model of the research which was developed from knowledge from previous studies and the findings of this research.

Research Conceptual Model (Enviro-TAM)

From the findings of the thematic analysis of this research, a modified technology acceptance model was developed from understanding from previous studies and was named the Enviro-TAM. The Enviro-TAM was developed to help understand technology adoption of users involved in environmental compliance and enforcement. One of the most influential models for Enviro-TAM is the previous M-TAM model used in UK police was done through adding tailored elements which can differ from general law enforcement and context of applications. Although the M-TAM was not initially used to explore the various case studies, many of its constructs and relationships were found to be similar and apply to this research.

Environmental Enforcement Technology Adoption

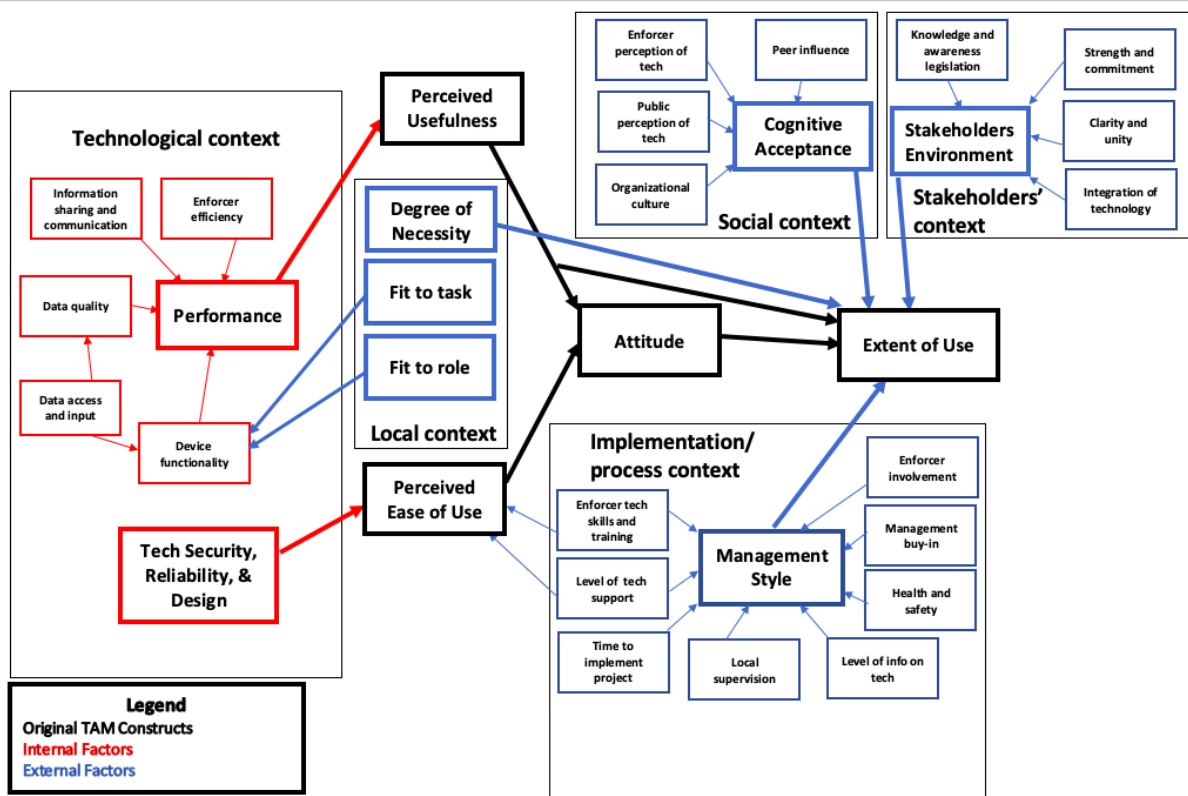


Figure 5. 1 Enviro-TAM (Technology acceptance model for environmental enforcement)

The research findings shows similarity and applicability of the M-TAM model to the field and context of this research. The four main constructs of Technological context, Social context, Implementation /process context, and Local context are the main categories of the M-TAM. The M-Tam also included construct from the original TAM. The findings gave adequate evidence of the applicability and transferability of the M-TAM for the general technology acceptance in the field of environmental compliance and enforcement in the Kingdom of Bahrain. Most of the constructs and their relationships were found to be similar and applicable, which to their representation in this model.

One main modification was added to deal with the issue of mandatory settings, by the addition of the newly generated construct of extent of use to replace intention to use and actual use. The perceived usefulness and perceived ease of use had significant influence on the attitudes of the users and the further the perceived usefulness had direct influence of the extent of use of the technology. The external

factors of social context, implementation, and process context the were found to have influence on the extent of use of the technology by users. The applicability of the constructs of the model to general technology use rather than only mobile technology. Further constructs were developed that were unique to the field and context of the research, mainly the stakeholder environment.

The model had three main categories of factors: original TAM factors, Internal factors, external factors. Detailed explanation and evidence of the constructs and their influence was provided in the previous section of the findings of this chapter. The following explains the constructs and their influence on technology use and adoption in environmental compliance and enforcement in the marine environment in the Kingdom of Bahrain.

The original TAM factors:

These are the original factors of the TAM model with similar relationships with one major modification. The new developed construct of extent of use which replaces the behavioral intention and actual use constructs from the original model which were found to have inadequate explanatory abilities of technology adoption in mandatory settings. The attitude towards a technology is influenced by both the perceived usefulness and perceived ease of use. The perceived usefulness and attitude further directly influence the extent of use of the technology rather than the intention to use, as in the original model. Although the two constructs of behavioral intention and actual use were omitted from this research's model and replaced with extent of use.

The other constructs from the TAM were found to be applicable and are the: 1) ***Perceived Usefulness***: Perceived usefulness is the realization that new technology will increase or improve overall performance (Davis, 1993). 2) ***Perceived Ease of Use***: Davis (1989) defines PEOU as "the degree to which a person believes that using a particular system would be free from effort." 3) ***Attitude***: The attitude the user has towards using the technology. A positive attitude results in increased use of the technology, and vice versa with negative attitudes.

As for the new developed construct of ***Extent of Use (NEW)***, it is defined as the degree the user will use the technology or to what potential they will use it. This construct arose from the knowledge gained by previous studies and this research's findings that Technology Acceptance Model does not adequately predict and explain technology use in mandatory settings. Although attitude and other factors had an influence on the extent of use of the technology, it had no influence on the intention to use the technology since it is mandatory, and the users do not have a choice of using. The intention construct irrelevant to technology acceptance in the mandatory setting of the research domain and replaced the intention with the extent of use which may be influenced by another factor of the model such as attitude towards the technology.

The Internal Factors:

These are the factors that are internal and related to the technology's attributes and performance. They are displayed in the research's model in the category of technological context. The degree of the technology's reliability, security (The degree to which the technology is perceived reliable and secure, in which the technology is secure from any malfunction and can be reliable to complete tasks), and design (The degree to which the technologies' design is tailored to users' needs and is user friendly) influences the perceived ease of use of the users. The user perceived the technology to be easy and effortless as the reliability, security, and interface design friendliness increased.

Another main technological context factor is ***performance*** which is defined as The perceived performance abilities of the technologies regarding the enhancement of the user's task or job. This factor directly influences the perceived usefulness of the users of the technology. The performance factor's main influencer was found to be the ***device functionality*** defined as the degree to which the user finds the technology purposeful in regard to their tasks, is affected by several internal and external factors. Other factors that influence performance were found to be enforcer efficiency, data quality, and information sharing and communication capabilities.

The Local Context factors:

Factors that are related to the technology application but not determined solely by the technology's attributes. The three factors within this context are fit to task, fit to role, and degree of necessity. The fit to task and role factors had positive influence on the device functionality, while the degree of necessity had direct influence on the extent of use of the technology. The higher the degree of necessity is for using the technology, the higher the extent of use of the technology.

The ***fit to task*** from the M-TAM was found to influence device functionality. The tasks that require more durable and agile technologies entail technologies that are usually more basic and dependable (Device functionality). For example personnel tasked with patrols require small and heavy-duty devices to withstand their limited spaces and harsh working environment. While operations personnel require more sophisticated systems to ensure proper understanding of situation and effective communication to ensure proper and clear communications. This factor of fit to task influences the prospection of the user on the device functionality. If the users perceive the technology fit to their task, they will have positive perception on the technology's functionality.

As for the ***fit to role*** from the M-TAM was found also influence device functionality in the same way the fit to task construct. Positive fit to role perceptions have positive influence on the device functionality perceptions. The main role found were monitoring, direct enforcement, coordination, awareness, legal, and self-compliance. Each of the previous roles require certain attributes and specification to be available in order to effectively achieve their role in the environmental compliance and enforcement process. For example monitoring uses complex and surveillance related technology, while legal processes required more data management technologies. The fit to task and role have strong influence on the device functionality.

Degree of Necessity (NEW) which is defined as the extent to which the user perceived the technologies' use is necessary or mandatory. The degree of necessity was found to be a highly influential factor of technology adoption and use in mandatory settings. The necessity of using the technology to complete the user's tasks and goals

is a direct influencer on the extent of use of the technology. This factor was found to have a strong positive influence on the extent of use of the technology by the user. The more necessary the use of the technology is, the higher the extent of use.

The External Factors:

Factors relating to issues outside the technologies' capabilities that influence the extent of use directly. They are the local context, Implementation/process context, social context, and stakeholder's context factors.

The Implementation/process context are organizational factors:

The main construct of this context is the ***management style*** which determines the implementation and process of the organization. The factors within the management style construct that were found to influence technology acceptance and use were enforcer involvement, management buy-in, health and safety, level of information on technology, local supervision, time to implement project, level of technical support, enforcer's technological skills, and training.

Although all these factors were found to influence the extent of use of the technology, some of these factors had positive influence on the perceived ease of use. These factors were the level of technical support and enforcer's technological skills and training.

The social context factors:

Factors regarding the social norms and perception of the technologies and their use. The main construct is ***cognitive acceptance***, which is the mental perception or degree of acceptance of the technology. Four factors are under the umbrella of cognitive acceptance: The enforcer's perception of the technology, public perception of the technology, peer influence, and organizational culture. These factors directly influence the extent of use of the technology.

The Stakeholder's context factors (NEW):

Environmental Enforcement Technology Adoption

Factors that are related to the stakeholder's involved in the environmental compliance and enforcement process. These factors were found to be highly influential on technology use and acceptance in multistakeholder processes. The stakeholder's environment construct has positive influence on the extent of use of the technology.

The four constructs are the factors that were found to be part of the stakeholder's environment that had influence on the extent of use of the technology in the context of the study: The legal system's strength and commitment, The knowledge and clarity of legislation, Having clear and unified technologies and procedures between related entities, and the Integration of technology across stakeholders. These factors were found to influence the extent of use of technology for environmental compliance and enforcement in the Kingdom of Bahrain.

a) Strength and commitment

This construct arose from the findings of the influence on the degree of strength and commitment of the environmental enforcement systems on the extent of use of the technology. This was found to be a highly influential factor, especially the strength and commitment of the legal system to delivering suitable and effective punishment to violations to ensure compliance. The stronger the system the more the enforcer's use of the technology will be as a result of the deterring and satisfactory outcome of the use of technology.

b) Knowledge & awareness

This construct is related to the factor of the knowledge and awareness of the legislation and regulation. The proper knowledge and understanding of the legislation by the enforcers as well as the public was found to influence the extent to which the technology will be used. This is the result of the proper understanding of the users of the purpose of the technology, boundaries of use, and how the technology can benefit their processes and procedures of implementing the legislation.

c) Clarity and Unity

This construct is related to the factor of the clarity and unity of technologies and procedures. This factor was found to influence the extent of technology use by both enforcers and the public. The availability of common procedures and goals through the use of technologies highly influence the extent to which the users to achieving their ultimate goal of environmental protection. The also enhances the sense of unity and having clear understanding and knowledge of required procedures for the use of the technology.

d) Integration of Technology

This construct is another factor found to influence the extent of use of the technology for the purpose of environmental compliance and enforcement. The integration of technology across all the stakeholders is essential to the users of the technologies to ensure the tractability, effectiveness, and satisfactory outcome of the use of the technology. This was found to be especially important when it comes to the authorization and tangibility of the data and information in the legal process. The research found that the tangibility of the information provided by the technology as evidence by the legal system is highly influential on the extent of use.

Chapter 6 Conclusion

6.1 Summary of the Research

The goal of this study is to explore technology use and adoption of users involved in environmental enforcement in the marine domain in the Kingdom of Bahrain. This information should help environmental enforcement entities improve the efficiency and effectiveness of technology use in their respective fields. A technology adoption model was developed to determine the factors that influence technology use and adoption of users involved in environmental compliance and enforcement in the Kingdom of Bahrain in order to achieve the study's objectives.

The study discovered several unique characteristics and influencing components to the field of environmental compliance and enforcement in the Kingdom of Bahrain. One factor discovered was the stakeholder's environment, which supplemented prior study on technology adoption in other law enforcement fields. This factor was found to be particularly relevant in this research due to the multistakeholder nature of the environmental enforcement mechanisms the Kingdom of Bahrain.

Another significant finding and explanation made by the research is the mandatory setting of technology use in law enforcement agencies. The traditional acceptance/adoption theories of technology were proven to be insufficient to explain the issue of obligatory technology use. The study's primary results on this subject are that intention to use is irrelevant and that the degree of necessity plays a significant role in determining the amount to which technology is used.

The model was created using previous research and research findings, through the use of a qualitative approach with multiple case studies triangulated with onsite observations, documents, and interviews with relevant stakeholders to explore the use and adoption of technology in environmental compliance and enforcement in the Kingdom of Bahrain. The research conducted interviews on a total of twenty individuals who were involved in environmental compliance and enforcement. The

participants all have a role in environmental compliance and enforcement and rely on a variety of technologies to carry out their responsibilities.

6.2 Theoretical Contribution

The major theoretical contributions of the thesis were listed in logical order and are as follows:

Contribution to technology adoption

A modified model is developed to explain and predict technology adoption in the field of environmental compliance and enforcement in the Kingdom of Bahrain. This research is the first attempt to establish a model examining the factors affecting technology adoption of users involved in environmental compliance and enforcement in the Kingdom of Bahrain. The model also gives insight into mandatory setting technology adoption and the model is both user group and technology independent, in that the majority of previous studies use a single group and technology. It is meaningful knowledge for researchers and practitioners in environmental compliance and enforcement. When adopting or enhancing technology applications in this field, this model maybe a starting point for further empirical research to implementers or decision makers.

The model provides a comprehensive understanding of technology use and acceptance for implementing or adopting technologies for the purpose of environmental compliance and enforcement, especially in the Kingdom of Bahrain and the Middle East, to enhance effectiveness and efficiency. The research finds that elements and their influence from previous models used in this research of technology adoption and the general field of law enforcement are applicable to environmental enforcement.

The main theoretical contributions for technology adoption will be described below:

Technology adoption for environmental enforcement: The model developed in this research discovered the new construct of Stakeholder's environment, which was found to have significant influence on technology adoption in a variety of ways, including legal system seriousness and strength, clarity and unity among stakeholders, legislative knowledge, and technology integration across stakeholders. Another significant conclusion is the insignificance of the intention to use and the significance of the degree of necessity of usage in determining the amount to which technology is used.

Technology adoption for mandatory settings: The researcher explored and attempted to explain technology adoption in mandatory settings. Previous research was conducted on technology adoption in mandatory settings. Some of the studies arrived at similar findings of the inadequate explanation of traditional models in mandatory settings. The technology use in this research was found to be of a mandatory nature, since most of the technology applications utilized by the BCG and related stakeholders are compulsory and are necessary to accomplishing their tasks, processes, and procedures.

The research finds the construct of behavioral intention to be inapplicable to mandatory settings. Rather the research finds the factor of the model to influence to extent of use. How much and to what potential will the technology be utilized. Another important factor discovered in the context of mandatory settings is the degree of necessity. This factor was found to be a direct influencer of the extent of use.

Technology adoption for entire professional group: The purpose of this study and the corresponding research model is to investigate the technology adoption by an entire group of professionals. The outcomes of the study suggest the applicability of the model to environmental enforcers regardless of their organization, location, kind of work, access to and familiarity with technological applications. Theoretical and practical considerations suggest that the model should be similarly relevant to different groups of environmental enforcers; however, more testing is necessary to validate this.

Technology adoption for both specific and general technologies: The research model was created to maximize its value by being applicable to particular or general definitions of technology, therefore filling a substantial vacuum in the literature (technology adoption studies apply to a single type of technology). On the basis of the model's theoretical foundation and the findings of this study, the model's constructs and relationships are system independent, and the model is therefore expected to apply equally to a general technology or a specific application technology; however, additional research is required to acquire empirical evidence supporting this claim.

In contrast to other research, which often limit the examination of technology adoption to a single work context and a single type of technology, this study examines the adoption of technology across several work settings and technologies. This study was independent of technology and user groups. This strategy has the potential to boost the generalizability of findings across user groups and technologies within environmental enforcement.

Contribution to current technology usage

The research identified the current technology utilized and its determinants. One tool to address some of the aspects that was found to have great potential to increase effectiveness of environmental compliance and enforcement processes and procedures including some of the issues found previously to hinder these systems is technological applications (Thomas, 2021). These applications were found to be utilized by many roles and responsibilities of the environmental compliance and enforcement stakeholders in different ways and through different technologies (Joe et al. 2018; Kumar et al. 2019; Manfreda et al. 2018).

The research explored the roles of entities and individuals involved and the technologies used for each role and process. The research clarifies the major roles of the BCG and related stakeholders in environmental compliance and enforcement in the marine environment. The research finds that the BCG has a major role in environmental compliance and enforcement, although the BCG is considered a supporting entity in environmental protection.

Environmental Enforcement Technology Adoption

Monitoring of maritime activity and direct enforcement of marine related environmental laws and regulations have been found to be the main role of the BCG and related entities in environmental enforcement and compliance and they also have the role of awareness and coordination with related entities with regards to environmental compliance and enforcement. For the purpose of environmental compliance and enforcement, BCG personnel utilize various types of technology for their roles in the enforced in the environmental compliance and enforcement process.

The main technologies are GPS, radars, cameras, and AIS devices, which in some cases are used in an integrated system which is used for surveillance and monitoring as well as coordination of patrols and other procedures. The BCG main IT software technology is the GSS. The type of technology used varies according to the job description, ranking, and job. The personnel working in direct patrols, such as patrol vessels, use more basic types of technologies such as GPS and radars. The personnel in the operations center and supporting officers use an integrated system that integrates most of these technologies together.

Contribution to benefits of technology use

Nearly all the BCG personnel and related stakeholders feel very comfortable with and use the technology full time in all their processes and procedures. Research finds the main factors that affect their comfort and the time they have spent using that technology is technology's benefits and the necessity to use the technology to complete tasks appointed to them.

The impact of the use of technology was evident on the individuals and entities involved in environmental compliance and enforcement in the Kingdom of Bahrain. Four main benefits were identified: speed, accuracy, transparency, and costs. All seem to be affected positively by the use of technology. Although the benefits of these technologies are evident, there are various limitations and concerns identified by the research. The main issues found were initial cost, privacy, understanding of the technologies, fit to background, integration, dependency on technology, speed of advancement, and security.

This provides an insight into the impact of the use of technology on environmental compliance and enforcement, as well as an indication of the relative success of technology adoption in the field of environmental compliance and enforcement in the Kingdom of Bahrain.

Contribution to environmental enforcement systems

From the extensive literature review and its analysis, the research was able to identify several factors that contribute to the insufficient effectiveness and efficiency of current environmental enforcement systems. Although globally, countries including the Kingdom of Bahrain have pledged great dedication and commitment to combating environmental degradation and challenges and to achieve sustainability goals. The speed and extent of environmental damage and degradation is increasing at an alarming rate which has resulted in extreme pressure on environmental organization and entities. Many initiatives have been implemented in an attempt to curb these impacts.

Increasing environmental compliance and enforcement capabilities through enhancing its effectiveness and efficiency was found to be one of the most crucial aspects. The research identifies several factors hindering current environmental compliance and enforcement systems around the world. The main identified factors were as follows (Giles et al., 2021; Komaki & Fluharty, 2020; Milmanda & Garay, 2020; Nemesio, 2014; Preston, 2013):

1. Weak and uncommitted legal systems
2. Lack of clear authority directly responsible for enforcement
3. Inadequate collaboration and coordination
4. Insufficient circulation and sharing of information
5. Weakened understanding of environmental laws and regulations
6. Inadequate incorporation of international laws into the local legal system
7. Corruption
8. Lack of specialized courts and understanding of laws by judiciary systems
9. Weak institutional capacity
10. Weak civic engagement

6.3 Implications

Addressing the issues of certain aspects of the research can help make an impact for environmental protection systems, especially in the Kingdom of Bahrain. This section will present general implications, as well as more specific implications for the Kingdom of Bahrain

Implication for technology adoption

Understanding the significance of technological acceptance and the elements that influence it can have a significant impact on the success of any technology. The characteristics found by the research can help to improve present technology applications by enhancing technological adoption among users, allowing them to realize the full potential of the technology. This is critical knowledge for the Kingdom of Bahrain and those trying to advance and improve their performance in environmental compliance and enforcement by embracing and investing in increasingly advanced technical solutions.

The model provides a comprehensive understanding of the factors and their influence on technology acceptance of users in mandatory settings to ensure optimal utilization potential and technology acquisition and tailoring to needs. The also provides knowledge beneficial for future institutional and legislature structures and development. The understanding of the technological requirements are needed to understand the needs of future organization structures and needs since most advanced entities require advanced technologies to achieve their goals.

Implication for technology adoption in mandatory settings

Another significant aspect of this research is the depiction of knowledge regarding technology adoption in mandatory contexts. The study's findings add to the explanation and prediction of technology adoption in required settings established by prior studies. This information is essential for academics working in the subject of technology, particularly technology adoption. Most previous studies attempted to investigate technology adoption in varied degrees of volatility of use technology.

Others are researching more forced usage of technology. The knowledge provided by this research contributes to the already growing body of knowledge on the subject.

Further, practitioners can apply this knowledge to predict and tailor technology for use in mandatory settings, especially in law enforcement systems. The Kingdom of Bahrain may benefit from this knowledge to enhance user acceptance and success of technologies. Especially through the complex understanding of the current issues facing technology use in mandatory settings in the context of the Kingdom.

Implication for technology use in environmental enforcement

When it comes to the technologies used and their impact on environmental compliance and enforcement, these factors are essential aspects that should be part of the adoption and integration scheme of the entities responsible. The manner in which these technologies affect their processes, either positively or negatively, should give a clear picture for decision makers and implementers to choose the most appropriate technology and to put in place proper implementation plans to ensure the effectiveness and efficiency of these technologies, including training and integration plans. These factors also get increased information to advance current technology efficiency.

Implication for environmental enforcement systems

Addressing the issues identified by the research to hinder the current environmental policy system can have an effect on the effectiveness of current compliance and important systems (Giles, 2020). The issues identified by the research have to be kept in mind by policymakers when tailoring or adopting compliance and enforcement plans.

Some issues can be resolved by lower-level decision makers such as the related entities involved in compliance and enforcement. For example, information sharing, coordination, and collaboration can be increased by certain organization agreements between the entities, while other issues require higher-level decisions,

such as the forming of a more specialized environmental courts and increasing institutional capacities.

Implications for the Kingdom of Bahrain

The Kingdom of Bahrain is strongly committed and invested in ensuring sustainability of the development process in multiple areas, including environmental protection and the achievement of a balance in the requirements of development, social and economic aspects. Bahrain has established several institutions, agencies, and commissions involved in achieving sustainability in various dimensions through programs, policies, and strategies. As well as the enhancement of laws and the ratification of many multi-lateral conventions and agreements related to sustainable development.

This research has several implications for the Kingdom of Bahrain that may enhance probabilities of attaining their targets and goals of sustainability and environmental protection. The research has emphasis on the implementation stage of environmental protection, and especially environmental enforcement. The implications range from general institutional capacity and structure issues to technology adoption issues.

When considering the broader and holistic concept of environmental enforcement in the Kingdom of Bahrain, the research provides knowledge and understanding on the nature of current systems and some of the efficiency hindering factors. The Kingdom of Bahrain has unique enforcement systems which rely on various entities and organizations to achieve their goals. The research provides a deep and insightful understanding of the importance of achieving effective networks and mandates among entities to ensure adequate data and process flows. Without proper coordination and collaboration the system will ultimately be at risk of failure to achieve effective enforcement. This is essential to practitioners and decision maker in the kingdom, especially for future planning and structuring of environmental enforcement systems and allocating mandates.

Further this research generated knowledge can potentially guide legislatures on the most effective laws and regulation. Devising clear and wholesome legislation that takes into account the whole system of multi stakeholders. The legislation should be clear and applicable across the stakeholders, to ensure clear understanding and unity of mandates.

The Kingdom of Bahrain is increasingly and continuously searching and investing in technological solution to advance their processes and achieve their goals of environmental protection and sustainability. This rising interest and commitment in technological solution requires advanced technology selection and adoption method for effective evaluation and assurances of success. The knowledge attained from this research provides comprehensive understanding of technology adoption and acceptance for environmental compliance and enforcement in the Kingdom of Bahrain. The application of the research's modified technology acceptance model can guide and help ensure proper technology selection and adoption. The knowledge regarding technology acceptance can further help implementers and decision maker in understanding the factors that enhance technology acceptance for enforcement entities. The technologies used for these systems are mostly mandatory in nature and require specific attributes and determinants to be successful.

Also the knowledge attained by the research on current technology use and its impact can help implementers to better evaluate and more appropriately advance selection and upgrading of technologies. This is further improved by the proper understanding of the way in which the benefits influence technology acceptance and vice versa. Ensuring maximum benefits of technologies is essential for their success.

6.4 Limitations of Research

The findings of this are significant in the field of technology and technology acceptance in environmental compliance and enforcement, therefore it is necessary to outline some general limitations of this research.

Environmental Enforcement Technology Adoption

One major external limitation of the research was the ongoing COVID-19 pandemic, especially in the data collection process. Social distancing and lockdowns caused severe interruption to the data collection, especially to the interviews and the researchers' observations. Archival data was not affected as much since it did not require direct human interactions. The preliminary method of interviews was direct face-to-face interviews which was not possible at the time of data collections from the last quarter of 2020 to the beginning of 2021.

The interviews had to be conducted through various techniques to accommodate social distancing procedures required in the pandemic. The interviews were conducted online through social media platforms such as WhatsApp video calls, meeting applications such as Zoom and Microsoft teams, and via telephone. This required increased time and effort to organize to accommodate differences in interviewees preferences and technical skills and availability.

Also, the increased responsibilities of the members of the Ministry of Interior dictated by the COVID-19 pandemic meant finding suitable timing to conduct the interviews was challenging, so the interviews had to be shortened to accommodate this issue. As for the direct observations, the initial plan was to gather observation from the field and offices from December 2019 to May 2020. This was cut short due the initiation of social distancing and lockdown procedure in late February 2020.

Another issue is restriction of data sources and difficulty of obtaining data from some sources (Yin, 2018). This is due to strict protocol of the Ministry of Interior from which the primary and secondary data sources are obtained. The Ministry of Interior is responsible for national and public security of the kingdom and some sources and types of data can be considered confidential because of privacy or security issues.

Low abundance of literature on technology in environmental compliance and enforcement and technology adoption was another limitation of the research. Also, the research did not directly investigate the factors influencing the effectiveness of environmental compliance and enforcement in the Kingdom of Bahrain or the surrounding region. The research only researched previous literature on the subject

of shortcoming all around the world. The findings do not reflect the situation in the Kingdom or the region and may be considered only somewhat inclusive.

6.5 Future Research

This study's theoretical framework and findings lay the groundwork for future research on technological adoption in the field of environmental enforcement. Further research is needed to verify and measure various aspects that were previously discussed in the contributions section, especially on the contributions to technology adoption.

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Appendix A: Interview Protocol BCG and related stakeholders

For the purpose of this case study the following terms will be defined as:

- Technology the use of any technology as a tool enabling environmental compliance and enforcement.
- Environmental compliance and enforcement: ensuring that the requirements of laws, regulations, and codes designed to protect the environment are met through self-compliance and direct enforcement.
- Technology acceptance: is the user's acceptance of the technology resulting in actual use of the technology

1. What is your role in environmental compliance and enforcement?
2. What technologies do you use for the purpose of environmental compliance and enforcement? (briefly explain each)
3. How often do you use technology for the purpose of environmental compliance and enforcement?
4. How has technology impacted the speed, accuracy, transparency, and cost (including direct financing and manpower) of transactions relating to environmental compliance and enforcement processes and procedures? (What other factors were impacted)
5. Please describe your level of comfort in using technology for environmental compliance and enforcement. (why)
6. To what extent and how does technology acceptance affect the actual use of technology in environmental compliance and enforcement?
7. To what extent and how does the legal environment impact usage intention of technology by environmental compliance and enforcement personnel?
8. To what extent and how does the legal system seriousness and strength impact the intention to use of technology by environmental compliance and enforcement personnel?

Environmental Enforcement Technology Adoption

9. To what extent and how does having a clear environmental authority impact the intention to use of technology by environmental compliance and enforcement personnel?
10. To what extent and how does the knowledge of legislation and its ambiguity impact the intention to use of technology by environmental compliance and enforcement personnel?
11. To what extent and how does the collaboration and coordination between related entities impact the intention to use of technology by environmental compliance and enforcement personnel?
12. Please describe any other factors that affect technology acceptance unique to the field of environmental compliance and enforcement?
13. Do you have any questions that you would like to ask?

Appendix B: Interview Protocol BCG and related stakeholders (Arabic)

لغرض دراسة الحالة هذه، سيتم تعريف:

- التكنولوجيا على أنها استخدام أي تقنية كأداة تمكن من الامتثال والإنفاذ البيئي.
- الامتثال والإنفاذ البيئي: عملية تنفيذ وتطبيق قوانين البيئة عن طريق الامتثال والتنفيذ المباشر للقانون.
- قبول التكنولوجيا: قبول المستخدم للتكنولوجيا الذي ينتج عن استخدام فعلي للتكنولوجيا.

١. ما هو دورك في الامتثال والإنفاذ البيئي؟

٢. ما هي التقنيات التي تستخدمها لغرض الامتثال والإنفاذ البيئي؟ **الرجاء شرح كل منهم بإيجاز**

٣. كم مرة تستخدم التكنولوجيا لغرض الامتثال والإنفاذ البيئي؟

٤. كيف أثرت التكنولوجيا على السرعة والدقة والشفافية والتكلفة (بما في ذلك التمويل المباشر والقوة البشرية) للمعاملات والجراءات المتعلقة بالامتثال والإنفاذ البيئي؟ **(ما هي العوامل الأخرى التي تأثرت)**

٥. يرجى وصف مستوى راحتك في استخدام التكنولوجيا في الامتثال والإنفاذ البيئي. **(لماذا)**

٦. إلى أي مدى وكيف يؤثر قبول التكنولوجيا على الاستخدام الفعلي للتكنولوجيا في الامتثال والإنفاذ البيئي؟

٧. إلى أي مدى وكيف تؤثر البيئة القانونية على نية استخدام موظفي الامتثال والإنفاذ البيئي للتكنولوجيا؟

٨. إلى أي مدى وكيف تؤثر جدية النظام القانوني وقوته على نية استخدام موظفي الامتثال والإنفاذ البيئي للتكنولوجيا؟

٩. إلى أي مدى وكيف يؤثر وجود سلطة بيئية واضحة على نية استخدام موظفي الامتثال والإنفاذ البيئي للتكنولوجيا؟

١٠. إلى أي مدى وكيف تؤثر معرفة التشريع وغموضه على نية استخدام موظفي الامتثال والإنفاذ البيئي للتكنولوجيا؟

١١. إلى أي مدى وكيف يؤثر التعاون والتنسيق بين الكيانات ذات الصلة على نية استخدام موظفي الامتثال والإنفاذ البيئي للتكنولوجيا؟

١٢. يرجى وصف أي عوامل أخرى تؤثر على قبول التكنولوجيا تنفرد بها في مجال الامتثال والإنفاذ البيئي؟

١٣. هل لديك أي أسئلة تود طرحها؟

Appendix C: Interview Protocol for Public

For the purpose of this case study the following terms will be defined as:

- Technology the use of any technology as a tool enabling environmental compliance.
- Environmental compliance ensuring that the requirements of laws and regulations designed to protect the environment are met through self-compliance
- Technology acceptance: is the user's acceptance of the technology resulting in actual use of the technology

1. What procedures do you take to ensure your compliance to environmental laws and regulations?
2. What technologies do you use for the purpose of environmental compliance?
3. How often do you use technology for the purpose of environmental compliance?
4. How has technology impacted the speed, accuracy, transparency, and cost of ensuring environmental compliance? (**What other factors were impacted**)
5. Please describe your level of comfort in using technology for environmental compliance. (**why**)
6. To what extent and how does the legal environment impact usage intention of technology for environmental compliance?
7. To what extent and how does the legal system seriousness and strength impact the intention to use of technology for environmental compliance?
8. To what extent and how does having a clear environmental authority impact the intention to use of technology for environmental compliance?
9. To what extent and how does the knowledge of legislation and its clarity impact the intention to use of technology for environmental compliance?
10. To what extent and how does the collaboration and coordination between related entities impact the intention to use of technology for environmental compliance?
11. Please describe any other factors that affect technology acceptance unique to the field of environmental compliance?
12. Do you have any questions that you would like to ask?

Appendix D: Interview Protocol for Public (Arabic)

لغرض دراسة الحالة هذه، سيتم تعريف:

- التكنولوجيا على أنها استخدام أي تقنية كأداة تمكن من الامتثال البيئي.
- الامتثال البيئي: عملية الامتثال لقوانين البيئة وذلك عن طريق التأكد من الالتزام بالقوانين والقرارات.
- قبول التكنولوجيا: قبول المستخدم للتكنولوجيا الذي ينتج عن استخدام فعلي للتكنولوجيا.

١. ما هي الإجراءات التي تتخذها لضمان الامتثال البيئي؟

٢. ما هي التقنيات التي تستخدمها لغرض الامتثال البيئي؟

٣. كم مرة تستخدم التكنولوجيا لغرض الامتثال البيئي؟

٤. كيف أثرت التكنولوجيا على السرعة والدقة والشفافية والتكلفة لضمان الامتثال البيئي؟

٥. يرجى وصف مستوى راحتك في استخدام التكنولوجيا في الامتثال البيئي. (لماذا)

٦. إلى أي مدى وكيف تؤثر البيئة القانونية على نية استخدام التكنولوجيا للامتثال البيئي؟

٧. إلى أي مدى وكيف تؤثر جدية النظام القانوني وقوته على نية استخدام التكنولوجيا للامتثال البيئي؟

٨. إلى أي مدى وكيف يؤثر وجود سلطة بيئية واضحة على نية استخدام التكنولوجيا للامتثال البيئي؟

٩. إلى أي مدى وكيف تؤثر معرفة التشريع ووضوحه على نية استخدام التكنولوجيا للامتثال البيئي؟

١٠. إلى أي مدى وكيف يؤثر التعاون والتنسيق بين الكيانات ذات الصلة على نية استخدام التكنولوجيا للامتثال البيئي؟

١١. يرجى وصف أي عوامل أخرى تؤثر على قبول التكنولوجيا تنفرد بها في مجال الامتثال البيئي؟

١٢. هل لديك أي أسئلة تود طرحها؟

Appendix E: Invitation to Participate

Date:

[Recipient]

Dear [Recipient]:

I am conducting research as part of the requirements for a PhD degree. The purpose of this study is to explore the effect of technology and technology acceptance on environmental compliance and enforcement and to develop and validate a conceptual framework for user acceptance of technologies for environmental compliance and enforcement enhancement. I am writing to invite you to participate in my study.

If you are part of the Bahrain Coast Guard or are involved in technology usage in environmental compliance and enforcement in the marine environment and are willing to participate. You will participate in an approximately 30-minute Face-to-Face Interview (online). Your data from the participation will be completely confidential, anonymous, and no identifying information will be required.

If you wish to participate please complete the informed consent form and contact me by email or phone so you can provide a time, date, and preferred electronic platform for the Face-to-Face Interview.

Sincerely,

Mohamed Al-Qassim

Phone:

0097339468222

Email:1837486@brunel.ac.uk

Brunel University Doctoral Candidate

Appendix F: Invitation to Participate (Arabic)

تاريخ:

[مستلم]

عزيزي [المستلم]:

أقوم بإجراء بحث كجزء من متطلبات درجة الدكتوراه. الغرض من هذه الدراسة هو استكشاف تأثير التكنولوجيا وقبول التكنولوجيا على الامتثال والإنفاذ البيئي وتطوير والتحقق من صحة إطار مفاهيم قبول المستخدم لتكنولوجيا من أجل تعزيز الامتثال والإنفاذ البيئي. أكتب إليكم لأدعوكم للمشاركة في دراستي.

إذا كنت جزءاً من خفر سواحل البحريني أو تشارك في استخدام التكنولوجيا في الامتثال والإنفاذ البيئي وعلى استعداد للمشاركة. سنشارك في مقابلة وجهاً لوجه مدتها 30 دقيقة تقريباً (عبر الإنترنت أو الهاتف). ستكون بياناتك من المشاركة سرية تماماً ومجهولة المصدر ولن تكون هناك حاجة إلى معلومات تعريفية.

إذا كنت ترغب في المشاركة، يرجى إكمال استمارة الموافقة والاتصال بي عبر البريد الإلكتروني أو الهاتف حتى تتمكن من توفير الوقت والتاريخ والمنصة الإلكترونية المفضلة للمقابلة وجهاً لوجه.

باخلاص،

محمد القاسم هاتف: 0097339468222 البريد الإلكتروني: 1837486@brunel.ac.uk

طالب دكتوراه بجامعة برونييل

Appendix G: Consent Form

Adapted Technology Acceptance Model for Environmental Compliance and Enforcement: Case Study of Bahrain Coast Guard

Mohamed Al-Qassim

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 22/11/2020 22/11/2020 22/11/2020 22/11/2020 AND 03/01/2021 03/01/2021 03/01/2021 03/01/2021

The participant (or their legal representative) should complete the whole of this sheet.

	YES	NO
Have you read the Participant Information Sheet?	<input type="checkbox"/>	<input type="checkbox"/>
Have you had an opportunity to ask questions and discuss this study? (via email/phone for electronic surveys)	<input type="checkbox"/>	<input type="checkbox"/>
Have you received satisfactory answers to all your questions? (via email/phone for electronic surveys)	<input type="checkbox"/>	<input type="checkbox"/>
Who have you spoken to about the study?		
Do you understand that you will not be referred to by name in any report concerning this study?	<input type="checkbox"/>	<input type="checkbox"/>
Do you understand that:		
• You are free to withdraw from this study at any time	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
• You don't have to give any reason for withdrawing	<input type="checkbox"/>	<input type="checkbox"/>

Environmental Enforcement Technology Adoption

- Choosing not to participate or withdrawing will not affect your rights or future care?rights or future care?rights or future care?rights or future care?
- You can withdraw your data any time up to 31/07/202131/07/202131/07/202131/07/2021

I agree to the use of non-attributable quotes when the study is written up or published

The procedures regarding confidentiality have been explained to me

I agree that my anonymised data can be stored and shared with other researchers for use in future projects.

I agree to take part in this study.

Signature of research participant:

Print name:

Date:

Witness Statement

I am satisfied that the above-named has given informed consent.

Witness signature:

Print name:

Date:

Appendix H: Consent Form (Arabic)

نموذج قبول التكنولوجيا المعدلة للامتثال والإنفاذ البيئي: دراسة حالة لخفر سواحل البحريني

محمد القاسم

تم منح الموافقة على هذه الدراسة ليتم إجراؤها بين 2020/11/22 و 2021/3/1

يجب على المشارك (أو ممثله القانوني) إكمال هذه الورقة بأكملها.

لا نعم

هل قرأت ورقة معلومات المشارك؟

هل سنحت لك الفرصة لطرح الأسئلة ومناقشة هذه الدراسة؟ (عبر البريد الإلكتروني / الهاتف)

هل تلقيت إجابات مرضية على جميع أسئلتك؟ (عبر البريد الإلكتروني / الهاتف)

مع من تحدثت عن الدراسة؟

هل تفهم أنه لن تتم الإشارة إليك بالاسم في أي تقرير يتعلق بهذه الدراسة؟

هل تفهم بأن:

لك الحرية في الانسحاب من هذه الدراسة في أي وقت

لا داعي لإبداء أي سبب للانسحاب

لن يؤثر اختيار عدم المشاركة أو الانسحاب على حقوقك أو رعايتك المستقبلية؟

يمكنك سحب بياناتك في أي وقت حتى 2021/07/31

أوافق على استخدام الاقتباسات غير المنسوبة عند كتابة الدراسة أو نشرها

تم شرح الإجراءات المتعلقة بالسرية لي

Environmental Enforcement Technology Adoption

أوافق على أنه يمكن تخزين بياناتي المجهولة المصدر ومشاركتها مع باحثين آخرين لاستخدامها في المشاريع المستقبلية.

أوافق على المشاركة في هذه الدراسة.

توقيع المشارك في البحث:

التاريخ:

الإسم:

Appendix I: Sample of Researcher Observations

Although observations were cut short due to the COVID-19 pandemic enough evidence was collected to develop their proposed model and adapted constructs of the legal environment the three main sections of the BCG in which these observations were conducted are the Operations center, patrol vessels, and the legal affairs.

Analysis of the observations should the legal environment as a main team unique to the field of environmental compliance and enforcement specially and enforcement agencies but have other tests responsibilities than environmental enforcement and compliance.

during the researcher's observations in the field, it became evident that the legal environment influences the effectiveness of environmental enforcement especially in the marine environment. Some of the main issues facing environmental enforcers was their attitude and satisfaction with the outcome of the legal process especially the prosecution (**end-result**). One example was found when dealing with the illegal fishing activities, in the past the public prosecution did not seem to have sufficient understanding of the marine environment and fisheries laws and regulation. illegal fishermen were in some cases able to mislead the public prosecution on what exactly happened. This was also the result of less collaboration and coordination with the enforcement agencies and the relatively low experience with implementing environmental laws and regulation including fisheries this is in strongly influenced the enforcers intention in dealing with environmental issues as well as using technology for this purpose.

"In the first days of the public prosecution some cases failed to be prosecuted either by lack of collaboration and coordination by related entities or inexperience by either in dealings required to achieve proper prosecution"

The integration and certificate certification of the technologies in the legal process or system and they creased experience and collaboration with had a positive effect on the outcome of the prosecution and satisfaction of the enforcement which led to increased intention of using the technology to achieve environmental compliance and enforcement as well as increased morale and satisfaction of the outcome

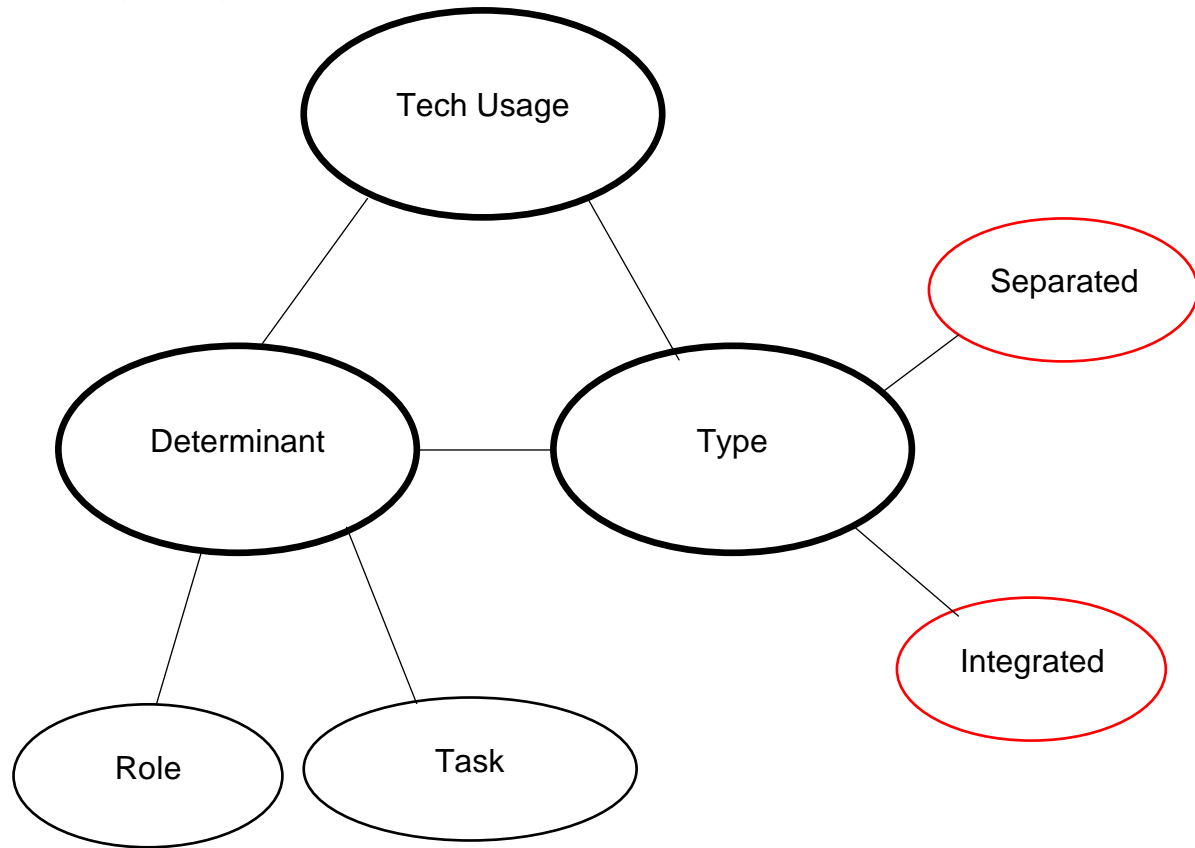
Inappropriate legal environments statements

Environmental Enforcement Technology Adoption

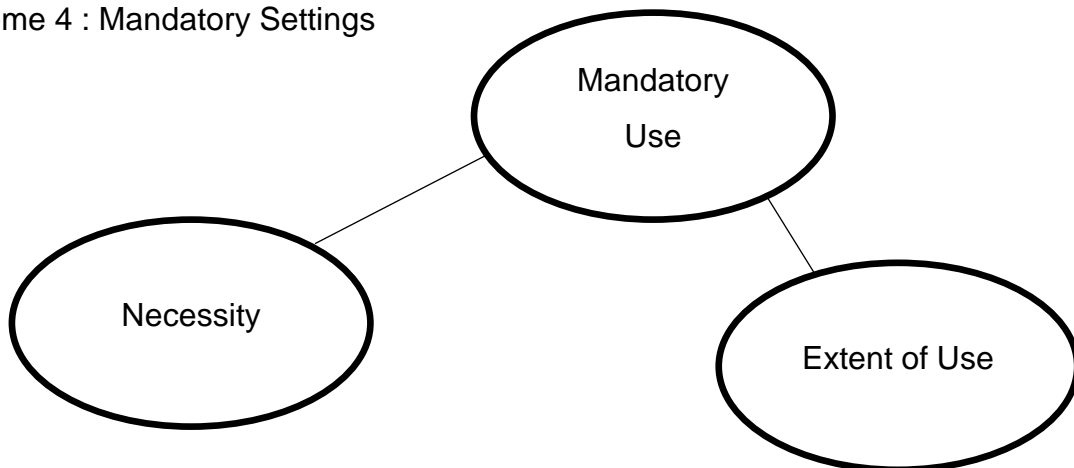
“what's the use of all this trouble and waste of money and time on these equipment and technology if at the end the violations will either get a weak conviction that does not the term violator then we'll go back to the same illegal activity and sometimes feels it is worth the risk but with strong convictions and increased collaboration between us and related entities we get better

Appendix J: Thematic Maps

Theme 1 : Technology Usage

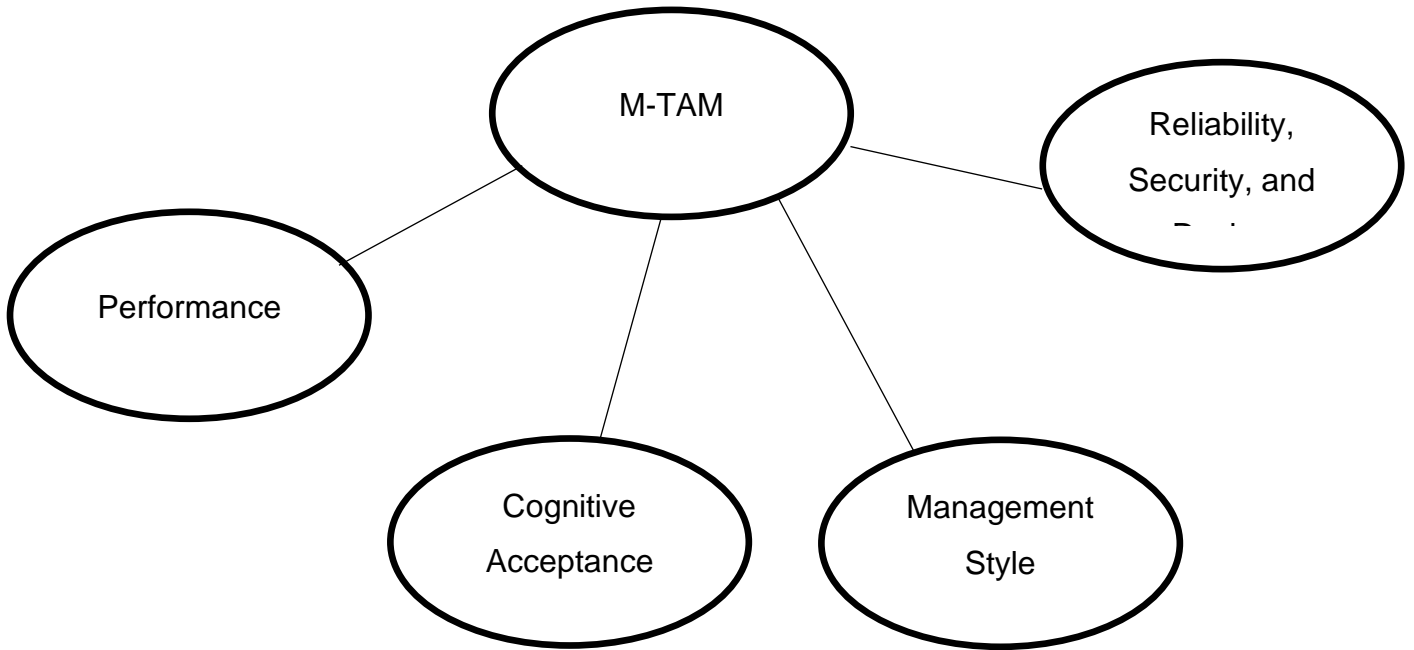


Theme 4 : Mandatory Settings

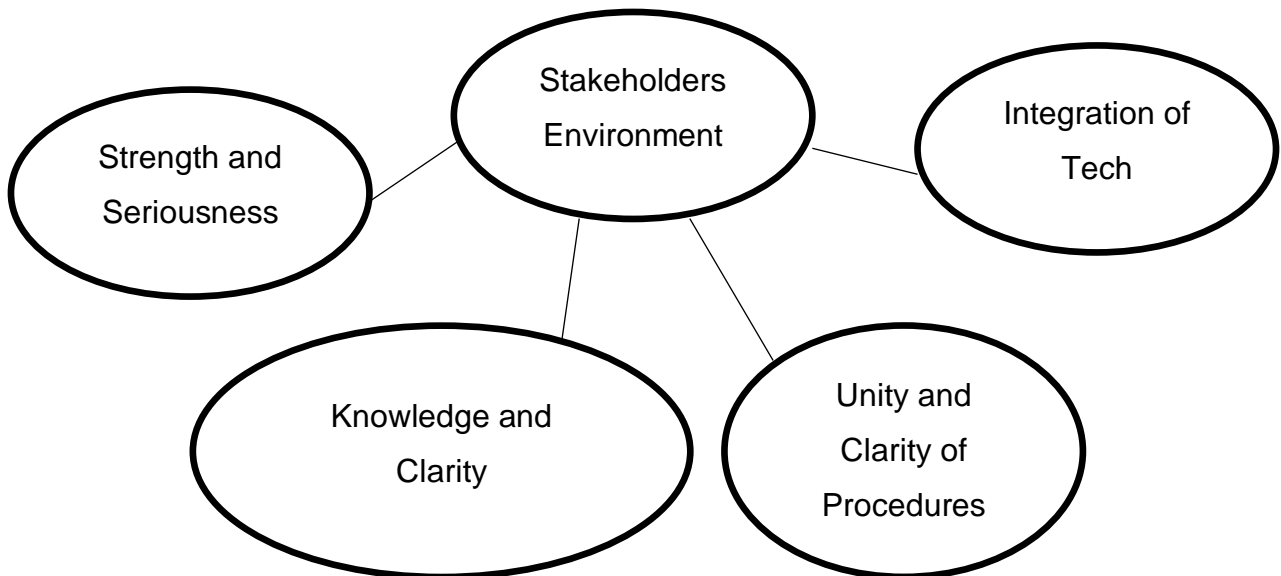


Environmental Enforcement Technology Adoption

Theme2: M-TAM



Theme 3: Stakeholder's Context



Appendix K: Thematic Analysis Sample

Theme Stakeholder's Environment

Sub-theme	Statement	Case
Legal system strength	<i>It has some impact. For example, the enforcement personnel will keep using radars because it makes their jobs easier as described above, but they might not use cameras to document the violations because that make their jobs harder and if the legal system is not serious enough, they would not bother.</i>	1
Legal system strength	<i>the legal environment / framework is the defacto guide for our activities. It is therefore very important for us and is a fundamental guide to our decision making in regard to technology. For example, we must be careful to remain within privacy laws at all times whilst achieving compliance with the applicable rules for environmental protection and conservation.</i>	2
Legal system strength	<i>A lot, The user of the technology used for enforcement has to be supported and encouraged by the legal system. The technology also has to be accepted by the legal system (evidence). If the legal system is weak or not serious the user will be negatively affected because he will feel the use of the technology is a waste of time, effort, and money.</i>	3
Legal system strength	<i>Very high, the legal system strength and seriousness in the prosecution process gives the users (enforcers) technology for environmental enforcement increased trust and satisfaction in the benefits of the technology used for this purpose. The stronger the end-result in court the more the intention to use the technology.</i>	4
Legal system strength	<i>It affects the results of our work because after monitoring violations using the technologies the environmental issues should be dealt with firmly. If not, the result will be slackness in the use of technology be enforcers</i>	6
Legal system strength	<i>Definitely, If the end results of the legal process are unsatisfactory or weak it may affect usage intention of enforcers. They may feel the technology is useless and in turn affect usage intention. Very much, Strong penalties and convictions for violators of environmental laws and regulations (end-result) give the enforcers</i>	8

Environmental Enforcement Technology Adoption

	<i>using technology satisfaction and encouragement to use the technologies for this purpose.</i>	
Legal system strength	<i>Stronger legal system especially in providing stronger conviction influences the intention to use these technologies.</i>	9
Legal system strength	<i>Very much, because the related entities are aiming for increased compliance insurance and enforcement which increases the necessity of the use technology to keep up with increased action requirements. This results in increased usage intention to use technology to keep up.</i>	10
Legal system strength	<i>Yes, a lot, moral encouragement is affected by environmental law enforcers because of the legal system, which affects the intention to use technology for the purpose of enforcing environmental laws.</i>	11
Legal system strength	<i>support for the technology and the integration of these technologies in the legal system results in increased usage intention and provides better results and satisfaction, including economic benefits.</i>	13
Legal system strength	<i>The seriousness and strength of the legal system influences the intent to use technology by environmental compliance and enforcement officials significantly, the presence of a strong legal system that believes in the need to keep pace with the use of technology in the areas of environmental enforcement, greatly helps to facilitate the process of approving and enacting laws and legislation necessary for environmental enforcement, which in turn facilitates the use of technology by compliance and environmental enforcement officials in the work of these employees.</i>	14
Legal system strength	<i>No doubt that the more serious is the willingness to enforce environmental compliance, the wider the application of technologies. I think incorporating the use of technology as an obligatory requirement in the relevant national legislation shall assist in maximizing the application of technology to monitor environmental compliance. In this regard, Bahrain has as a good successful case study of imposing the fixing of AIS on all non-military vessels as a legally binding requirement.</i>	15
Legal system strength	<i>The seriousness and the strength of a legal system will ensure that all users implement technologies to comply with the law. intention to violate the law will vanish and there will be seriousness in adopting to the laws.</i>	16
Legal system strength	<i>Strong and serious legal system results in increased compliance and the technology provides protection to users and also can be used as evidence against them if made mandatory. The intention will increase especially when the user knows there are strong prosecutions to his violations.</i>	17

Environmental Enforcement Technology Adoption

Legal system strength	<i>Very much, because the public will not be willing to use the technology for this purpose if the deterrent is weak or not serious. They will not feel it to be necessary or worth the time and effort if there are no legal deterrent.</i>	18
Legal system strength	<i>Very much, the strength of the legal system especially in prosecution strength influences the intention of using technology for environmental compliance. The technology has to be mandatory. The strong systems force users to use technology to ensure they comply with the laws.</i>	19
Knowledge of legislation	<i>It has a big impact. Actually, if enforcers do not have knowledge of legislation, they will not be able to see violations thus will not enforce the laws using technology.</i>	1
Knowledge of legislation	<i>Very much, for us any ambiguity can be problematic. Where this exists, we will always seek guidance and advice from all stakeholders and ultimately be guided by the relevant legal bodies. Having a good knowledge of legislation is very important for us in considering which technologies we should be adopting. Of course, there is always ambiguity and so sometimes we must make educated judgements in this regards and once adopted configure technologies appropriately as this level and nature of ambiguity changes. In the end we are, again, always guided by the rules in our application of technology and operations.</i>	2
Knowledge of legislation	<i>Also, a lot, The knowledge of the legislation by the public and the implementers of environmental policy makes the enforcers use of the technology easier because he has knowledge of the legislation he is trying to enforce. The public knowledge also increases the acceptance of the technology by the enforcer because it makes his job easier especially when it comes to explaining what is required to the public. Clear legislation also helps the users accept the technology because they know exactly what is needed and required from them.</i>	3
Knowledge of legislation	<i>Very much, the knowledge of legislation specially by the users of the technology give them a sense of purpose and understanding of how, why, when, what, and where to use the technology. Ambiguity means not knowing and understanding the purpose of using the technology and how to implement but clear legislation does the opposite.</i>	4
Knowledge of legislation	<i>Greatly affects, legislation must be clear and known to everyone, which contributes to the understanding of the society and facilitating the use of technology.</i>	6
Knowledge of legislation	<i>A lot, It makes environmental compliance and enforcement in general easier, especially if everybody understands what is required from them including the public. The same applies for the use of technology.</i>	8

Environmental Enforcement Technology Adoption

Knowledge of legislation	<i>Very much, clear laws and regulation help environmental compliance and enforcement personnel complete their tasks using technology by making the purpose and procedures clear and understandable.</i>	9
Knowledge of legislation	<i>Very much, This especially influential to usage intention when it comes to the clarity and understanding of the legislation regarding the protocols and procedure of using the technology at hand. Ambiguity and weak understanding of these legislation can result in insecurity of using this technology by enforcers.</i>	10
Knowledge of legislation	<i>Very much, the knowledge of legislation by enforcers and the public makes are job easier including the use of the technology for purpose of environmental compliance and enforcement. If regulation is set or standard such as set fines this can result in reoccurring violations especially if they are weak because offenders will find it worth the risk. These factors affect the intention of using the technologies at hand by enforcers.</i>	11
Knowledge of legislation	<i>Very much, awareness makes it easier for implementers of environmental law to deal with the public, especially if there is awareness of the technology used for this purpose and the technology supportive legislation.</i>	12
Knowledge of legislation	<i>Very much, understanding of the legislation including the legislation regarding the technology used results in increased intention of use by both enforcers and public because they understand it purpose, importance, and result of non-compliance.</i>	13
Knowledge of legislation	<i>Knowledge and ambiguity of the legislation impacts the intent to use technology by environmental compliance and enforcement officials significantly clarity and robustness of the legislation and the familiarity of the compliance and environmental enforcement officer with it greatly helps in the ideal application of the legislation by using all the necessary tools for this, including tools and technological means to assist the work of the compliance and environmental enforcement officer.</i>	14
Knowledge of legislation	<i>the use of technologies for environmental compliance purposes can benefit from national laws clearly and expressly specifying the legally binding requirements of the use of technology in this field. These laws should be made widely available for all stakeholders and, also, public should be made aware about them.</i>	15
Knowledge of legislation	<i>Very important as understanding the legislation and having the knowledge will give owners the answers why these technologies are used and help achieve results.</i>	16

Environmental Enforcement Technology Adoption

Knowledge of legislation	<i>Understanding of the legislation and regulations especially when it comes to the use of technology for compliance gives the user increased intention on using the technology and clear understanding of its purpose. The technology is only helpful if the user understands what is needed and how he can achieve and why. He will be confident and more willing to use it to help achieve his goals.</i>	17
Knowledge of legislation	<i>Understandable and clear legislation simplifies the procedure of compliance and the technology used for this purpose. It also eliminates confusion and malpractice.</i>	18
Knowledge of legislation	<i>Definitely, the understanding by fishermen of these legislation gives a clear picture of the purpose and procedures of using these technologies which increases the intention to use these technologies.</i>	19
Clarity and unity of procedures and technologies	<p><i>It will have a big impact because it will make enforcement hesitant to act upon the environmental violations and regard it as being the job of other agencies.</i></p> <p><i>It has an impact but not a big one, because entities can work alone effectively using technology; however related entities working together by collaborating and coordinating will yield better results thus the intention of using technology will increase.</i></p>	1
Clarity and unity of procedures and technologies	<p><i>It can aid them in understanding the SOPs and requirements related to the environment. Moreover, it will also help them selecting the technology matching the desired requirements. I think this comes down to us all understanding the rules related to environmental protection, both to the letter as they are written, but also in regard to the spirit/intent of the laws. What I mean by this is that we need to bring with us both the legal and moral authority when operating. To this end for example, we look at technology to help us justify and explain the rules, for example being able to use data analytics to show people how activities can affect the environment.</i></p> <p><i>This is an important factor, as all concerned authorities should always have information sharing or joint meetings in order to discuss all matters and have a clear understating in order form an organized procedure for running tasks. Adopting such an approach can help all involved parties utilize the system in an optimized manner.</i></p>	2
Clarity and unity of procedures and technologies	<i>A lot, having a clear authority means having clear and unified processes and procedures which in turn give the users of these technologies clear and concise procedures and outcomes of the utilization of the</i>	3

Environmental Enforcement Technology Adoption

	<p><i>technologies. Lowering the confusion and effort need to use the technology and understanding its benefits and outcomes.</i></p> <p><i>A lot, If all the parties involved have good coordination and collaboration the user will feel that they are all on the same track and makes him feel part of a team. Also, this will mean faster and easier info transfer which will make the technology more useful and give better results affecting the user intention to use the technology.</i></p>	
Clarity and unity of procedures and technologies	<p><i>Greatly, more collaboration and coordination specially through the use of unified technology applications makes the process easier, faster, more accurate, and transparent. This also saves time and money.</i></p> <p><i>Also very much, having a clear authority in general, means having clear processes and procedures for the use of the technology for the purpose of environmental enforcement. This eases the using the technology and increases the sense of working in one team.</i></p>	4
Clarity and unity of procedures and technologies	<p><i>Greatly, it helps in the employee's use of technology by making the processes and procedures clear and understandable. the employees use of the technology will be serious, monitored and with standardiyised procedures with the authority itself, resulting in increased acceptance of the technology used.</i></p> <p><i>Very much, It unifies and clarifies work concepts and makes facilitates stronger and easier procedure to take action by all entities involves.</i></p>	6
Clarity and unity of procedures and technologies	<p><i>Very much, the procedures and protocols of using the technology will become clear and unified which makes the use of the technology better for enforcers.</i></p>	8
Clarity and unity of procedures and technologies	<p><i>Very much, A clear authority increases accountability and monitoring of related entities enforcers use of technology and makes the use a necessity to complete tasks which increase usage intention.</i></p> <p><i>Very much, it makes the environmental compliance and enforcement personnel task of protecting the environment easier and requires less effort and time. The duties and responsibilities are distributed among related entities, which makes for less work for one single entity.</i></p>	9
Clarity and unity of procedures	<p><i>Very much, The goals and procedures of the personnel tasked with environmental compliance and enforcement become clear and unified</i></p>	10

Environmental Enforcement Technology Adoption

<p>and technologies</p>	<p><i>which should increase efficiency of the end-result, influencing usage intention.</i></p> <p><i>Very much, because it gives extra support and shared responsibilities, providing better results. For example, extra reporting and monitoring potential. This influences usage intention by enforcers because of enhanced results.</i></p>	
<p>Clarity and unity of procedures and technologies</p>	<p><i>YES, this our processes and procedures clear and transparent when using the technology especially when it come the outcomes of the prosecutions or penalties.</i></p> <p><i>Not in all entities, the entities responsible for prosecution and penalties very much because of the end-result acquired by the technologies.</i></p>	11
<p>Clarity and unity of procedures and technologies</p>	<p><i>A lot, the clarity of the procedures required of technology users for the purpose of enforcement in order to work as a unified team for one goal, which increases the intention to use technology for this purpose.</i></p> <p><i>It affects positively through a sense of unified team and also unifies procedures.</i></p>	12
<p>Clarity and unity of procedures and technologies</p>	<p><i>Very much, this would lead to increased positive impact to our processes and give better end-results.</i></p> <p><i>Very much, this is a very important factor that influences intention of use because the evidence is a determining factor of the end-result which will impact the effectiveness of environmental compliance and enforcement. If the evidence is not tangible the enforcer will not intend to use the technology as much.</i></p>	13
<p>Clarity and unity of procedures and technologies</p>	<p><i>as the presence of a clear environmental authority greatly helps to implement legislation in an integrated manner and develop it continuously, which frames and regulates the use of technology by compliance and environmental enforcement officials in environmental work.</i></p> <p><i>the use of technology by compliance and environmental enforcement officials is one of the most important elements of linking between the various entities and institutions and an important element that would ensure the speed and durability of the procedures taken and the speed of law enforcement, which ultimately leads to strengthening the principles of integration in the institutional work system, which would cast a positive shadow on the intention of the compliance and environmental enforcement officials to use technology in general.</i></p>	14

Environmental Enforcement Technology Adoption

<p>Clarity and unity of procedures and technologies</p>	<p><i>The lack of coordination among concerned organizations weakens the regulatory use of technology and leads to unnecessary duplication. In contrast, sharing the environmental compliance data gathered by modern technologies will promote a more efficient use of available logistic, technical, and human resources.</i></p>	<p>15</p>
<p>Clarity and unity of procedures and technologies</p>	<p><i>it will identify what need to be done and will clear all ambiguity, which results in comfort to use technologies. Follow ups and implementation will be easier and faster.</i></p> <p><i>Clear instruction and flow of information will be done easier and transparent, questions can be answered, solution can be found, and achievements will be reached.</i></p>	<p>16</p>
<p>Clarity and unity of procedures and technologies</p>	<p><i>clear roles and responsibilities and should eliminate any confusion including when it comes to the technology used. The unification and clarity of these procedure are very important to us in the commercial sector since we have more protocols and regulations to adhere to. If the technologies' purpose and procedure are clear it will definitely increase our intention to use these technologies because of their positive impacts.</i></p> <p><i>Commercial sectors are always trying to achieve close and transparent relations with authorities to ensure compliance and improve companies' reputation, if the entities are collaborative with each other and have unified and clear goals especially ones that are achieved by technology the users will be more intent on using them.</i></p>	<p>17</p>
<p>Clarity and unity of procedures and technologies</p>	<p><i>the procedures of using the technologies will be clear and unified for using the technology. For example, they will know who to report to and how the data is used.</i></p> <p><i>It enhances the transparency and awareness which reduces the negative impacts on the marine environment, especially if the technology is an enhancing factor.</i></p>	<p>18</p>
<p>Clarity and unity of procedures and technologies</p>	<p><i>This gives clear and united goals and procedures to use the technology which increases the intention to use them.</i></p>	<p>19</p>
<p>Integration of technology</p>	<p><i>Evidence. The degree of acceptance of technology data by courts will impact the intention of use of technology by the enforcers.</i></p>	<p>1</p>
<p>Integration of technology</p>	<p><i>the framework within which we operate. The laws therefore define the activities and events that we need to be able to detect and identify in terms of environmental compliance and enforcement. Therefore, we look for technologies that enable us to identify activities that are relevant to these specific laws – and where possible, technologies that will</i></p>	<p>2</p>

Environmental Enforcement Technology Adoption

	<i>prevent these laws being infringed such that enforcement action is a last resort. Therefore, the legal environment guides both our selection and use of technology.</i>	
Integration of technology	<i>The user of technology used for environmental enforcement may not accept the technology or intended to use it if he feels the legal environment does not support the technology being used or that the use of the technology is useless because the end results is unsatisfactory. (ex. no goes to court or the fined) - Evidence: The technology outcomes should stand in court or be used in investigation.</i>	3
Integration of technology	<i>Very much, The legal environment makes it mandatory to apply the approved and implemented technologies to complete the tasks, especially in the context of the legal process. It also gives clear responsibilities and guidelines that should be follow and the user is responsible and accountable for the way he uses the technology.</i>	4
Integration of technology	<i>Very much, Integration of the technology used in the legal environment is essential. Having a clear legal legislation for the technology use enables me to use technology efficiently.</i>	6
Integration of technology	<i>100%, If the legal environment is not suitable for proper environmental enforcement especially when it comes to the technology used by the enforcer, procedure can be very time and effort consuming which can influence the usage intention. For example, if the technologies data is not accepted as evidence in court the procedures to produce evidence will require increased manual data gathering and documentation lowering usage intention.</i>	8
Integration of technology	<i>Very much, because the legal environment specifies the policies which the environmental enforcers need to comply with when using their technology. If the regulations and protocols for using the technology are clear and result in trust but the same time accountability the usage intention will increase.</i>	9
Integration of technology	<i>Very much, if the technology is considered valid and accepted as evidence by the legal system and helps provide strong convictions the enforcers intention to use will increase.</i>	10
Integration of technology	<i>Very much, legislation has to support the technology being used for the purpose of environmental enforcement. The legal system has to accept the data from the technology, especially as proof is the legal process.</i>	11
Integration of technology	<i>the legal environments dependance and acceptability of the technology is very important factor affecting the intention of use by the personnel.</i>	13

Environmental Enforcement Technology Adoption

	<i>the personnel accept the technology more if they are necessary or mandatory because they are not able to complete tasks without them. For example, report of violations can not be accepted unless the data from the sensors or mentoring technologies are not within the report.</i>	
Integration of technology	<i>the necessary evidence is collected to achieve environmental compliance and assess the extent to which projects comply with environmental standards and standards, especially in cases of environmental non-compliance (environmental violations), in the event of a strong legislative and legal environment, which would lead to. Contributes significantly to facilitating the work of environmental compliance personnel during the process of collecting evidence and samples needed for verification the degree of environmental compliance and enforcement.</i>	14
Integration of technology	<i>I think incorporating the use of technology as an obligatory requirement in the relevant national legislation shall assist in maximizing the application of technology to monitor environmental compliance. In this regard, Bahrain has as a good successful case study of imposing the fixing of AIS on all non-military vessels as a legally binding requirement.</i>	15
Integration of technology	<i>Technologies are in use always as we need to comply with international laws and all international ports that we call. Some of the technologies are mandatory and being checked by port control or by class surveyors.</i>	16
Integration of technology	<i>ensure regulations are implemented with proper and sufficient results especially if the use of technology is mandatory and authorized by the legal system which increases our intention to use them.</i>	17
Integration of technology	<i>it has become necessary to ensure adherence to regulation in the marine environment. the legal environment must be in line with the technology and adequate to result in adherence to the placed laws and regulation to ensure people be forced to follow them. The intention is increased with better legal environment results.</i>	19

Appendix L: Ethics committee approval



University Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom
www.brunel.ac.uk

20 November 2020

LETTER OF CONDITIONAL APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 22/11/2020 AND 01/03/2021

Applicant (s): Mr Mohamed Al-Qassim

Project Title: Adapted Technology Acceptance Model for Environmental Compliance and Enforcement: Case Study of Bahrain Coast Guard

Reference: 24049-SS-Oct/2020- 28194-2

Dear Mr Mohamed Al-Qassim,

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **Approval is given for remote (online/telephone) research activity only. Face-to-face activity and/or travel will require approval by way of an amendment.**
- **Recruitment advert: You indicate in this document that interviews will take place face-to-face. Please amend to indicate that interviews will take place remotely (online or via phone).**
- **Consent Form: As your participants are over 18 and able to consent for themselves, you can remove the witness statement.**
- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **In addition to the above, please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Kind regards,

Dr Derek Healy

Chair of the University Research Ethics Committee

Brunel University London