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RISKS IDENTIFICATION AND MITIGATION IN UAV APPLICATIONS DEVELOPMENT PROJECTS

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Under the Supervision of Dr. Nader Mohamed

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Declaration of Original Work

I, Ahmed Yousif Mohamed Idries, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Risks Identification and Mitigation in UAV Applications Development Projects*", hereby, solemnly declare that this thesis is an original research work that has been performed and prepared by me under the supervision of Dr. Nader Mohamed from the College of Information Technology at UAEU. This work has not been previously formed as the basis for the award of any academic degree, diploma, or similar title at this or any other university. The materials borrowed from other sources and included in my thesis have been properly cited and acknowledged.

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Abstract

With the recent advances in aircraft technologies, software, sensors, and communications, Unmanned Aerial Vehicles (UAVs) can offer a wide range of applications. UAVs can play important roles in applications, such as search and rescue, situation awareness in natural disasters, environmental monitoring, and perimeter surveillance. Developing UAV applications involves integrating hardware, software, sensors, and communication components with the UAV's base system. UAV applications development projects are complex because of the various development stages and the integration complexity of high component. This research addresses the business and technical challenges encountered by UAV applications development and Project Management (PM). It identifies the risks associated with UAV applications development and compares various risk mitigation and management techniques that can be used. The study also investigates the role of Knowledge Management (KM) in reducing and managing risks. Furthermore, this study proposes a KM framework that reduces risks in UAV applications development projects. In addition, the proposed framework relies on KM and text mining techniques to enhance the efficiency of executing these projects.

Keywords: Unmanned Aerial Vehicles-UAV, Software Project Management, Knowledge Management, Risk Management, UAV Applications.

Title and Abstract (in Arabic)

إطار عمل لتقليل و تجنب المخاطر في مشاريع تطوير تطبيقات المركبات الجوية الغير مأهولة

الملخص

مع التقدم الحالي في تقنيات الطائرات، البرمجيات، المجساة و الاتصالات أصبح بامكان المركبات الجوية الغير مأهولة أن تلعب دورا في تطبيقات البحث و الانقاذ، التنبوء و رصد الكوراث الطبيعية، المراقبة البيئية، المساحة و التخطيط و أنشطة الرصد عموما.

تطوير هذه التطبيقات يشمل دمج المكونات الصلبة، المعدات، البرمجيات، المجسات و مكونات الاتصالات مع النظام الأساسي للمركبة. مشاريع تطوير تطبيقات المركبات الجوية الغير مأهولة تعتبر من المشاريع المعقدة نظرا لتعدد مراحل التطوير و مراحل الدمج بين مكونات الطائرة و التي توءثر على درجة تعقيد المشروع.

هذه الرسالة توضح التحديات التقنية و الادارية التي تواجه تطوير تطبيقات المركبات الجوية الغير مأهولة. كما تناقش الرسالة المخاطر التي تواجه تطوير مثل هذه التطبيقات و مشاريعها . بالاضافة الى ذلك تناقش هذه الرسالة المخاطر المتعلقة بمشاريع تطوير هذه التطبيقات و تستعرض بعض الطرق المستعلة لتجنب و ادارة المخاطر في مثل هذه البيئات .

كما تناقش هذه الرسالة دور ادارة المعرفة في تقليل و ادارة المخاطر في مشاريع تطوير هذه التطبيقات و دور ادارة المعرفة في مثل هذه البيئات و بيئات عمل مشابهة لها . في النهاية هذه الرسالة تقترح اطار عمل ادارة معرفة لتقليل المخاطر في مشاريع تطوير تطبيقات المركبات الجوية الغير مأهولة، هذا الاطار يعتمد على تقنيات ادارة المعرفة و استخراج البيانات من خلال تحليل المخاطر لزيادة كفاءة المشاريع.

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Dedication

To my beloved parents and family

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List of Abbreviations

IO-SECI	(Input-output Socialization-Externalization-Combination-Internalization)
KM	Knowledge Management
OO	Object Oriented
PIP	Process Improvement Plan
PM	Project Management
PMP	Project Management Performance
PP	Project Performance
PPM	Project Portfolio Management
QoS	Quality of Services
SLA	Service Level Agreement
SOM	Service-Oriented Middleware
SPL	Software Product Line
SSD	Single System Development
UAV	Unmanned Aerial Vehicle

Chapter 1 : Introduction

This chapter highlights this study in term of scope, problem statement, potential, and expected contribution; it also highlights the limitations of this study. The remainder of this chapter is as follows: Section 1.1 provides an overview of Unmanned Aerial Vehicle (UAV) systems as an emerging trend; Section 1.2 highlights the main problem statement that this study aims to solve; and Section 1.3 highlights the main contributions of this study. Furthermore, Sections 1.4, 1.5, 1.6, and 1.7 discuss the scope, research methodology, limitations, and structure of this study.

1.1 Overview

UAVs are inventions mostly used for military purposes. However, civil applications are currently integrating UAVs. For example, the fields of agriculture, environmental protection, public safety, and traffic flow control all use UAV applications.

The world population is increasing and it is foreseeable to be doubled by the year 2050. Consequently, these expectations create new challenges and opportunities for delivering and creating new services and applications. Therefore, there is increased interest in utilizing ICT services and smart solutions for long-term developments. UAV applications are an undeniable part of this long-term development.

UAVs have a wide range of applications and models. They are categorized into three classes: safety control, scientific research, and commercial applications. However, in order to achieve a well-designed UAV application, there must be accurate information support that is necessary for a successful system. It is well known that UAV applications have become involved in many industries ranging from agriculture to oil and gas production and transport.

The architecture of a typical UAV consists of components such as the control, monitoring, data processing, and landing systems. The internal system provides a wide range of functions, from navigation and data transfer to ground. The UAV market is still growing, and UAVs are involved in new activities and solving new problems daily. Many organizations are interested in developing UAVs in order to reduce the cost of related services. Furthermore, many countries consider UAVs as part of their smart transformation to deliver governmental services (e.g., UAE smart transformation policy).

To date, some of the inhibiting factors for using UAVs in many civilian applications include the cost of acquiring these devices and building the required applications and operating systems. UAVs are easy to deploy, they have flexibilities in performing difficult tasks, support high-resolution imagery, and cover remote areas. On the other hand, a device with such abilities must have some ethical and legal impacts. Some countries have privacy and data protection acts and laws. However, most UAV applications are mainly deployed in the military and security fields.

1.2 Problem Statement

The quick growth of UAV applications creates a demand for these systems. Hence, many challenges appear to be technical and managerial. Those challenges include resource allocation and Project Management (PM), as is the case for UAV civil applications and services.

The process for developing civil applications and those of a military nature is extremely different. Differences arise because of the standards, to which each type of application is held, the architecture of the applications' systems, and other factors. One of the issues that affect the development of UAV applications is system complexity and lack of standards in the civil context of these applications. In addition, sensitive applications require well-integrated components in the UAV platform. Furthermore, UAV development consists of mixed industry backgrounds, which can vary from the aerospace industry and complex systems, to robotics and the IT industry.

Therefore, the risks associated with such technology need to be addressed, and the sharing of knowledge within this industry needs to be identified. Identifying those two elements can help future developments in reducing cost and time, and delivering the final products on time and with expected standards and requirements.

1.3 Potential Contributions

A. Discussion of the challenges encountered by UAV applications development.

B. Identification of the risks associated with UAV applications/systems development.

C. Discussion and comparison of various risk mitigation & management techniques that can be used in the field.

D. Investigation of the role of Knowledge Management (KM) in reducing, managing, identifying and mitigating the risks in this field.

E. Proposal of a theoretical framework that can help mitigate and reduce risks in UAV applications development projects with respect to the civil applications context.

1.4 Scope

This thesis aims to investigate the challenges encountered by UAV applications development and the risks associated with this technology. Furthermore, it aims to investigate the impact of KM in UAV project environments with respect to the environments that are similar to UAV development projects. Moreover, this thesis investigates the different and most current approaches used to solve and reduce risks in environments similar to UAV applications development environments. This study investigates the PM and IT management issues related to UAV applications development, but do not study the technical side of this technology.

1.5 Research Methodology

The purpose of this thesis is to study the risks associated with UAV applications development projects. UAV applications development is an area with quick growth and demand. Therefore, the area is exploratory in nature.

In this thesis, a literature survey is conducted on UAV applications development issues and challenges from different aspects. The literature survey is covered in Chapter 3, titled "Challenges of developing UAV applications;" such survey divides the challenges into two main categories: project resource and technical.

The references were collected from UAEU E-library resources and databases, such as IEEE, ACM, and springer. The organized literature covers the main issues in risk management with respect to UAV applications development projects. The main risks are highlighted. Based on the highlighted issues, Chapter 5 discusses the utilization of KM in reducing risks in such project environments with respect to many factors.

1.6 Study Limitations

The study proposes a comprehensive framework for developing UAV civil applications. Furthermore, we aimed to reach local UAV developers and manufacturers, but because of limitations in information and confidentiality, this was not achieved. In addition, the field of UAV applications is a new area of study that requires much work and research. Furthermore, because UAV systems are mainly used in military applications, and have only recently started to be used in civil services and applications, limited access to information was a great obstacle for our research because historical data were not easily found. Moreover, in order to find a case or situation that uses UAV development was a tedious task because of the confidentiality in most UAV development projects, given their military essence. In addition, information sensitivity was another of the obstacles we encountered in this research.

1.7 Next Chapters

The remainder of this thesis is divided as follows.: Chapter 2 covers background and related works; Chapter 3 covers the challenges encountered by UAV applications development from the PM perspective; Chapter 4 investigates the risks associated with UAV applications development projects, and different risk mitigation techniques used in similar environments; Chapter 5 discusses the role of KM (Knowledge Management) in project environments with focus in reducing risks in UAV applications development projects. Furthermore, Chapter 5 proposes a KM framework for reducing risks in UAV applications development projects. Finally, Chapter 6 discusses the conclusion and limitations of this study, and addresses future related works.

Chapter 2 : Background & Related Works

The aim of this study is to investigate the challenges, risks, and issues that affect the process of developing and manufacturing UAV applications from the Information Technology (IT) management perspective. Therefore, this chapter introduces the key terms mentioned in this study. The remainder of this chapter is structured as follows: Section 2.1 discusses UAVs; Section 2.2 provides PM highlights; Section 2.3 highlights and introduces PM; and finally, Section 2.4 highlights risk management, identification, and mitigation.

2.1 Unmanned Aerial Vehicles (UAVs)

According to Finn & Scheding (2010), the "instantiation of Intelligent Decision making Techniques (IDT) within UAVs that allows functional replacement of a manned asset obviously requires development of behaviors approaching those of a human and there are currently many limitations that make this aspiration very unrealistic." For example, portable computer processing cannot currently mimic the processing capacity of the brain, the relevant architecture is not yet sufficiently well-understood, and therefore optimized to allow (for example) complex perception or high level reasoning, and the software and algorithms cannot yet imitate the contextual decision-making or visual perception capabilities of human behavior. Therefore, UAV applications have huge potentials to take role in future technological advancements. Any development of UAV systems and applications need to consider the following key functional components of such systems:

A. Energy storage that varies in UAVs according to UAV type and class. Furthermore, energy storage varies from typical electrical systems for small UAVs to fuel or hybrid electrical systems for large UAVs.

B. Impulsion systems that should meet and fit the required tasks for which the UAV is developed.

C. Health & Usage Monitoring Systems (HUMS) used to monitor the performance of UAV internal devices. Such systems usually exist in large UAVs. Furthermore, they are frequently used for self-monitoring, diagnosis, and remediation of systems or functional components.

In addition, any UAV system consists of the following components: internal, external, and environmental sensors; navigation; perception; communication; human interaction; mobility; response; and platform. According to Finn & Scheding (2010), platforms are the integrating frames for the total system, which must be designed according to the missions they are to accomplish. Relevant technologies include mechanical design, structural mechanics, materials, launch/recovery techniques, etc. Hence, the development of any UAV application must consider and study platform architecture and capabilities.

According to Mohammed et al. (2014a), the US Federal Aviation Authority (FAA) pays significant attention to all Class A airspace from 18,000 to 60,000 feet where commercial planes fly. This is followed by the airspaces around airports, called Class B (14,500–18,000), and C and D (2,000–14,000). Finally, Class G (700–1,200), which is unregulated airspace, is allocated for the use of UAVs. Furthermore, Small Unmanned Aerial Vehicles (SUAV) is likely to grow most quickly in civil and commercial operations because of their versatility and relatively low initial cost and operating expenses. According to the US Army (2010), UAVs are divided into five categories according to payload. UAVs vary from less than 20-pound payload for Group 1, to up to 1,320 pounds for Groups 4 and 5, which are large UAVs. Furthermore, those groups are from 1 to 5 according to their payloads, normal operating altitude and air speeds.

2.2 Project Management (PM)

PM has many definitions that vary based on schools of thoughts and standards, and such definitions are affected by many factors, most of which are cultural and organizational. The Projects Management Institute (PMI) standard is followed in most countries, whereas Japan follows the Projects Management Association of Japan (PMAJ), and the UK and Western Europe follows Projects in Controlled Environments (PRINCE2) standards. Those standards might be different from each other, but they deliver the same PM definition.

According to PMI (2014), PM is the application of knowledge, skills, tools, and techniques to project activities in order to meet the project requirements. PM is accomplished through the appropriate application and integration of 47 logically grouped PM processes categorized into five process groups: initiating, planning, executing, monitoring and controlling, and closing.

A project is a temporary endeavor undertaken to create a unique product, service, or result. The temporary nature of projects indicates that a project has a definite beginning and end. The end is reached when the project's objectives are achieved or when the project is terminated because its objectives will not or cannot be met, or when the need for the project no longer exists. A project may also be terminated if the client (customer, sponsor, or champion) wishes to terminate the project. Temporary does not necessarily mean the duration of the project is short. It refers to the project's engagement and durability. Temporary does not typically apply to the product, service, or result created by the project; most projects are undertaken to create a lasting outcome. For example, a project to build a national monument creates a result expected to last for centuries. Projects can also have social, economic, and environmental impacts that far outlive the projects themselves. Therefore, some of the projects have long-term periods under specific programs and portfolios.

In addition, a project itself is a process for creating and developing knowledge in different formats, shapes, and means. Hence, in the next section we highlight KM.

Any project has specific tasks, but they are not limited, for example, developing new services or products (such as UAV applications), developing or acquiring new or modified information systems (hardware or software, such as UAV applications development), and implementing, improving, or enhancing existing business processes and procedures, as is the case of managing UAV applications development projects. Further details on PM in the context of UAV projects and complex environments are discussed in Chapters 3 and 4.

2.3 Knowledge Management (KM)

According to Karapetyan & Otieno (2011), KM is the way organizations construct and add knowledge to their routines and culture in order to increase efficiency. Furthermore, it is a set of practices that organizations apply to create, store, reuse, and share knowledge. KM definitions are wide and many authors and researchers continue debating such definitions. KM is a core part of any project because information needs to be accessible to all project sides. Hence, many details on this are discussed in Chapter 5.

2.4 Risk Management

According to the Institute of Risk Management (IRM), risk is defined as the combination of the probability of an event and its consequence. Consequences can range from positive to negative (IRM, 2002). Risk management is a wide definition that differs based on the environment and industry. Risk management is a rapidly growing area of study, especially in the IT and software industries, and there are different definitions of what risk management does and how it acts in different environments. Furthermore, risk management has different objectives that vary based on the industry, and might also differ according to required business goals and strategies (IRM, 2002). Risk management consists of risk assessment, reporting, and treatment, in addition to residual risk reporting and monitoring. The most important process is risk assessment because it consists of the following: risk analysis, identification, description, estimation, and evaluation (IRM, 2002). In addition, this study investigates two processes related to risk management: risk identification (assessment) and mitigation.

A. Risk identification is known as the process for determining those risks that could potentially prevent the program, enterprise, or investment from achieving its objectives. This includes documenting and communicating the concern (PricewaterhouseCoopers, 2008). Hence, when it comes to risk management in environments similar to UAV applications development projects, team members and project managers should review any single detail on project and program scope, technical ability, key performance indicators, development challenges, client expectations vs. proposed project, technical challenges, integration, interoperability, supportability, supply vulnerabilities, testing, and regulatory obstacles (PricewaterhouseCoopers, 2008).

B. Risk mitigation is defined as a process for reducing adverse effects. There are four types of risk mitigation strategies that are unique to project stability and disaster recovery. Developing a strategy that closely relates and matches project scope and portfolio is important. Those strategies and techniques are: risk acceptance, avoidance, limitation, and transference (MHA Consulting, 2013). Furthermore, risk mitigation progress monitoring includes tracking identified risks, identifying new risks, and evaluating risk process effectiveness throughout the project.

Chapter 3 : Challenges of Developing UAV Applications

3.1 Introduction

UAV applications offer great opportunities for providing cost-effective solutions to diverse applications that require different capabilities for various tasks. Therefore, the demand for UAV civil applications is increasing significantly along with the growth of the UAV market. According to Forecast International, which predicts strong growth in the UAV industry, a thousand UAVs of all types will be manufactured this year, with the output rising to 1,100 units in each of the following two years. From 2017, production is forecasted to average about 960 large UAVs annually for the remaining seven years of the 2014–2023 forecast periods (DefenceWeb & International, 2014). In addition, another report published by Teal (Luley, 2014) shows that there is an expected growth for UAV production between 2012 and 2021, especially for smaller UAVs, and the sales growth for larger UAVs is expected to reach 43 billion USD.

Although UAV production is expected to remain relatively stable over the next ten years, the value of production will steadily climb, from about $942 million in 2014 to $2.3 billion in 2023 (DefenceWeb & International, 2014). Much of the growth can be attributed to large UAVs. To that point, many countries worldwide lack the capabilities and funding to either procure or manufacture these large and complex systems. However, countries such as India and Brazil are forming partnerships to help build these capabilities so that, in the near future, they can manufacture more expensive systems indigenously (Luley, 2014).

Thus, the larger UAVs will continue to dominate total sales while representing only a small portion of the total volume, as shown in Figure 3-1. However, UAVs of all sizes have great opportunities for growth.

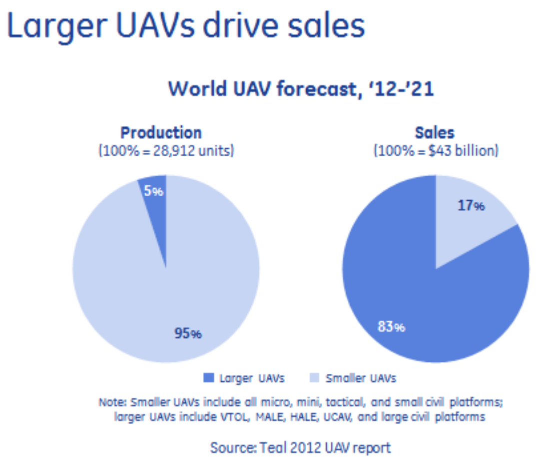

Figure 3-1: World UAV Market Forecast (Luley, 2014).

Although UAVs have currently become important tools for performing many tasks, building applications that will effectively and efficiently operate UAVs and utilize them for certain problems still requires a huge number of man-hours in design, development, testing, and deployment. This is mainly because of the lack of existing technologies and management methodologies that can be utilized to effectively develop UAV applications.

This growth requires efficient and cost effective development processes, whereas UAV applications can be considered as complex systems that create several challenges for UAV applications development at different stages. Several technical and non-technical challenges encountered by their development processes need to be solved. Many PM and technical challenges are encountered by UAV applications development in terms of resource management, power management, security, communication, and other challenges related to testing, simulation, and regulations.

Furthermore, integrating these components into a final UAV applications product is also a challenge. The purpose of this chapter is to study the challenges of developing UAV applications from the IT PM perspective. UAV applications development projects are considered complex because of the difficulties of the development stages and component integration complexity. Developing UAV applications involves integrating hardware, software, sensors, actuators, and communication components with the UAV mechanical systems.

The remainder of the chapter is structured as follows. In Section 3.2, we provide a brief background on PM in the UAV industry. In Section 3.3, the PM business and technical challenges for UAV applications development are discussed. Section 3.4 provides some discussions regarding some possible technologies that can be utilized to relax the challenges and risks of UAV applications development. Finally, we conclude this chapter in Section 3.5 with remarks and conclusions on the main contributions of this chapter.

3.2 PM in UAV Industry

UAV applications development is considered a complex project because of system difficulties and sensitivity. Because UAVs are considered complex systems, most UAV applications development projects rely on the Product Lifecycle Management (PLM) approach throughout the different stages of the project. PLM is an all-encompassing approach for innovation, New Product Development and Introduction (NPDI), and product information management from ideation to end of life. Furthermore, its strategic business approach applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across an extended enterprise, and spans from product concept to end of life, thus integrating people, processes, business systems, and information. UAV applications development projects consist of many processes and components from different sides, such as payload, engines, avionics and software development, and integration and testing. As a result, sound and effective PM methods that involve system dynamics, program evaluation and reviewing techniques, critical path methods, design structure matrixes, earned value methods, Gantt charts, and object process methodologies are necessary.

These methods are used in various stages of the development process (Sharon et al., 2011):

1. System dynamics: project planning and dynamics modeling.
2. Program evaluation and reviewing techniques: project planning and scheduling.
3. Design structure matrix: project planning and product design.
4. Earned value method: project control
5. Gantt chart: project planning and scheduling.
6. Object process methodology: combined project.

In aerospace industries, the challenges in product development are alignment of resources, controlling costs, and improving programs and PM practices. Many aerospace professionals consider UAV projects as comprehensive programs; such consideration led to many program management challenges. In addition, growing regulatory requirements create a big challenge for UAV development projects. One of the problems encountered by UAV applications development is the lack of simulation environments, either virtual or real. Some countries do not even have testing areas for UAVs.

Because current UAV applications rely more on computational processes, they require more effective resource allocation and management models during the different development stages. In the case of FALTER (Mutter et al., 2011), a UAV equipped with many sensors and devices, testing is more difficult because of many obstacles. Testing a UAV complex system poses threats to the equipment under development and to the test environment and personnel (Mutter et al., 2011). Because UAVs can move with considerable speeds using propeller rotation, they pose physical risks during testing. Many risks and factors need to be considered when designing a portfolio for a PM framework, which include (Oehmen & Rebentisch, 2010):

1. Strategic fits.

2. Financial rewards.

3. Timing.

4. Maintaining a competitive advantage.

5. Properly and efficiently allocating resources, providing better objectivity for project selection, achieving focus, and having better communication between the projects, organizations, and stakeholders.

One of the issues that need to be considered in developing any UAV application is the cost of the development process. Hence, it is highly important to consider cost using suitable cost estimation models. In addition, some factors affect the maintenance performed on the application, including the repair of defects incorporated in the software during the development process, or changes in the agreed upon requirements, or the desire to improve performance. There is a statement that states, “The totality of activities required supporting at the lowest cost while some activities start during its initial development, but most activities are those following its delivery” (Sams, 2011). Therefore, cost estimation techniques play a core role in reducing the project cost risk issue. UAV applications are currently considered active trends in IT, and they can be integrated with other technologies, such as the Internet of Things (IoT), cloud computing, smart cities, and big data. Thus, many challenges are encountered when developing advanced solutions that integrate UAVs with these technologies to create useful applications. These challenges and factors that originate from different entities, such as technology and human and institutional bodies (Nam & Pardo, 2011), are:

1. Technological challenges: system integration, availability, support and maintenance, and disaster recovery and backup.

2. Human challenges: human capital, education, and awareness.

3. Institutional factors and challenges: collaboration and cooperation, partnerships between different sectors and parties, and citizen engagement to avoid administrative obstacles.

In addition, UAV applications development projects encounter some issues in integration because the UAVs might be integrated with many other services, applications, and platforms. One example is integrating UAVs with smart city platforms. In this case, the challenges may include several managerial issues: project size, manager attitude and behavior, user or organizational diversity, lack of alignment with organizational goals and mission, multiple or conflicting goals or conflicts of interest, resistance to change, and turfs and conflicts. In addition, the IT-related challenges have two dimensions: IT skills and the organizational:

1. IT skills: IT training programs and lack of employees with integration skills and culture.
2. Organizational: lack of cross-sector cooperation, lack of interdepartmental coordination, and unclear vision of IT management, politics, and cultural issues.

Furthermore, governance could be a challenge in UAV development projects because there could be many stakeholders and business partners if the UAV were involved in complex services development (in the case of smart cities) (Chourabi et al., 2012). In addition, collaboration, leadership, communication, accountability, and transparency are challenges in such projects. UAVs consist of embedded systems and other complex sub-systems.

The design of embedded systems for UAVs can follow two approaches: the software lifecycle ends, and the lifecycle for the process of integrating the software with the hardware begins at the time a system is designed. Both cycles concurrently proceed when co-designing a time-critical sophisticated system. In such approach, hardware/software co-design is an important aspect of the design process and software and hardware integration. In addition, before developing such complex systems, detailed specifications need to be considered, such as specifications related to product functions and tasks, delivery time schedule, product lifecycle load on the system, human-machine interaction, operating environment, sensors, power requirements, and environment and system cost (Inc, 2009). One of the challenges encountered by any project is required resources. In UAV applications development, resources allocation might be a critical issue during the period where the demand for UAV civil applications is rapidly increasing. Resources can be divided into two types: physical and logical. Physical resources include processors, memory, peripheral devices, storage, APIs, workstations, workshops, network elements, and sensors.

Although all software, data, and control modules are examples of logical resources, they are defined as system abstractions with temporary control over physical resources. They can provide support for applications development and required functions, such as efficient communications protocols. These resources include operating systems, energy/power, network throughput/bandwidth, load balancing mechanisms, data security/protection mechanisms, APIs, and protocols for signal and image processing. In resource management, there are several issues to consider, such as resource provisioning, allocation, adaptation, and mapping (Manvi & Shyam, 2014a).

Each of these issues has its own challenges, and this chapter attempts to discuss those challenges and find solutions, as discussed in the next section. Furthermore, other issues that occur in any development project are seen and unseen risks. For both types, we need to identify the risks and analyze them during the project lifecycle. In addition, we require effective mechanisms for risks evaluation, monitoring, and reporting. New risks appear along with the emergence of new UAV civil applications. Because the trend is to engage UAVs with the several other IT trends, some issues have been imposed by law or regulations, in addition to the operational risks and risk occurrences that appear during the development of such products. These risks can have great impact on UAV applications during and after the development process. The risk management techniques are driven by business strategies and must be integrated into the decision-making processes within the UAV development firms. Some risks are associated with UAV application development, such as lack of simulation and testing environments, loss of direct control over resources and software, and risks associated with data protection and security in addition to legal risks, regulatory compliances, and interference with civil aviation regulations (Fito & Guitart, 2014). In automated system development, some challenges occur, such as change management challenges, scheduling, planning, monitoring, adherence, and communications (Inc, 2009), as shown in Figure 3-2.

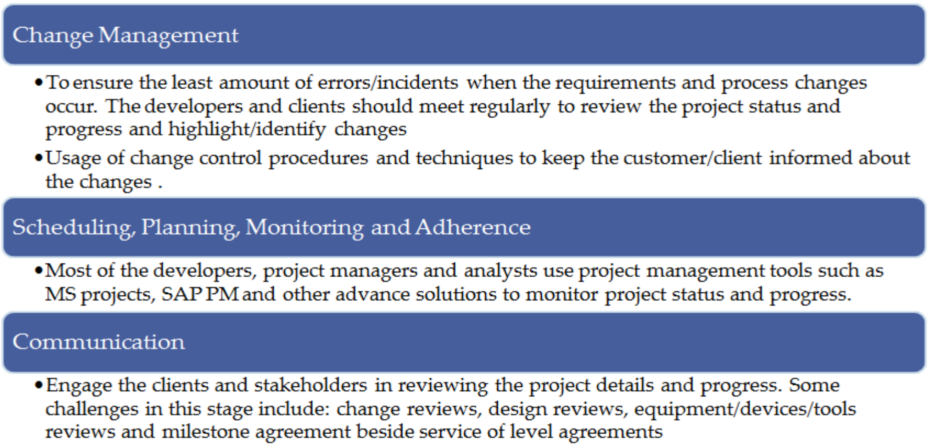

Figure 3-2: PM Challenges.

UAV applications development is all about integrating software (applications) and hardware (UAVs). A case study on Oerlikon Aerospace shows that the software engineering manager is the owner of the software process. The process owner is responsible for the effectiveness and efficiency of the process, methods, and tools. This person is also responsible for developing the software Processes Improvement Plan (PIP). Moreover, many other responsibilities are assigned to this person, such as reviewing and tailoring the software engineering processes before the development plan is approved. Many issues need to be considered in different stages of the project.

UAV applications development projects are considered complex because of the difficulties of UAV systems and software requirements. Such projects involve complex IT components with several characteristics, such as lack of constraints, visualization, flexibility, complexity, uncertainty, software failure, and the need for supporting change. In addition, these components have key success factors, such as project parties' relationships, contractual agreements, evolutionary PM, change management, risk factors, risk avoidance, organizational culture, software upgrades, testing and test planning, technical issues, requirements capture, system architecture, reusability, verification, validation, and the most critical part: the integration process. Many problems occur during the development of complex computer-based systems mainly because of the integration between the system and software processes. Furthermore, many problems occur during the integration stages.

To avoid such issues, using the process that decomposes the systems into multiple parts to be developed independently and integrated easily at the system level is advisable. Because of the digitization of electro-mechanical systems using emerging software technologies, the non-recurring activities in system development have arisen from nominally 30% during the mid-1970s, to almost 70% in 2004 (Royal Academy of Engineering/The British Computer Society, 2004).

3.3 Challenges in UAV Development Projects

In this section, we discuss the challenges encountered by UAV applications development from different perspectives, such as business, managerial, and technical.

3.3.1 Project Resource Management Challenges

A. Resource management challenges: resource management is a core challenge in any project, not only UAV applications, because it affects the stages of product development. Foremost, resource management is defined as the efficient and effective deployment and allocation of an organization's resources when and where they are required. Those resources may include financial, human, production, IT, and other types. Resource management consists of planning, allocating, and scheduling resources to jobs and tasks, which mainly include developers, integrators, analysts, hardware and software designers, manpower, and materials. Resource management has an impact on budgeting, financing, and the overall cost of the project. Resource management as an issue also has some sub-issues or related issues that might affect the process or the project of developing UAV applications (Manvi & Shyam, 2014b). These include resource provisioning, mapping, adaptation, modeling, estimation, discovery, selection, brokering, and scheduling. Each of these imposes some challenges to projects:

   1. Resource provisioning: in UAV applications development, a challenge occurs in how to make the application that is hosted on UAV platforms achieve economy of scale while preserving the application-specific Service Level Agreement (SLA), such as response time and throughput. In addition, designing resource provisioning algorithms that correctly

converge to the optimal CPU allocation based on data rate and computational requirements is a challenge. In the case of UAVs, because they can manage and host many applications, the challenge is in how to design a scheme that can support n-tier clustered applications to be hosted in UAV platforms.

2. Resource allocation: resource allocation refers to dividing resources economically among competing groups of people or business units or programs. Designing an SLA-oriented resource allocation scheme that integrates customer-driven service management is one challenge. Other challenges in resource allocation include finding a planning mechanism that compromises between the costs of reconfiguration and maximizing the UAV utilities and parts, and creating techniques for allocating services to applications depending on energy efficiency and expenditure of the clients/developers.

3. Resource mapping: resource mapping refers to the way of creating symmetry between the resources taken by the customers and the resources available with the project parties. Resource mapping might face some challenges, such as mapping physical and logical components, and determining the physical resource allocation to satisfy the logical demand that can be prevented by some physical constraints and obstacles. Another challenge is designing an algorithm that can obtain fast mapping using a generic algorithm, which can accelerate the mapping process while satisfying the tasks and mission deadlines. Moreover, mapping the application assignments to the UAV platforms and hardware attributes to

validate the compatibility between UAV specifications and application prerequisites need to be addressed. In addition, another challenge is in producing models that can predict application performance considering different parameters, such as CPUs, computer storage, communication protocols, and information warehousing. In addition, the load balancing between the factors considered is a core challenge in resource mapping.

4. Resource adaptation: resource adaptation means the ability or capability of that scheme to adjust the resources dynamically in order to meet and satisfy the demands of users/customers. Some UAV applications are considered mission critical, which require extremely robust SLAs. Such stringencies cannot be met by some UAV vendors; for instance, high-level UAVs that require high standards might still not find it desirable to consume key resources and services from some vendors because of intrinsic risks.

B. Business and project risks: Selecting the best strategy in a project structure in the preparatory stage of a project is often complicated, particularly when the project should bear a product that presents technological novelty. Because the UAVs for civil applications are currently considered a new trend, there are some risks that might bear on developing such products, which can be called New Product Development (NPD). Thus, firms need to adopt steps for reducing hazards associated with NPDs. The risk management framework should integrate the three most significant risk genes that affect NPD performance: technology, marketing, and governance. Risk management methodologies refer to a standard process that presents the well-known steps of risk identification, evaluation and quantification, mitigation for treatment, and/or impact minimization and risk monitoring (Marmier et al., 2013). Risks that might occur in any project for several reasons include the modification of existing tasks related to the risk influence on the duration or cost. Another cause is the modification of the project structure by treatment strategies (treatment actions are presented by new tasks in the planning) that might affect the project resources from different prospectus. Such projects need configuration management defined as the management discipline that applies technical and administrative directions to the development, production, and support lifecycle of a configuration item. The discipline is applicable to hardware, software, processed materials, services, and related technical documentation. Configuration management is an integral part of the lifecycle management (Xu et al., 2013).

In addition, configuration management is described as the act of managing the parts of a product and design to ensure that the products perform as intended. One of the challenges encountered by risk management in UAV applications development is the design/implementation of a model that could involve risk mitigation. Risk management is considered important for many reasons, such as analyzing the possible scenarios to determine the global risk level. In addition, the global risk level represents the opportunity for the project to satisfy commitments and choose the best treatment strategies. As mentioned earlier, change and configuration management are linked and related to resource management and risks because any change that might occur on the product/application requirements can lead to changes in resource allocation and risk expectations. Therefore, risk assessment is a means for allowing decision makers select and accept design and mission scenarios and technical implementation aspects (Altavilla & Garbellini, 2002). UAV applications development is gaining popularity among aerospace manufacturers, and thus they use several tools to control change management, such as (Xu et al., 2013) standardizing the processes, extending the configuration management with advanced capabilities, and allowing configuration management.

Change management in such industries encounters some challenges that might involve the product/application development, which can involve the entire operation that is preparing the products. Such products usually require a large number of components and are highly complex in nature. In addition, these companies are bound by various regulatory bodies and are involved in managing complex and diverse teams to react to all the client needs. The major element that drives aerospace industries to implement configuration management is delivering a product per the customer needs while managing the cost, schedule, and quality of the product.

Risks are highly associated with development and post-development activities, such as testing (Altavilla & Garbellini, 2002); therefore, risk assessment is important in such stages because of several purposes:

1. Identifying drivers and requirements.
2. Supporting risk management policy definition.
3. Driving the definition of the design and operations strategy from the early phases of the project.
4. Supporting tradeoffs and optimizations among alternative system design concepts and variables.

5. Ranking the risk contributors to modulate the risk reduction efforts.

6. Verifying the adequacy of safety measure implementation.

7. Justifying design and operations with respect to the probabilistic targets.

8. Supporting risk management in the selection of the most cost-effective engineering techniques and development approaches.

3.3.2 Technical Challenges

A. Communication: communication is considered the backbone of any UAV application, especially if that application serves multi-UAVs or data processing and transferring. In addition, communication is related to UAV safety (more commonly for large UAVs and high complexity UAV systems (Pongracz & Palik, 2012) for several reasons:

    1. Loss of voice communications between a UAV pilot and Air Traffic Control (ATC).

    2. Intelligibility and latency of voice communication between a UAV pilot and ATC.

    3. Loss of command and control links between a UAV and Ground Control Station (GCS).

    4. Interruption of command and control links between a UAV and ATC (because of system reliability).

One of the most significant issues in UAV communication, which is the most fundamental between UAV and the ground station, is that the data link is lousy and transient (Jong, 2009). These effects should not require management by an application such as the flight controller. Therefore, the messaging layer should hide and resolve problems such as misplaced or out-of-order packets from the application layer. For instance, commands sent from the ground station to the UAV flight computer usually require confirmed result feedback to the ground station.

Security and privacy: UAVs are in essence “tethered” to ground-based links that are, in some cases, widely distributed geographically. These connections are used for vehicle control, monitoring, and air traffic communications and are, to varying degrees, vulnerable to jamming, spoofing, and interference or attempts to seize control. To prevent this, a system of high-integrity, secure data links between the aircraft, GCS, and air traffic facilities is a central requirement in approving UAV operations in a National Air Space (NAS). Modern encryption and authentication techniques, including augmented version, can mitigate the event (DeGarmo, 2004). Nevertheless, high power jamming imposes a risk even with advanced encryption and certification technologies. Communication security depends on the frequency used, communications media, encryption technology utilized, and associative properties of the communication connection. Typically, encryption with a lower frequency and low bandwidth poses more of an issue than higher, pricier frequencies and bandwidths. In that respect, there is also a tradeoff concerning security, operations, and price. In general, the higher the security, the lower is the public demonstration.

Because UAVs are usually fully autonomous systems, security is a key concern. Given that UAVs are equipped with sensors and different types of communication tools, the possibilities of hacking are high, and therefore high standards of authentication and encryption are highly recommended. Several types of possibilities, consequences, and incidents might occur in such case. Therefore, different techniques are used in UAV system protection, such as using state variables in the system, redundant detection systems, and alarm systems connected to the UAV GCS and other techniques that need to be discussed technically.

Likewise, there are some proposed methods for preventing UAV hijacking. The methods for risk mitigation proposed by the Department of Defense (DoD) and Humphreys in 2013 address the prevention of hijacking. However, there is limited published information on insurance options for detecting and mitigating the effects of a hijacking (Faughnan et al., 2013). Some examples of UAV hijacking are malware embedded during the application development stages, spoofing attacks, and sensor manipulation. Other examples include non-cyber-attacks, such as radio wave interference, and unit redirection manipulation of feed via the control station hardware. Other types of attacks also include transmission of faulty data and gaining control in order to manipulate and disable some functions. In parliamentary law, in order to mitigate the effects of these hijacking scenarios, the team used questions connected with risk management: what can be sufficed with usable options? What are the tradeoffs among all risks, benefits, and prices? What are the impacts of current conclusions on future choices? In general, the execution of a UAV hijacking detection system is beneficial because it informs the operator that the vehicle is compromised.

Limitations to the performance of such systems include implementation costs, the cost of training the operator to utilize the system, potential load increase on the UAV, and the potential for the system to falsely identify or fail to identify a hijacking. An accurate detection system might allow decision makers to take a more appropriate course of action in a hijacking situation. Examples of detection techniques and methods include data link, software and hardware encryption, pilot authentication, backup for control systems, and physical tracking confirmation systems.

B. System integration: system integration includes UAV system integration during the development stages, and subsequently setting up the final product integration. In the UAV industry, UAV system integration has a wide scope of issues, challenges, and definitions. In this part, we cover the topics and challenges that concern system integration in the different phases of application development. System integration involves the discernment of the application operational requirements in terms of software and hardware components, and it involves agreement of the UAV aerodynamics and system mechanisms.

For example, in order to combine measurements from a set of sensors that contribute towards a motion estimate, the spatial interpretation between the sensors has to be known precisely (Nikolic et al., 2013). Therefore, there must be some synchronization between sensors, hardware, and UAV platforms. Otherwise, there might some delays in data capturing. Another challenge that needs to be considered during system integration is the system integration with the regulatory framework. FAA summarizes the issues as follows (US Department of Transportation Federal Aviation Administration, 2013):

1. UAVs must operate safely, efficiently, and compatibly with service providers and other NAS users so that overall safety is not decreased.

2. UAVs should receive admittance to NAS provided that they have appropriate equipage and the power to fulfill the requirements for flying in various categories of airspace.

3. Routine UAV operations should not involve the institution of new special use airspace or the alteration of existing special use airspace.

4. Except for some peculiar events, such as small UAVs with an extremely limited operational range, all UAVs require design and airworthiness certification in order to fly civil operations in NAS.

5. UAV pilots require certification, although some of the requirements can differ from manned aviation.

6. UAVs should comply with ATC instructions, clearances, and procedures when receiving air traffic services.

7. UAV pilots (the pilot-in-command) should always have the responsibility for the UAV while it is operating.

8. UAV commercial operations should demand the operational control concept to be appropriate for the type of functioning, but with different functions applicable to UAS operations.

In addition, integration issues also concern sensors integration because the sensors are the core component for data capturing. Inertial Sensors (INS) are often affected by bias, drift, and noise, and are prone to sensor-based navigation errors. Moreover, by using INS alone, the vehicle cannot reduce its errors and requires external information on its absolute position (Melega et al., 2013). Therefore, some research uses algorithms to avoid such problems. One of the extremely important elements of the communication system dedicated for exchanging information between a UAV and the operator is the antenna system. This system consists of two antennas, each for a communication subsystem. For construction reasons, the antennas might be mounted on the fuselage, whereas the wings are destined for fuel tanks, and hence antenna integration needs to consider the hardware and body structure to avoid any errors and defects (Kurek et al., 2013).

System integration issues are mainly concerned with communication protocols, techniques, and devices. Another extremely important requirement is that transmission delay, including processing time in the transmitter and receiver modules, should not exceed 100 ms. The transmission should be encrypted using the AES128 encryption protocol, and the modules should ensure proper operation at ambient temperatures that range from 30° to 50° C, and relative humidity of up to 95%. An important limitation is the maximum size of the modules (limited because of the available free space in the UAV) and weight.

C. Energy: power is considered the core of any autonomous system; in the case of UAVs, it is considered a big challenge for UAV applications development. Some research and approaches are currently under way in order to address and solve power-related matters and issues. The quick growth of the UAV market has pushed many firms and organizations to find solutions for power issues. The U.S. naval science and technology strategic plan (Office of Naval Research Science and Technology, 2011) has been applied in the military.

This suggests that there must be a focus on alternative power sources; development of more efficient power storages solutions; design of energy efficient components, processes, and algorithms; and design of compact, low power perception, and mapping for different types of UAVs.

The weight of a UAV, and thus its power needs, is determined by the payload, type of sensors, and application specifications and requirements. However, there are some limitations in UAVs power abilities that can lead to some shortages in their tasks. Such issues may lead to failure of UAV development and growth because power requirements differ based on the application. Because of such issues, the US Air Force (USAF) attempted to retire the RQ-4B drone; however, the decision was opposed by the US congress (Weinberger et al., 2012); with the growth of research on power saving solutions, we expect the availability of these solutions soon.

D. System autonomy: The main goal of any UAV system is to provide full autonomy for its components to achieve their goal. Any autonomous system must meet the following minimum requirements (Anderson et al., 2014): no driver error, high safety; less mobility of human elements; less traffic flow in shell for both UAV and unmanned ground vehicles; meet low costs in terms of building, planning, and operating; fuel efficiency can be increased and alternative energy sources facilitated; and occupy less physical spaces. Furthermore, autonomy in unmanned systems is divided into four categories:

   1. Remote control and tele-operated: a human operator controls a robotic vehicle from a distance. The human performs all the cognitive processes. The onboard sensors and communications allow the operator to see the location and movement of the UAV within its surroundings, and its on-board effectors allow the human to act on the information supplied.

2. Semi-autonomous: these systems have advanced navigation, obstacle avoidance, and data fusion capabilities that minimize the need for operator interaction (e.g., to achieve point-to-point mobility or target point). They also have sufficient on-board processing to conform to simple changes in objectives designated by an operator.

3. Platform-centric autonomous: a fully autonomous UAV can undertake complex tasks/missions, gaining data from other sources as needed. Alternatively, it can respond to additional commands from a controller without the need for further guidance.

4. Net-centric autonomous: these collections of UAVs have sufficient autonomy to function as independent nodes in a Network Centric Warfare (NCW) engagement, in the case of military applications. They should be capable of obtaining data from the web, incorporating it in their mission planning and implementation, and reacting to other information requests, including the resolution of conflicting instructions.

The primary challenge in autonomy is the interaction between humans and unmanned systems, such as UAVs. Achieving a high degree of autonomy requires high system integration and high communication techniques with extremely high communication throughput. Another problem in this area is the interaction between the vehicles and the ground controller, which is related to the human decision-making process on the system performance; in general, to reach high levels of autonomy, high levels of communication and integration are highly required. This duality in the levels of automation presents a problem for the UAV application developer (Finn & Scheding, 2010). See Figure 3-3.

vehicles are in full collaborative communication and individual vahicle-tasking changes according to autonomously re-assigned , re-perioritised ,co-operative goals , there is no human intervention.	maximum network autonomy
vehicle collaborate with one another , but the human interacts by dynamically re-assigning or re-priotirising the co-operative's goals	↕
Vehicles communicate with each other for seperation and threat deconfliction but still depend on human for new tasking	minimum network autonomy
Vehicles do not communicate with one another and follow original tasking , unless human identifies new task.	

Figure 3-3: Intra Vehicles Level of Autonomy (Weinberger et al., 2012).

3.4 Discussion

Complex systems are primarily independent networked systems that feature the ability of integrating systems, products, and services to achieve the required goals. The breadth of complex systems facilitates integration of technological, human, cultural, environmental, and political arrangements. The survey of complex systems is used in both the innovation and entrepreneurship of PM Fields. UAV applications are considered complex systems for many reasons, as follows (Australian Government Department of Defence, 2012):

1. They usually consist of adaptive systems of systems.
2. They have high uncertainty in scope definition.
3. They are distributed and have ongoing environmental and internal turbulence.
4. They are implemented through wave planning and cannot be easily decomposed into elements with clearly defined boundaries.

Many challenges might arise in the future because UAVs are targeted to be fully autonomous. UAVs are considered a special case because their complexity is all about sensors, image processing, working on networked vehicles, and connections with ground stations and other services. With the correct resource allocation and management techniques, efficient power solutions, and enhanced middleware systems, we can guarantee a well-functioning system. However, more issues and aspects require more effort to address, such as a management framework for developing UAV solutions.

Many issues concern software PM, including risk assessment and mitigation, software architecture, requirements engineering, testing, quality assurance standards, configuration, software metrics, and best practices.

In the case of UAV applications development, such issues need to be considered in order to guarantee a high quality application with extremely good performance. Therefore, in UAV applications development, many challenges occur from different aspects. During development and in the post-development stage, challenges related to integration, power, resource management, and communication must be addressed.

Project planning is a core key of success for developing UAV applications. Project planning is a form of operational planning (European Commission, 2012) whereby the consecutive steps for implementing the project activities are carefully mapped based on an analysis of relevant information, and linked to the program in which the project occurs and to which it should contribute. Essentially, project planning involves establishing the scope, aims, and objectives of a project the way in which the project is to be performed, the roles and responsibilities of those involved, and the time and cost estimates.

Planning entails a series of decisions, from general and strategic to specific operational ones, based on information gathering and analysis. The field of planning encompasses a broad range of different approaches, including strategic, program, and operational planning. Therefore, such issues need to be addressed in future work to find solutions. In addition, other challenges need to be considered, such as the standards, licensing, and lack of simulation platforms and environments. Middleware is considered a valuable solution for UAV development issues. However, it is not easy to develop middleware that will meet the many requirements in terms of considering UAV characteristics and different application architectures, as well as the required specifications for the middleware (Mohamed et al., 2013). Middleware can provide the following features and advantages for UAV application developments:

1. Offers tools and functions to simplify the development of collaborative UAV applications.

2. Offers high-level abstractions and interfaces to facilitate UAV application integration, reuse, and development.

3. Hides the heterogeneity of UAV devices, platforms, and operating environments, as well as the distribution and communication details in the environment.

4. Facilitates communication among different components of the UAV systems.

5. Provides common services for general-purpose functions required by different UAV applications in order to reduce development efforts and avoid service duplication.

6. Provides a common architecture to add new services and features without having to change UAV applications.

7. Offers value-added features and nonfunctional properties, such as security, reliability, and Quality of Services (QoS).

8. Supplies the necessary tools to enhance performance and increase the stability, safety, and scalability of collaborative UAV applications.

To design a middleware framework, many challenges and issues need to be considered, such as QoS, hardware resources, changes in network topology and size, heterogeneity, network organization, application knowledge, and security and integration with other systems. Furthermore, the middleware design can include advanced services, such as collaborative sensing, acting, communication, data processing, data storage, and control. Usage and deployment of an advanced middleware for UAVs can reduce the cost of development, deployment, and operations. A new and advanced approach in middleware technologies is the use of Service-Oriented Middleware (SOM) (Al-Jaroodi & Mohamed, 2012). This approach has already been proven to simplify implementation and help relax the PM issues of several industrial domains.

SOM (Service Oriented Middleware) is used for wireless sensor networks (Mohamed & Al-Jaroodi, 2011), telecommunications (Bo et al., 2010), manufacturing (Groba et al., 2008), and distributed monitoring and control systems (Taylor et al., 2006). The approach is used in these domains to reduce the effort and cost of development, testing, and operations. Similarly, SOM can play an import role for developing and operating UAV applications. Accordingly, we anticipate a successful migration of the model to support UAV applications development and provide a generic middleware platform to highly increase productivity and widen the range of applications that can be designed and built using UAV systems in various domains.

Moving forward, SOM extends the capabilities of middleware and provides high flexibility for adding new and advanced functions to UAV applications. SOM logically views UAVs as providers for a set of services for user applications. With SOM, all hardware devices, such as sensors, actuators, data storage devices, communication devices, and processors can be viewed and utilized as services (Mohamed & Al-Jaroodi, 2013). In addition, other advanced services, such as data aggregation, adaptation, security, safety, system autonomy, reliability, and management can be designed, implemented, and integrated in a SOM framework to provide a flexible and easy environment to develop effective UAV applications (Mohamed et al., 2014). SOM for UAVs is necessary for supporting several, otherwise difficult to incorporate, functionalities in the Service-Oriented Computing (SOC) model. These functionalities include the functional and non-functional requirements that different services might need. For any service-oriented application, there are several common functionalities, such as service registry, discovery, communications, reliability, and security, that are irrelevant to the application. These can be easily generalized and made available via a SOM platform to be used by different applications developers (Mohamed et al., 2014).

In this chapter, we discussed the challenges encountered by UAV applications development and highlighted some of the approaches developed in order to reduce some of the technical challenges, such as SOM. In addition, Table 3-1 summarizes the challenges mentioned in this chapter, and provides a condensed overview of the UAV challenges.

Table 3-1: Challenges of Developing UAV Application

Type of Challenge	Examples	Authors
PM	— Resources management challenges. — Business and project risks	— (Manvi & Shyam, 2014b) — (Marmier et al., 2013) — (Altavilla & Garbellini, 2002) — (Xu et al., 2013)
Technical	— Communication — Security and privacy — System integration — Energy — System autonomy	— (Pongracz & Palik, 2012), (Jong, 2009) — (DeGarmo, 2004), (Faughnan et al., 2013) — (Nikolic et al., 2013), (US Department of Transportation Federal Aviation Administration, 2013), (Kurek et al., 2013), (Melega et al., 2013) — (Office of Naval Research Science and Technology, 2011), (Weinberger et al., 2012).

		— (Anderson et al., 2014), (Finn & Scheding, 2010)

3.5 Conclusion

Because of the rapid growth of UAV applications development and the global demands for UAV technology, many challenges need to be addressed. In this chapter, we identified the challenges encountered by such applications development projects. For the future, we aim to address those challenges by creating different solutions to avoid and mitigate them. The market demand for small UAV technology is increasing because it is considered an effective and low-cost alternative to manned aircrafts. The market overall has numerous players for mini-UAVs from Europe and the US. The players from these regions have the technical know-how and capability of introducing updated applications to the market. The current market trend is to transition towards faster and more efficient payload systems with the ability of reducing UAV weight significantly. Future work might include the development of effective simulation frameworks, platforms and standards, PM frameworks, and use of PM software to manage UAV applications development.

Chapter 4 : Risks of Developing UAV Applications

4.1 Introduction

In this chapter, we discuss the risks encountered in the development of UAV applications. Because the UAV applications market is growing globally, and there is a direction for using these applications in different levels and sectors, the demand for UAV applications will increase, with a subsequent increase in risks. UAV systems are known to be both complex and sensitive with some limitations in power and communication, as well as the regulatory part of this industry, but there is still no clear regulatory framework. Therefore, most organizations hesitate before committing to UAV applications development. Hence, the risks will increase and appear before, during, or after the development processes. Initially, we need to understand the term "risk," which can be defined as the combination of the probability of an event and its consequences. In all types of undertakings, there is a potential for events and consequences that constitute opportunities for benefit (advantage) or threats to success (disadvantage). For systems, it is extremely important to recognize different types of risks and evaluate them.

In UAV applications and systems development, risks vary from business to operational, strategic, PM, external, and financial. The CHAOS manifesto (The Standish Group, 2013) is a global report published by Standish International Group, Inc., and it is based on a wide collection of IT environment, software, and applications development projects. In CHAOS report, they have a database that covers over 50,000 projects, and their researchers used many tools to study the projects in terms of project profile, project tracking, individual projects surveys, case interviews, general surveys, project postmortems, and other tools. According to the

CHAOS manifesto, 43% of the projects in the database are challenged, 18% failed, and 39% succeeded. Success is measured by on-time delivery, meeting the budget, and mapping with requirements, standards, and specifications, whereas most of the challenges occur because of the budget, and difficulties in meeting requirements, standards, and budgets.

According to the CHAOS manifesto, success rates can increase because of several factors, such as the entire project environment of processes, methods, skills, costs, tools, decision, optimization, internal and external influences, and team structure and chemistry. In the case of developing UAV applications, those factors need to be considered, especially the requirements, standards, and specifications because of the sensitivity and complexity of the system. According to this report, the rate of using Agile methodologies has increased, whereas use of the Waterfall model has decreased compared with previous years. According to the previously mentioned statements, UAV applications development is considered a complex project because of system and architecture complexity. According to the report, small projects have more than 70% ability to succeed, whereas large and complex projects (and UAV applications development is considered one) have virtually no possibilities for finishing on time, on budget, and within scope. The factors for success include executive management support, user (client) involvement, optimization, skilled resources, PM expertise, Agile process, clear business objectives, execution, tools, and infrastructure.

According to the CHAOS report, the success rate for UAV projects is extremely low at 38% failure and 52% challenged. To avoid risks, clear business objectives must be defined carefully; therefore, the Project Management Owner

(PMO) and PM expert should identify the risks, limitations, and possible problems, and map them to the business vision and objectives. In such projects, most risks arise because of time, cost, specifications (standards), and licensing issues. The report presents an important aspect because it states that 20% of system features are used often, whereas 50% of the features are scarcely or never used, and the remaining 30% is comprised of functions used infrequently.

The main goal of this chapter is to identify risks based on categories, and discuss and compare risk management techniques that can be used in UAV applications development, while discussing and comparing the main risk mitigation techniques that have been used in UAV applications development.

4.2 Types of Risks

As mentioned earlier in this section, it is extremely important for systems to recognize different types of risks and evaluate them. Identifying risks earlier and avoiding them in order to manage them later leads to a high-quality project and product; therefore, it is important to link quality with risk because both are considered success factors for any project. Project quality is the factor that can significantly affect the possibility of risks appearing and the extent of the consequences of these risks during the development process of software projects. The total quality of given software project is measured using two sub-factors: process and people quality.

Risk dimensions include user, requirements, project complexity, planning and control, team, and organizational environment. The factors and dimensions include user, requirements, complexity, planning and control, team, and organizational environment risks, in addition to management, staff, and process quality. In addition, many software development projects often fail because of a lack of understanding of the risks involved. Specialists in this field claim that the risk related to software development projects have to be defined first, and then managed during the development process. Risk management methods that focus only on one risk aspect may even lead to riskier projects with great possibility of failure (Sarigiannidis & Chatzoglou, 2014). According to Kremljak & Kafol (2014), risks can be categorized as follows:

1. Strategic: this is associated with those risks that can affect the strategic direction and survival of an organization. The factors that play into this category include the macroeconomic risks created by the fiscal policies of central and federal governments, as well as the impacts of disruptive technologies, such as the Internet. Such risks are also associated with poor business decisions and direction setting, and extend to such things as mergers and acquisitions. For example, it is well known that mergers and acquisitions are notorious for failing, with up to 80% never realizing the benefits expected of them. Considering the amount of money invested in such ventures, the very fact that so many fail suggests poor risk management.
2. Business/financial: this covers those risks that can affect the business in terms of general financial viability. This includes risks associated with the market in which the organization operates (market risk), as well as the ability to finance growth through loans (credit risk). These risks are generally well understood, with a large number of financial instruments and techniques available to the risk manager.
3. Program and project: this is the risk where a major change initiative could fail, or the benefits expected might not materialize. With an increasing use of projects

and programs to drive through change within organizations, this type of risk is often closely associated with strategic risk because failure can have significant impacts on an organization. Moreover, with the increasing complexity of organizations, managing this type of risk is fast becoming an essential skill.

4. Operational: this is a wide-ranging category of risk that includes the failure of any aspect of a business's operations. This includes management failure, system and software failure, human error, process inefficiencies, and procedural failures. Although comparatively new, it is recognized as being an important part of an overall risk management framework.
5. Technological: this is different from operational risk in that it is associated with bringing new technology products to market and introducing new technology (and IT systems) to the organizational setting, both of which are high risk ventures.
6. Technical: this includes incomplete design, incomplete environmental analysis or in error, unexpected technical issues, change requests because of errors, inaccurate assumptions on technical issues in the planning stage, surveys that are late and/or in error, incomplete materials/hazardous waste site analysis or in error, need for design exceptions, design standards, context sensitive solutions, and factsheet requirements (exceptions to standards).
7. External: includes landowners unwilling to sell priorities that change on existing programs; inconsistent cost, time, scope, and quality objectives; local communities that pose objections; funding changes for fiscal year; changing political factors; stakeholders that request late changes; new stakeholders that emerge and demand new work; influential stakeholders that request additional

needs to serve their own commercial purposes; threat of lawsuits; and stakeholders that choose time and/or cost over quality.

8. Organizational: this includes inexperienced staff assigned, losing critical staff at crucial points in the project, insufficient time to plan, unanticipated project manager workload, internal “red tape” that causes delay in obtaining approvals or making decisions, functional units not available or overloaded, lack of understanding of complex internal funding procedures, insufficient planning time, priorities that change on existing programs, new priority project inserted into program, and inconsistent cost, time, scope, and quality objectives.
9. PM: includes poorly defined project purpose and need; poor or incomplete project scope definition; project scope, schedule, objectives, cost, and deliverables that are not clearly defined or understood; no control over staff priorities; too many projects; consultant or contractor delays; estimating and/or scheduling errors; unplanned work that must be accommodated; communication breakdown with project team; pressure to deliver project on an accelerated schedule; lack of coordination/communication; lack of upper management support; changes in key staffing throughout the project; inexperienced workforce, inadequate staff, and resource availability; and local agency, public awareness/support, and agreement issues (Kremljak & Kafol, 2014).

In order to be more specific about the risks encountered by UAV applications/systems development, we defined those risks above, and here, we highlight them. Organizational risks include lack of communication, career changes among the teams, remotely located team members, high workload for few experts, and centric knowledge. Business and financial risks include wrong market target, unclear business objectives and vision, and budget limitations. Technical risks are the most important because most risks in UAV applications development originate from the technical part, given the lack of standardizations and regulations. Technical risks include centralized knowledge because UAV applications are some of the current trends; however, there are still some limitations in sharing knowledge and information on this field, as well as sudden changes in requirements. In addition, insufficient definition of the functional and non-functional requirements either by the client or developer might cause technical risks during and after the development process (Lobato et al., 2012a).

Other types of risks related to scoping and requirements include lack of documentation and communication, delays of final product output, and insufficient reusing of techniques and resources. Therefore, the requirements planning and scoping of any UAV application must be considered carefully in order to overcome and avoid risks. Other risks are related to regulatory and certification risks because UAVs are known to be complex and safety critical systems, and hence there are some standards that need to be followed in developing such applications in order to overcome the risks. Therefore, in the next sections we discuss those standards and techniques that could be used to avoid and mitigate risks. Table 4-1 offers a condensed and summarized view of the various types of risks discussed in this section.

Table 4-1: Risks Classification.

Type of Risk	Examples
Strategic	Correct time to launch UAV applications aligned with market and business requirements.

Business/Financial	Financial abilities to run projects, risks originating from lack of funds and budget allocation.
Program/Projects	Project lifecycle, mapping between project lifecycle and requirements. (Idries et al., 2015).
Operational	Lack of running UAV systems, human factors risks, training and knowledge.
Technological	Risks of coping with dynamic technology growth (Lobato et al., 2012a).
Technical	Risks of integration, specification, and licensing (Idries et al., 2015).
External	Regulatory risks, rigid rules and regulations (some countries have no regulations for UAV operations) (Mohammed et al., 2014a) & (Mohammed et al., 2014b)
Organizational	Team structures and geographically allocated teams might cause risks in UAV projects (Kremljak & Kafol, 2014).

PM	PM risks, lack of clear scoping, changes in client requirement, and mapping between licensing and project stages.

4.3 Risk Management Techniques in UAV Applications Development Projects

In this section, we discuss various risk management techniques that can be used in UAV applications development. As mentioned earlier, this industry has room for great growth. Therefore, within a short period, both UAV size and number of applications will increase; furthermore, limitations will be eliminated because of the continuous research and development (R&D) in this field. Nevertheless, risks will continue occurring. First, a thorough understanding of the term “risk management in software projects” is necessary. Software project risk management is a series of rules or practices that can identify, analyze, and monitor risk factors and increase the success rate of the project. Such risk management and analysis practices could positively influence budget, schedule, project scope, and other project components. Risk management process consists of two stages/steps (Hu et al., 2013):

1. Risk assessment that involves risk identification, analysis, and prioritization. Risk identification requires the systematic identification and classification of risk factors. Risk analysis assesses the state of each identified risk factor and analyzes the relationship among risk factors and project outcome. Furthermore, risk prioritization determines the priority sequence in controlling each risk factor.

2. Risk control that involves risk planning and monitoring. Risk planning involves not only planning for each risk factor, but also coordinating individual plans. Continuous monitoring of the states of risk factors, examination of the effectiveness of the risk-control plan, and prompt discovery of impending risks are required during and after plan implementation.

In such projects, most risks are related to different factors, such as regulatory, modeling, and simulation. According to Pinto et al. (2011), the term risk can be caused by desirability that varies based on firms or systems/applications. Pinto et al. (2011) divided risks into qualitative and quantitative, wherein quantitative risks are a function of R = F(S, L, X), where S = risk scenario, L = likelihood of the scenario, and X = damage of the resulting sequences. Some of the risks that usually occur in such systems are operational because of insufficient internal processes, financial because of the lack of funding and insufficient finance processes and resources, and strategic because of unclear business vision and objectives, and market and technology changes. Risk management is a process divided into several steps: identification, assessment, selection of the appropriate risk management technique/strategy, implementation, and monitoring. Therefore, most software PM professionals prefer modeling and simulation to describe and simulate the expected risks. Risk management is used to describe the probability of incidents within a specific system or project, the consequences of those errors/decisions, alternative ways to overcome the impacts of these errors, and perceiving the expected and predicted risks.

In order to manage risks, such risk management must be part of the Project Portfolio Management (PPM), which is also defined as the management of the schedule, costs, and resources entailed in supporting the performance of a group of projects (Xiao et al., 2013). According to Xiao et al. (2013), risk mitigation needs to be well planned in PPM when different mitigation actions are proposed in order to generate well-supported decisions that are produced rapidly. In addition, during the planning stage, PM can consider risk mitigation against factors such as cost, scheduling, resources, and process stability. In the case of UAV applications development, risk mitigation strategies are important and critical because of system complexity. In the case of UAV applications development, risks should be observed and controlled continuously during the entire development lifecycle and process. Risk mitigation differs based on project environments according to different circumstances, factors, and context.

In the UAV industry, developers use different approaches. Risks occur when the developers change their approach because of system complexity and sensitivity. Furthermore, Software Product Lines (SPLs) used to develop UAV systems are useful because they reduce cost and time. According to Lobato et al. (2012b) SPL has some disadvantages and challenges because it raises some technical and managerial challenges, and needs well-matured software engineering practices and environments. In (Xiao et al., 2013), the firm's shift from Single System Development (SSD) to SPL incurred many risks, and therefore, in order to avoid further risks, developers used Reuse in Product Line Engineering (RiPLE), a re-usability process that reduces risks, but such process needs scoping, requirements, design, implementation, risk management, and testing. RiPLE is known as an Agile, systematic process for scoping discipline, and it is responsible for identifying SPL potentials.

In the case of UAV applications development, risks can include a lack of documentation, lack of user involvement, requirements that are not well documented, some team members working remotely, cultural barriers, regulatory and licensing requirements, tied delivering time, and sudden or unexpected changes. For the Tiribe project (Braga et al., 2012b), developers used the SPL approach and FAA standards DO-178 B and C that were developed to certify avionics software. Because of the growing demands of UAV technologies, applications standards will be required more in order to achieve high-quality levels. According to the Radio Technical Commission for Aeronautics (RTCA) (for Aeronautics, 2014; Adacore, 2011), DO-178B, officially known as RTCA DO-178B/European Organization for Civil Aviation Equipment (EUROCAEI) ED-12B, and titled "Software Considerations in Airborne Systems and Equipment Certification," is a software certification standard for airborne systems on commercial aircraft. Published in December 1992 (and revised as DO-178C in December 2011), DO-178B contains guidance for the planning, development, and verification of airborne software. Such guidance comprises several elements: a series of objectives keyed to the various software lifecycle processes, specified activities for accomplishing these objectives, and required artifacts (lifecycle data) that serve as evidence that the objectives were met. The intent behind DO-178B is to achieve a degree of confidence in a software component proportional to the component's criticality, i.e., the impact of a software anomaly on the continued safe operation of the aircraft. Those standards have been used in developing UAV systems (Braga et al., 2012a, 2012b, 2012c).

4.4 Risk Mitigation Techniques in UAV Applications Development

Risks are the main threats in any technical or system development project. In the case of UAV applications development, risks originate from different parts, for example, operational risks that need to be well managed and mitigated. Many frameworks and standards are used to manage IT-related risks, which vary from ISO standards on risk management that can be divided into scopes and categories. Some examples include ISO 31000 and 31010 for risk management, and ISO 27000 for information security management, in addition to several standards deployed by the US National Institute of Standards and Technology (NIST) and the Control Objective for Information and Related Technologies (COBIT) deployed by the Information Systems Audit and Control Association (ISACA), which covers a wide range of IT management and governance standards. Risk reduction usually appears through the strategic placement of control with the application/system workflow (Yeo et al., 2014).

In this industry, some of the risks occur because of changes that might occur in different development stages; this statement leads to the definition for "Change management," which represents changes in product features and requirements. Because of the complexity and sensitivity of UAV applications, any bugs that occur in the application might not affect the application only, but also the entire UAV platform because it is an unmanned system, and thus there is no human interference. In any software project, risk management plays a strategic role in pushing the success factor of that project, as well pushing success possibilities. The lack of efficient risk management is the main reason behind the delay of software projects. Furthermore, most technical risks are related to system bugs during or after the development stages (Shihab et al., 2012). The type of risks varies between different projects teams. For example, in the case of developing UAV applications, there are different teams, each of which works on different tasks, and the risks might differ between teams. According to Yeo et al. (2014), any changes that occur during the development stages lead to potential risks that affect the entire product/system/application. Many factors affect the risks that might occur because of changes to software specifications, such as time, size, files, code, purpose, and human resources (HR; personnel). In most cases, researchers use data mining techniques (regression models, for example) to evaluate risks.

According to Shihab et al. (2012), risky changes can be studied by several factors and dimensions, as follows:

1. Time: hours, weekdays, month, day.
2. Size: lines added to code, chunk coding, lines and code modification.
3. Files: number of files, bugs in file.
4. Code: coding language, Application Program Interface (API).
5. Purpose: bug fixing, number of linked bug reports.
6. Personnel: developers with experience and skills.

According to the aforementioned points, changes performed by experienced developers are less risky. Hence, in UAV development, experienced developers play a strategic role in reducing the technical risks and bugs, whereas modifying the API is riskier (Shihab et al., 2012). Hence, most risks occur because of unclear requirements analysis, as side-effects of other changes, unclear project documentation, inadequate testing plans, scope changes, coding errors, integration errors, other errors, and hazy design flow and system architecture.

UAV is considered an embedded system because it contains many sub-devices and sub-systems to control it and achieve autonomic level. In Braga et al. (2012c), SPL was used in UAV development; in the case of developing UAV applications, some standards related to the aviation industry are involved in the process, such as DO-178B and DO-178C. Nevertheless, there is a lack of standardizations in UAV applications development because most international organizations related to the field are still debating about developing standards and procedures. DO-178B and DO-178C were developed by RTCA. The main problem is that these two standards do not follow a specific development process. Therefore, in this case, the process needs to be allied with standards. In addition, because most developers reuse assets in order to reduce costs, these two standards do not provide any information on certifying reusable items and systems (Braga et al., 2012c).

Some of the risks encountered by UAV applications development are legal or regulatory, such as:

1. Certification level of complex products: complexity needs to be considered in risk management.

2. Level of usage and certification: the application context needs to be allied with licensing. Therefore, the certification process might affect risk management.

3. Additional features that might lead to more certification levels.

4. Demand for new features/requirements can lead to new certifications that can cause new risks: if the developers want a cost effective system, new certifications might be required.

5. System architecture alternatives might have an impact on the certification issue, thus being risky.

6. The development stages need to be aligned with the certification level.

In the case of developing UAV applications and systems, if the system requirements verification results are only required for certification levels A to C, the requirements analysis could probably be isolated for each component, so that this verification is only performed for components with levels A to C, whereas other components omit this activity. In addition, certification needs to be aligned with the development stages (Braga et al., 2012c), as shown in Figure 4-1.

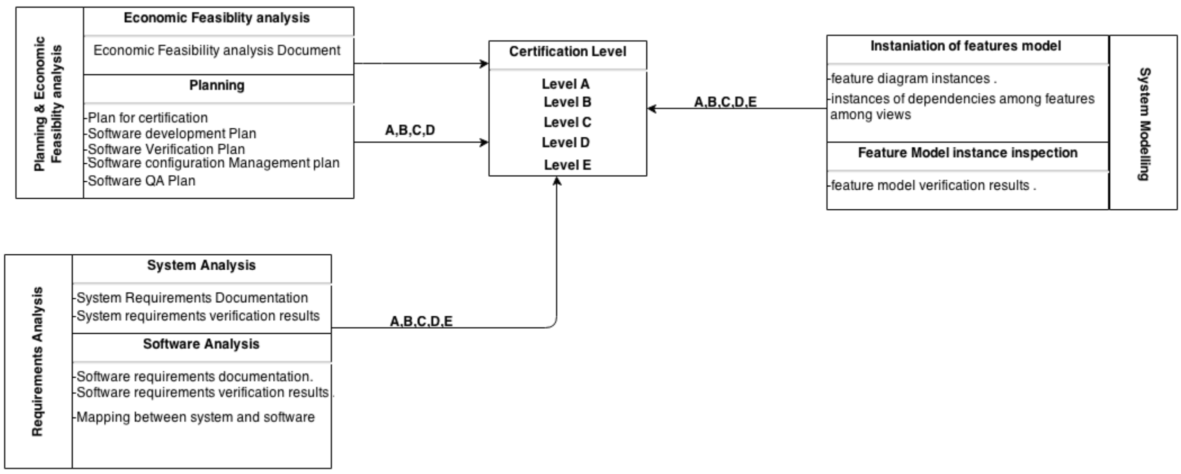

Figure 4-1: Mapping Between Development Stages and Certification (Braga et al., 2012c).

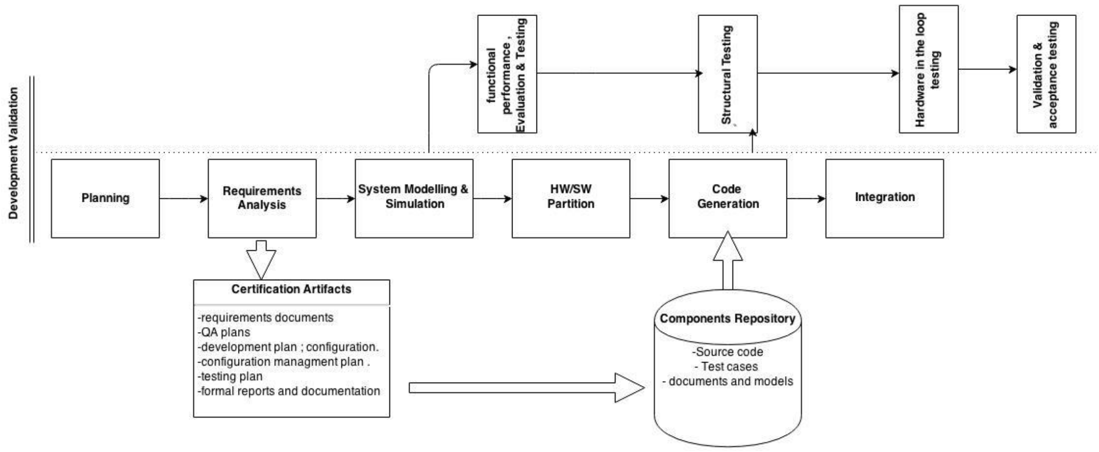

Figure 4-2: SAFE-CRITES Approach

In order to understand UAV systems, we need to understand the idea of embedded systems. Embedded systems are a class of system that presents at least four of the following features: multiple process or multi-core, 10 K ++ lines of code, multi-programing language, Real-time Operating System (RTOS), different types of communication and sensors, and critical nature (Braga et al., 2012a). In software development, some developers use some techniques and mechanisms for software reuse, such as Model Driven Development (MDD) and SPL. The latter does not consider more real-time requirements.

SPL has been used to ease the dynamic configuration of product lines because it is based on rapid line prototyping systems (Braga et al., 2012a). In addition, there is another approach called SAFE-CRITES, as shown in Figure 4-2, which maximizes the use of modeling, simulation, and automatic code generation tools in order to reduce development times, reduces errors, and makes documentation easier; it also helps when certifying the generated code. In order to reduce risks, developers should maximize code reuse of previously tested UAV applications components. Hence, the project team should map their components with hardware and software architecture (Braga et al., 2012a). One of the issues is that most developers rely on Object Oriented (OO) languages to develop UAV systems. However, according to Chatzigeorgiou & Stephanides (2002), OO does not contemplate this technology. In order to deepen this study, we need to compare domain and application engineering in order to identify and manage the risks associated with this industry.

Risk analysis is an important process to consider as the main aim is to highlight risks identification and mitigation in UAVs projects environments. The analysis process lies between risk identification and risk mitigation. In the context of UAV applications development and complex systems development, risk analysis is important in the design stage to evaluate and asses the critical components and the complexity of the system, where risks are analyzed and important metrics are highlighted. The main goal of the risk analysis process is to understand the risks involved in a better manner and to verify the correct risk attributes. Therefore, successful analysis is inclusive of the following; problem definition, problem formulation and data collection (Rojabanu and Alagarsamy, 2012). Data collection facilitates the process of utilizing knowledge to reduce risks associated with such a complex environments. Furthermore, risk analysis must involve creating and constructing a risks repository for such application development project. The repository could be built using techniques such as previous projects reviews, experts/developers and analysts’ reports, analysis of scope change requests and analysis of requirements change requests. Deployment of text mining techniques in such project environments and such nature of risks will ease and support future risk assurance operations. Risk assurance is known as the use of quality assessment techniques such as Validation & Verification (V&V) to ensure and guarantee that an efficient risk analysis has been done and performed. Therefore, risk assurance is a part of the risk management process in UAV applications development projects to improve the application quality and performance. In such environments, risk assurance could face some challenges such as risk assurance auditors need time to become familiar with the development related details as they are not involved in the development activities. Most of the risk descriptions are mostly documented in human language. Therefore, redundancies and inconsistencies will occur across different versions of documents. In addition, risks are often stated with vagueness as to render detecting their connections to architectural and design choices (Huang et al., 2010).

In conclusion, to avoid risks, many standards need to be followed and many procedures need to be deployed. In addition, the lack of standardization of UAV technologies causes many risks both to developers and users. Lack of organized knowledge is one of the instigators of high risk in UAV projects. Thus, KM plays an important role in helping development teams reduce risks. In the following chapter, we discuss the current KM approaches by concentrating on projects similar to UAV projects.

In this chapter, we discussed the risks related to UAV applications development, related issues—such as risk management techniques—and approaches to overcome such issues, and listed the examples of Braga et al. (2012a, 2012c). According to the previously mentioned statements, centralized knowledge is one of the causes for risks in UAV applications development projects. As indicated above, in the next chapter, we discuss the role of KM in project environments, with concentration on projects similar to UAV applications development. Furthermore, we discuss the role of KM in project environments, and how to utilize KM to manage the risks of UAV applications development.

Chapter 5 : KM in UAV Projects Environments

5.1 Introduction

Knowledge is the ability of building upon and acting according to available information. Any KM model consists of three main levels of knowledge, and these are, from top to bottom: task, inference, and domain. Each of these levels has its process and mission. Task knowledge describes the goals of an application and how these goals can be realized through decomposition into sub-tasks and inferences. Inference knowledge describes the basic inference steps that we want to make using domain knowledge. Domain knowledge describes the basic inference steps required to facilitate use of the information necessary to describe the application (Liebowitz & Megbolugbe, 2003). In addition, the KM cycle consists of three stages: knowledge sharing (dissemination), capturing (creation), and acquisition (application), as shown in Figure 5-1. This chapter aims to address the KM issues in the project management environment, and UAV applications development is an example. Furthermore, it addresses the challenges encountered by implementing KM in the UAV development environment because this is a new technology that will grow in the future. In addition, this chapter discusses the proposed framework for KM in UAV development environments with a focus on reducing the risks associated with such technology.

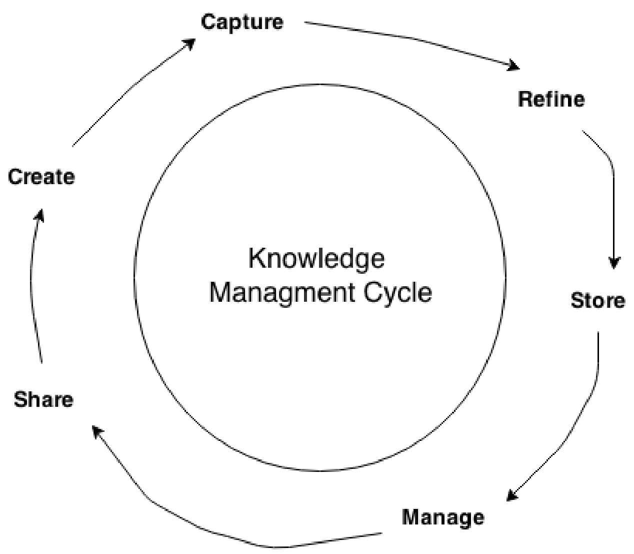

Figure 5-1: KM Lifecycle

Furthermore, this part of the thesis focuses on the relationship between PM and KM, and how to use this relationship to minimize risk in the case of developing UAV applications. Therefore, we need to understand two main concepts, project management and KM, and then elaborate on the relationship between these two concepts.

1. PM vs. project KM: the Project Management Institute (PMI) defines PM as the application of knowledge skills, tools, and techniques to project activities in order to meet or exceed stakeholder requirements and expectations from the project. In addition, most PM chartered bodies describe the project as a method for solving complex organizational problems.

2. Project KM: the application of KM in project environments.

3. Relationship between KM and PM: this relationship is represented as an application of KM in project environments. In PM, the knowledge drawn from projects is known as the kernel knowledge. The knowledge-based risks that

might affect the project and are expected to occur in new technologies development (UAV applications development is an example) are:

a. Flaws in learning from past project lessons.

b. Problems integrating and transforming knowledge.

c. Lack of knowledge map.

In general, in the context of the project, KM is the application of principles and processes designed to make relevant knowledge available to the project team. Effective KM in project environments facilitates the creation and integration of knowledge, and helps minimize risks from different aspects (Karapetyan & Otieno, 2011).

In project environments, projects-based firms are increasing in terms of importance because of product innovation and development activities, as is the case of UAV applications development. In project-based firms and environments, the role of KM is increasing from several sides, as well as the characteristics of project-based firms, especially in the case of developing new products and technologies that consist of R&D activities.

In addition, in the field of project-based industries and firms, knowledge is a vital resource. Therefore, well-established KM in project-based firms is essential for establishing learning project organizations, improving the utilization of core abilities and capabilities of technological platforms, and reducing time and risks in projects, all of which are important for UAV applications development.

Crisplant Inc. deployed a stage-gate model whose aim is to initiate a common set of rules for project control, management, and execution internally, as well as cooperation with customers, suppliers, and other partners. In the case of UAV applications development, competent, efficient, and reliable project implementation is decisive for business success. Furthermore, this model acts as a dynamic model where knowledge is accumulated and later disseminated through the application in the individual project (Christensen & Bukh, 2008), as is the case of UAV applications development. In the stage-gate model, each phase ends with a gate where the project managers/leaders of different teams, companies, and clients prepare a report on the status and situation of the project with regard to progress and build. Hence, the gate acts as a critical point in relation to KM because knowledge needs to be transformed between teams (Christensen & Bukh, 2008). Some of the authors proposed/claimed that the knowledge originates from explicit knowledge sources because the project managers strongly benefit from sharing and codifying tacit knowledge associated with the management of former projects.

As is known, many factors affect project success, hence KM plays a role in PM practices in order to achieve the required success (level of success). Based on the CHAOS manifesto, a minimal number of IT projects achieved the required level of success (The Standish Group, 2013). Because of continuous technology development, PM and KM play a significant role in technology business competitiveness.

There are many standards for PM, such as:

1. PMI: globally known among PM practitioners.

2. PRINCE2: widely used in Western Europe, including the UK.

3. PMAJ: used mainly in Japan.

These standards are similar to each other, and complement each other. Knowledge affects PM practice, which in return affects the project success. In our case, developing UAV applications, knowledge can play a critical role because the area is new and still growing. Each UAV development project needs to be achieved on scope, time, budget, and accepted quality. Here, we can determine that KM affects projects in terms of risks and challenges. The relationship between KM and PM focuses on the relationship between effective knowledge-sharing practices and project success. One of the most well-known models is the Socialization-Externalization-Combination-Internalization (SECI) model, or the Nonaka knowledge conversion model, that focuses on the socialization of tacit knowledge, considered a gap in most project-based atmospheres. The two most helpful knowledge practices for project managers are shared project repository, and document and content management systems.

5.2 Issues of KM in PM Environments

Initially, IT-enabled business projects are knowledge intensive. Hence, in any PM environment, knowledge needs to be aligned with the business objectives and project stages. In KM, a project-based model consists of project-based knowledge, knowledge alignment, Project Performance (PP), and Project Management Performance (PMP). In the case of UAV applications development, there must be knowledge alignment because of project and system complexity, and the centrality of knowledge that can cause risks for the project. Knowledge alignment comprises the strategic and social dimensions of the project (Reich et al., 2014). In a PM environment, KM consists of an enabling environment, knowledge practices, and knowledge stock. According to Reich et al. (2014), projects based on knowledge rely on the documentation usually performed by project team members. This documentation is comprehensive and deep, and includes the technical architecture, designs, organizational plans, expected outcomes, and risk management plans. Alignment includes the key domain knowledge (technology, organizational change, and business value). In addition, in the context of UAV applications development, such field combines different areas of knowledge and different areas of expertise. Furthermore, it is a complex system environment.

Therefore, the alignment of KM, PM, and business goals is important for achieving business value in such projects. As mentioned earlier, the key domain knowledge includes technology, organizational change, and business value. Hence, the alignment of knowledge explains and predicts more of the variance in business value than producing knowledge. KM impacts the project team and performance. In fact, KM has a direct impact on the dependent measures of the project performance. Hence, knowledge sharing has direct impact on project team performance. In the PM environment, budgeting, scoping, and scheduling are negatively affected by subsequent KM outputs, such as project-based knowledge and knowledge alignment. In (Reich et al., 2014), project management performance is driven positively by KM. Therefore, in the case of UAV applications development, project managers should invest more in KM activities. One of the issues that affect KM in the PM environment is ambidexterity, which means the state of being equally adept in the use of both left and right appendages. In the case of UAV applications development projects, the environment needs to be dynamic in order to avoid risks (such as knowledge centrality). Therefore, ambidexterity is required in such project environments.

The KM strategy affects three main areas: human, social, and organizational capital. The KM strategy shows how knowledge is processed from different prospectus, socially, organizationally, or HR perspective. The processes concern the abilities to manage change, technical changes, and organizational changes, as well as the social abilities of the project team. These skills are helpful for gaining knowledge and avoiding risks (Turner et al., 2014); see Figure 5-2.

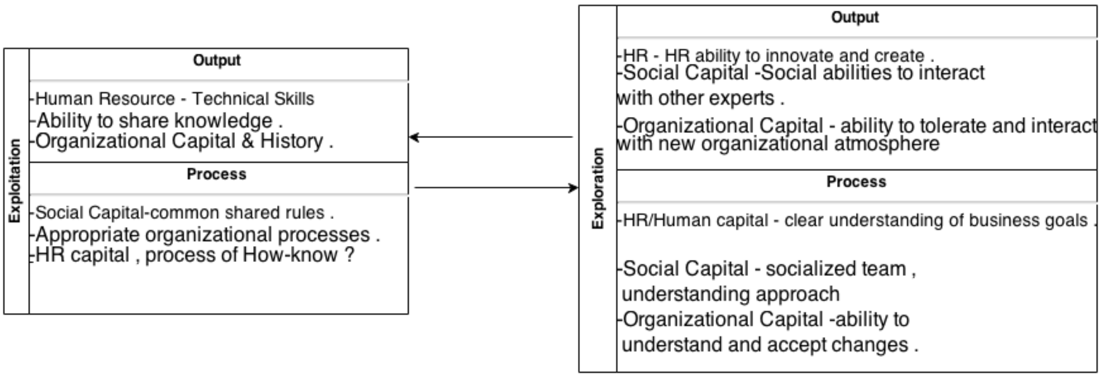

Figure 5-2: PM Knowledge Tactics.

Disruptive technologies are involved in critical business domains and applications; hence, UAVs are considered disruptive technologies. As a disruptive technology that is growing fast and covering a wide range of applications, knowledge alignment will play a key role in UAV projects. Knowledge alignment is encountering many challenges, such as shifting the focus from creation to addition of new ideas and concepts. In UAV projects, establishing a knowledge process is a complicated process because of the project's complexity. In this case, the knowledge process models provide services, including developing intensive and concentrated processes by enriching them with business rules that allow collective information mapping. In addition, as more innovative applications of UAVs emerge, there must be an alignment between the innovation process and the knowledge in organizational level. In addition, it is necessary to map the emergence of this technology and its impact on the business roles that will directly impact the process of building: modeling and sharing knowledge (Jaanus & Ley, 2013), as shown in Figure 5-3.

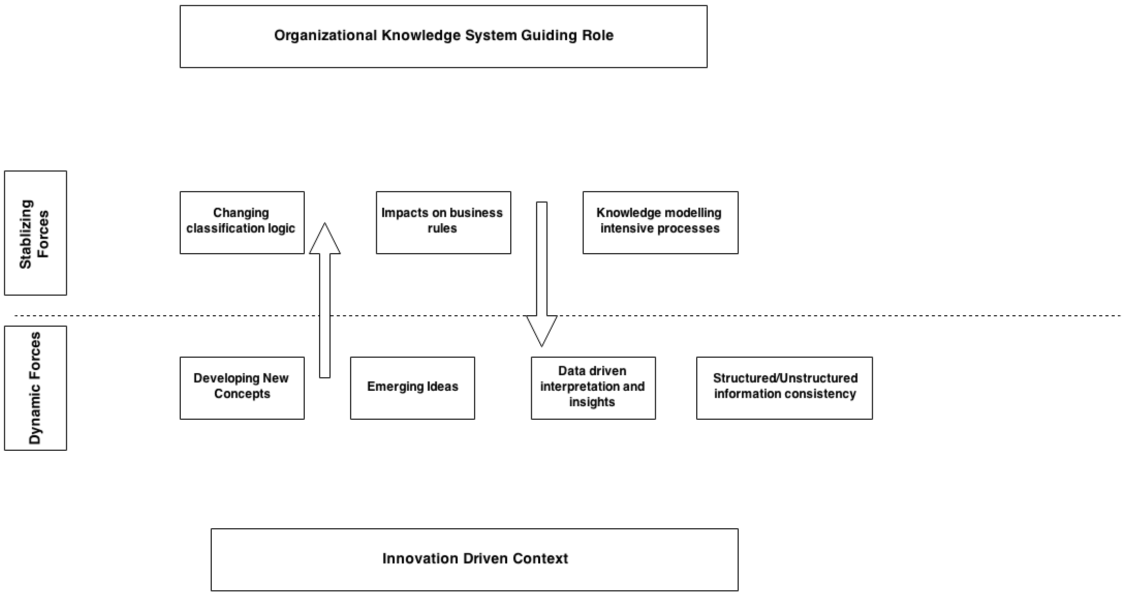

Figure 5-3: Knowledge Alignment Model (Jaanus & Ley, 2013).

The success of any IT project relies on the success of the IT project portfolio management behind it. Success is measured by assessing individual project risk and considering risk aggregation in the project portfolio. The risk model structures consist of risk factor, production factor, and impact. Hence, in (Rosselet & Wentland, 2009) the risk knowledge-base allows for direct access to the experiences of past projects and sources of expertise, such as staff and consultants.

Therefore, the generated knowledge allows the update of risk factors, production factors, impacts, and responses according to observations made during project and portfolio management. The storage/retrieval and transfer phases of the knowledge process are thus supported which builds individual and organizational memory, and fosters interrupter knowledge access. These new sources of knowledge are then combined by experts in the risk assessment process. The application of risk patterns allows for identification of new, and updates of existing, risk patterns. In the next section, we discuss KM in the context of UAV applications development.

5.3 KM in UAV Applications Projects

The UAV applications development industry is mostly project-based and driven by scheduled tasks. Hence, many difficulties occur in knowledge sharing and creation. As is known, UAVs have two main application streams, civilian and military. Because of the quick growth of UAV applications, many challenges, risks, and issues start to appear. One of those challenges is the knowledge of UAV domain. In such environments, KM becomes a core issue because of the current quick growth of this technology, and future growth. UAV applications development is characterized by different issues, factors, and challenges. The main characteristics that define UAV applications development are:

1. System complexity that results in huge amounts of data to be managed and shaped.
2. Highly restricted standards and regulations that govern the design, operations, and maintenance of the development process.
3. Excessive market growth and increase in demand, resulting in tough competition between different developers and manufacturers to deliver excellent UAV applications that meet requirements and specifications.

Moreover, the huge demand growths lead to strong competition between different developers and manufacturers to deliver excellent UAV applications that meet requirements and specifications. Hence, there will be a demand for approaches and designs that can affect product specifications, requirements, safety, and airworthiness. Furthermore, the relationship between challenges/risks and KM in UAV applications development project needs to be highlighted carefully with respect to the UAV applications development context. In such context, KM encounters those characteristics (Harvey & Holdsworth, 2005).

In the context of safety, standards, airworthiness, and certification, we need standards in UAV applications design, which directly impact application performance. The regulatory affairs firms, such as civil aviation authorities, request process consistency and redundancy to ensure that the airworthiness and validity of the applications exist. In addition, the demand for accurate and accessible information will increase. Furthermore, a project team's access to more accurate and detailed information will radically improve product efficiency in terms of safety. The purpose is to integrate safety factors into the product through the use of accurate data, tools, and efficient processes and approaches by trained, skilled, and certified team members.

Another issue that affects the KM in such project environments is data confidentiality and disclosure. In UAV applications development projects, some information is limited because of the industry origin, which has a military and aerospace background. In such context, KM is not about providing, and making accessible, data and information to many people, but it is more about optimizing the information context. There are situations where knowledge is required to be provided to the project team members.

Furthermore, rigid processes affect the flexibility required for KM-driven and focused firms. Hence, KM can make regulations to be flexibly applied in such context. In the UAV applications development context, any development stage needs a certain type of certification from regulatory firms. Furthermore, KM makes the licensing and certifying requirements more flexible and efficient. In addition, some organizational factors need to be considered in such context. The main obstacle is not the technology, but the logistics and costs in deploying KM technologies and processes in such context.

In UAV applications development projects, KM is not a supplement for regulations, standards, or safety measurements. At the same time, however, KM has some advantages for the UAV applications development context. It provides enhanced information in the context of UAV applications development and improves information accessibility for authorities, regulatory firms, and decision makers. Furthermore, it improves the availability of the provided contextual data and enhances the expectations of considering all relevant information. In addition, KM allows project team members to share knowledge, and allows them more time in sharing knowledge. Furthermore, KM facilitates and improves the key team member's skills. Moreover, KM can help the UAV applications industry in identifying the future needs of its applications development. In addition, KM helps in capturing non-externalized capabilities, skills, and knowledge of project team members and stakeholders. It also improves knowledge dissemination within the project lifecycles.

In any new technology development project, developing a Knowledge Management System (KMS) requires a serious and deep consideration of several aspects and issues, starting from HR, PM environment, finance, cultural and organizational capital, and more. Those aspects and issues differ based on the environment. In the case of the UAV projects context, the system is complex, hence the information is huge and there are different teams. Therefore, such issues affect the KM process that is helpful in mitigating and reducing risks.

To propose, design, and implement KMS for any business environment, there should be an alignment between KMS and the business environment in order to achieve the right goal of capturing and managing knowledge. Different approaches can be used in developing KMS systems and frameworks, but those approaches should align between the KM process and business environment. According to Dehghani & Ramsin (2014), a KMS development approach consists of three core components/stages: initiation, development, and termination. See Figure 5-4.

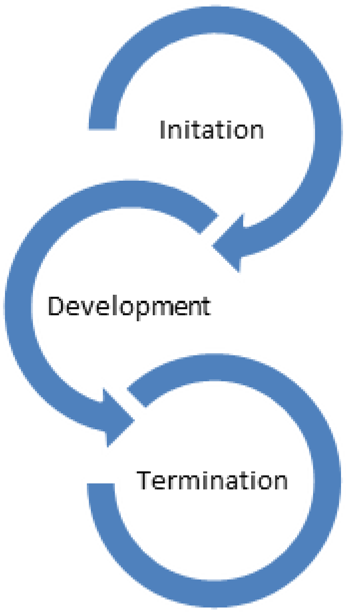

Figure 5-4: KMS/Framework Development Process.

Each stage has its own processes. For example, the initiation process starts with investigating the problem domain, planning, analysis, and knowledge elicitation, and ends with identifying the level of authority. Furthermore, in the next stage, it starts with designing, KM technology determination, implementation, and knowledge distribution. The last stage, which is termination, consists of transition, test, knowledge evaluation, training, and maintenance. Those processes are aligned with risk management, PM, and complexity management processes. Any KM framework should follow these criteria (Dehghani & Ramsin, 2014):

1. Attention to discover and grasp the knowledge source.
2. Provision of methods for assessing organizational knowledge sources.
3. Ability to discover and explore organizational knowledge flow.
4. Ability to explore the organizational knowledge taxonomy.
5. Potential knowledge requirements.

At the same time, there are some weaknesses that should be avoided, such as:

1. Lack of planning for project KM processes.
2. Lack of consideration for the project processes, policies, requirements, and standards (which can interfere with UAV standards).
3. In the context of UAV applications development, there is failure in aligning between HR, R&D, and communication policies.
4. Lack of documentation.
5. Lack of continuous assessment of different aspects of the project and system.
6. Failure to identify level of governance required for access to user activities.
7. Lack of attention to user requirements at different project levels among team members.

8. Lack of distinguishing between tacit and explicit knowledge.

9. Failure to gather knowledge based on the required knowledge.

In order to understand the KM role in the UAV context/environment, we need to understand and identify the barriers encountered by the KM process in such complex environments. Those barriers are related to social communication, inter-project documentation transfer, and PM/managers (Wiewiora et al., 2009). In addition, different types of knowledge can be created during the project lifecycle, and this knowledge can be categorized into three main classes: technical, PM, and project-related, as shown in Figure 5-5. Furthermore, the process of project knowledge is diversified into different bases, such as organization, PM, and project-specific. Moreover, knowing the different forms and meanings to which knowledge translates throughout the project lifecycle is essential. Figures 5-5 and 5-6 provide a detailed overview of the different knowledge segments in a project lifecycle.

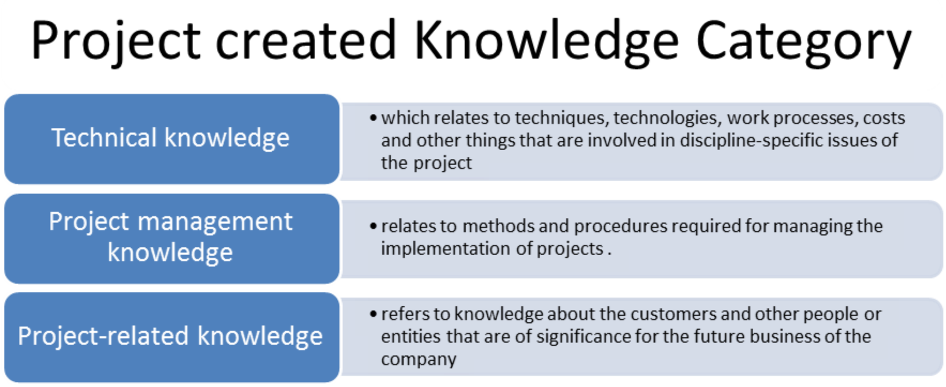

Figure 5-5: Project-Created Knowledge Category.

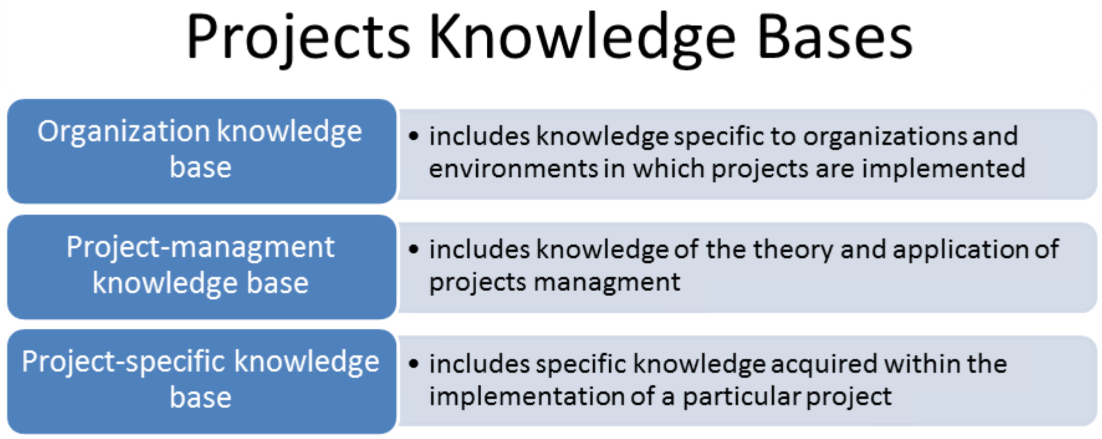

Figure 5-6: Project Knowledge-Bases.

As mentioned earlier, UAV applications projects are known as complex; therefore, such complexity indicates that the huge number of complex technical and social relationships should be considered seriously by project managers. Therefore, KM occurs in different means during the project lifecycle, as shown in Figure 5-8. In general, KM use in project environments has many benefits and impacts, either on the business organizations or human capital. These reasons and benefits include (Polyaninova, 2010):

1. Capturing and reusing structured knowledge. The knowledge from project or project phases, such as project proposals, reports, implementation documentation, or software code can be used to reduce the time and resources required to produce new output.

2. Embedding knowledge in the project's products and processes. This seeks to enhance or create new knowledge-intensive products, services, and processes.

3. Structuring and mapping the knowledge required to enhance performance. Project efforts, such as new product development or process redesign are reduced by making clear the specific knowledge needed at particular stages of the project.

4. Enhancing project performance in terms of cost and time because it adds a competitive advantage that can transform the firm into a future learning organization.

5. The gathered knowledge and experience can serve as repository for future projects and businesses because KM can help solve many obstacles.

6. Helping facilitate the decision-making process. Furthermore, in the UAV entire, decision making is considered a complex process because it can affect the whole system development.

7. Providing access to both good and bad project practices because KM can help future projects and remove knowledge gaps.

8. Having a positive impact on the projects' customers/clients because the out-put/product could be delivered in a better mean/way.

In addition, insufficient KMS could result in negative impact and failure factors because of:

1. No incentives to promote sharing knowledge among project team members.

2. Lack of attention and time given to identify lessons learned from past project failures and successes.

3. Unreliable assumptions made on new projects (not challenged projects).

Furthermore, many approaches and techniques can be used to assess KM in UAV development environments, such as Balanced Score Card (BSC), critical success factors, and strategic KM model (Jafari et al., 2010).

5.4 Current Approaches

In the previous chapter, we covered the risks that might affect UAV applications development projects; some such risks might come from suppliers and vendors that provide the project with communication systems, sensors, or any equipment that should be integrated in the application. In addition, those risks originate from different resources, such as operational, external, and internal. Furthermore, the supply chain plays a role in causing risks for the project. In 1997, Boeing experienced supplier delivery failure of two critical parts, which caused an estimated loss of 2.6 billion USD. Solomon et al. (2012), solved risks by addressing the impact of supply chain on project failure. In addition, the proposed Supply Chain Risk Management System (SCRMS) in Solomon et al. (2012) is integrated in agent-based decision support systems. Furthermore, alignment of the risk management system with decision making creates a process of generating knowledge.

In (Sousa et al., 2013), the Input-output Socialization-Externalization-Combination-Internalization (IO-SECI) model is used to solve problems within a specific time, whereas SLA describes services requirements from the enterprise perspective. Hence, in UAV projects, the environment is challenged by service level issues among developers, clients, and vendors. The proposed solution uses the Information Technology Infrastructure Library (ITIL) and Bibliometrics (i.e., the study of the quantitative aspects of the production, dissemination, and use of registered information) to analyze the key factors that maintain knowledge. These factors are the importance of combining explicit knowledge and assessing the value that represents certain knowledge recorded and maintained in the system. The model consists of four processes and four modules (one per process). The processes are externalization (tacit to implicit), socialization (tacit to tacit), combination (explicit to explicit), and internalization (explicit to tacit). The socialization process has the social networking module, externalization has the input KM module, combination has the combination and optimization module, and internalization has the search browse-and-suggest module. This approach helps implement specific software to record such occurrences that assist in information management based on the rating process. The socialization process includes face-to-face meetings and experience sharing, whereas externalization includes published and written knowledge. In addition, combination includes integrating different types of explicit knowledge by utilizing networks and large-scale databases. Finally, internalization is where knowledge is received and applied by individuals. Furthermore, the proposed approach is used in incidents management and problem management because it provides dynamic atmosphere for knowledge and knowledge creation, as shown in Figure 5-7.

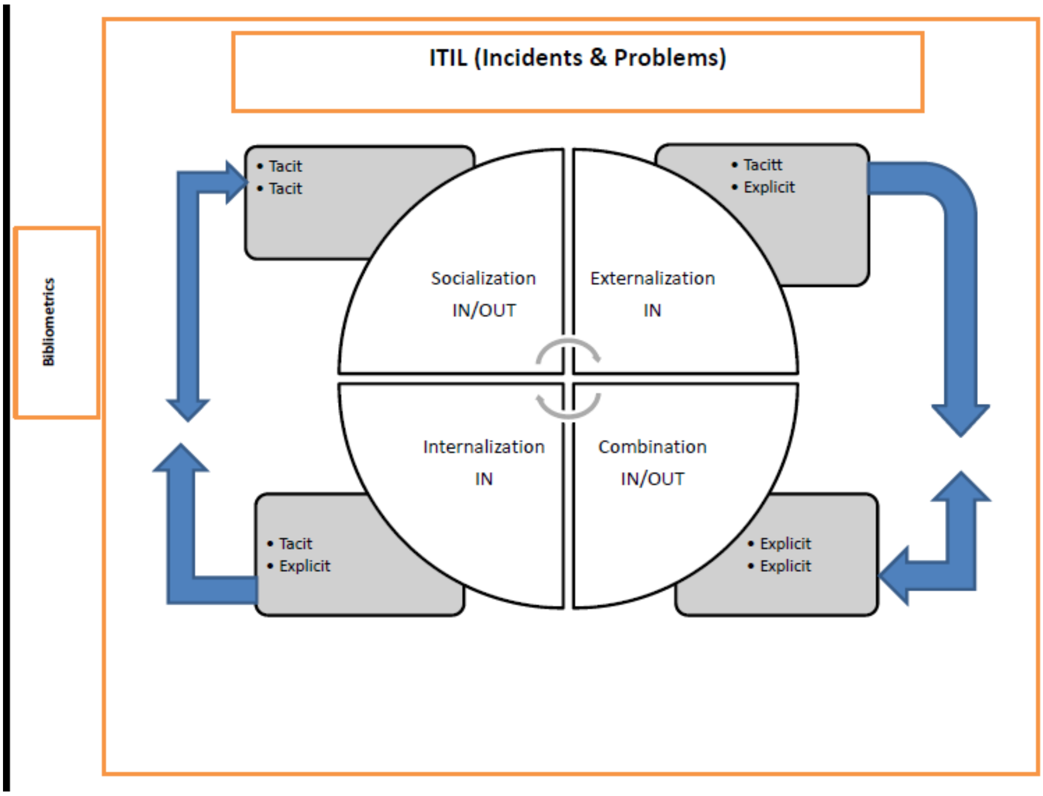

Figure 5-7: IO-SECI KM Model (Sousa et al., 2013).

A framework for KM in aerospace collaborative industries was presented in (Faris et al., 2011); this framework relies on a semantic search engine designed to target the collaborative aerospace industry environments. It relies on collaborative search engine design principles, such as modularity, high scalability, abstraction, and collaborative sharing. Shared knowledge files among knowledge workers are collected and stored in a knowledge repository. Moreover, semantic techniques are used to analyze the expanded query and stored knowledge documents, as shown in Figure 5-8.

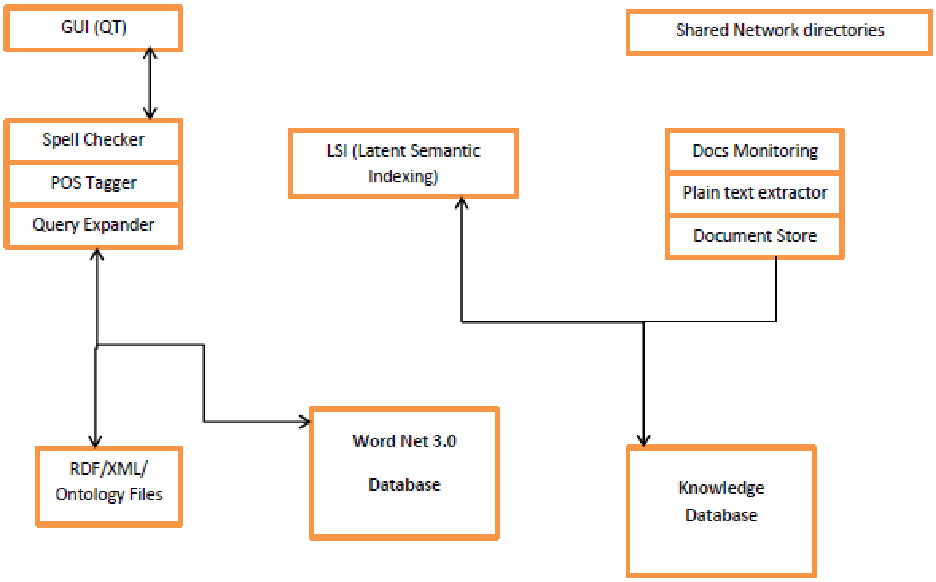

Figure 5-8: System Architecture for KM Implementation (Faris et al., 2011).

In (Gourova & Toteva, 2014), the authors identified the relationship between KM patterns used to design KM systems. Furthermore, these patterns are involved in auditing the knowledge and knowledge strategy. The identified patterns cover knowledge auditing from different aspects, such as planning, team skills and qualification, auditing methodology and technologies, analysis, reporting, data collection, mapping, assets and resources, KM practices, and analysis of critical knowledge functions. In addition, on the strategic level, the patterns are used to identify KM strategic choices, and convert goals into a solid ground for KM implementation. Hence, such approach could be helpful in evaluating the KM practices in UAV projects as well. This approach focuses more on aligning the business processes with KM processes and requirements. Consequently, such approach could be helpful in evaluating KM practices in UAV developments in future work, as shown in Figure 5-9, whereas in (Orlic et al., 2011), the architectural reasoning diagrams have been used to design KM architecture and systems.

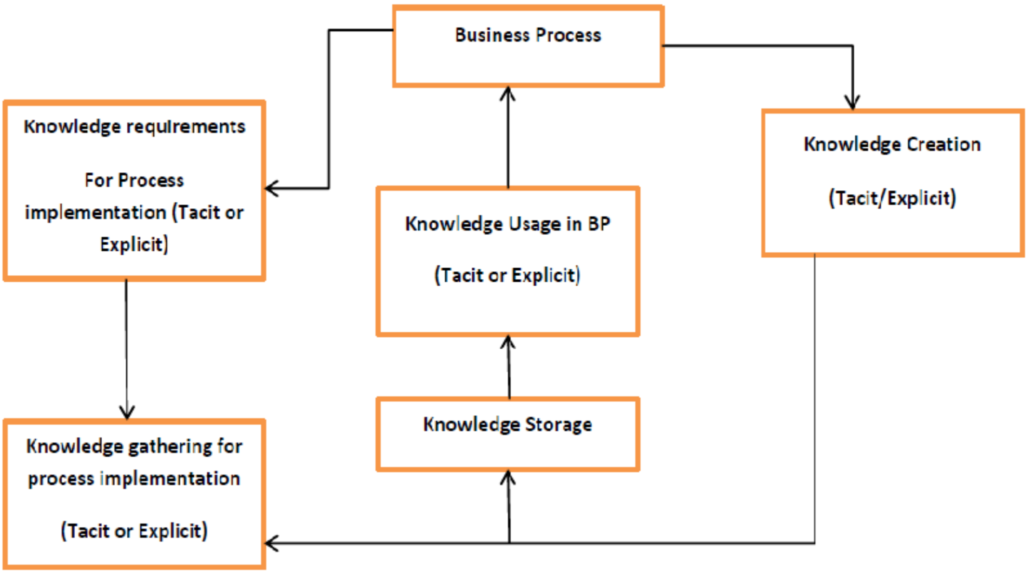

Figure 5-9: Business Process and KM (Gourova & Toteva, 2014).

According to Jafari et al. (2010), in the Strategic Knowledge Management Model (SKMM), KM is implemented at a strategic level to achieve the strategic goals. Here, a case on the aerospace industry is used as an example. SKMM involves many activities, such as costs, milestones, product development, forecasting future needs, and risk assessment. Different types of knowledge, such as experiential, conceptual, routine, and systematic were discussed. The main focus in this study is conceptual knowledge that consists of specialized meetings and seminars, Communities of Practice (COP), knowledge sharing, risk-taking climate in the organization, flexible and dynamic organizational structure, and integration of KM and current systems. Because most risks originate from technical and project-related issues, KM can be utilized for reducing and overcoming these risks. Table 5-1 offers a condensed and summarized view of the various KM approaches and examples discussed in this section.

Table 5-1: Analysis of Current Approaches.

Author	Approach	Limitation
(Solomon et al., 2012)	Integrated in an agent-based decision support system for supply chain risk management	Did not cover entire industry, only risks related to supply chain
(Sousa et al., 2013)	Conceptual model for KM based on SECI model with metrics analysis (ITIL+Biliometrics)	Did not cover risks context in ITIL
(Faris et al., 2011)	Framework for semantic-based KM system for aerospace collaborative working environments	Covered environment in its entirety, did not cover risks. Covered and classified knowledge in such industry
(Gourova & Toteva, 2014)	KM model based on KM patterns	Did not cover architectural design of knowledge
(Orlic et al., 2011)	Architectural reasoning diagrams used to design KM architecture	No real implementation
(Jafari et al., 2010)	KM is implemented in strategic level (SKMM)	Did not cover risks associated with such industry.

5.5 Proposed Framework

Knowledge discovery is a process for identifying useful knowledge patterns from a large collection of data and processes. Therefore, data mining plays a core role in such process. In addition, data mining has many applications in the field of KM because it helps with text mining and knowledge generation. In this paper, we discuss KM in project environments, and highlight the different approaches to reduce risks in environments similar to UAV projects. In this section, we discuss our proposed KM framework.

The main goal of the proposed framework is to be linked with a regulations database (which includes certifications, standards, and licenses). This database could be a collaborative database between UAV developers and authorities, such as the Civil Aviation Authorities. In addition, it has another risk management framework to help reduce risks and align the licensing process with the project stages.

Figure 5-10 illustrates the components of the proposed KM framework. The main philosophy of the framework is to interact efficiently with the risk management module, discussed later. Initially, data and knowledge discovery is performed both from the regulatory database and data conversation with risk management module from which real-time data is mined and managed. Then, some data discovery processes (evaluation and exploitation) are performed again in collaboration with the risk management module in order to achieve the business goals and incorporate risk management activities. In addition, knowledge exploitation is automatically identified through the risk management module (future, real, and predicted risks).

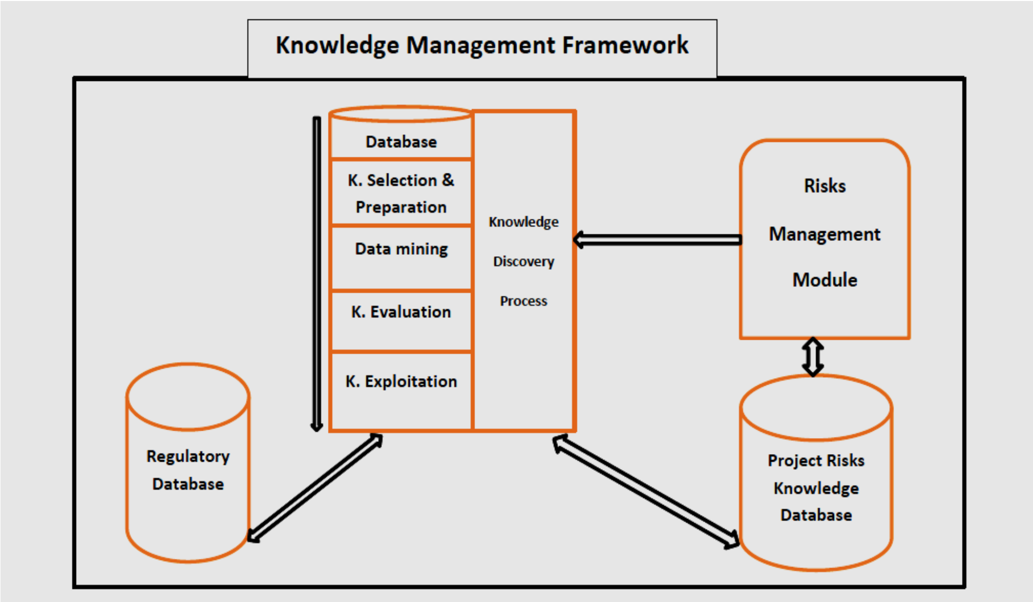

Figure 5-10: Proposed KM Framework.

The proposed project risk management module consists of three components (see Figure 5-11): the solution evaluation agent, risk evaluation agent, and the project risk database integrated in risk management processes. Furthermore, this proposed framework and module can be integrated easily with an agent-based decision support system for project risk management systems and a framework for developing UAV applications in later stages. This module consists of two agents, one to manage solution evaluations, and another to manage risk evaluation process.

When this module receives a request, it works as follows:

1. The request is passed to the risk evaluation agent that then sends it to the project risk database in order to add the request to the risk management processes.
2. The module determines whether the risk exists in the project risk database and risk knowledge base.
3. If the risk does not exist, a mitigation strategy mitigates and avoids risk by sending a request to the regulatory database, and then retrieving the specific data

or knowledge (on licensing, standards, and specifications) required to generate the solution.

4. If a solution exists, the solution evaluation agent is requested.

5. The solution evaluation agent requests the risk evaluation agent whether the proposed solution is in accordance with the project goals and business strategy, and whether it is applicable under the current project situation.

6. If the solution is not applicable, the risk evaluation agent is requested again.

7. If the solution is applicable, the project risk knowledge base is updated on this solution.

The proposed framework allows the projects of such complex technologies and environments to manage and interact efficiently with potential risks because such technologies will have a huge demand and wide applications in coming years. The collection of knowledge and systematic methods to access them will be beneficial for UAV project developers because they can quickly find the required knowledge and build up on it as new knowledge is generated.

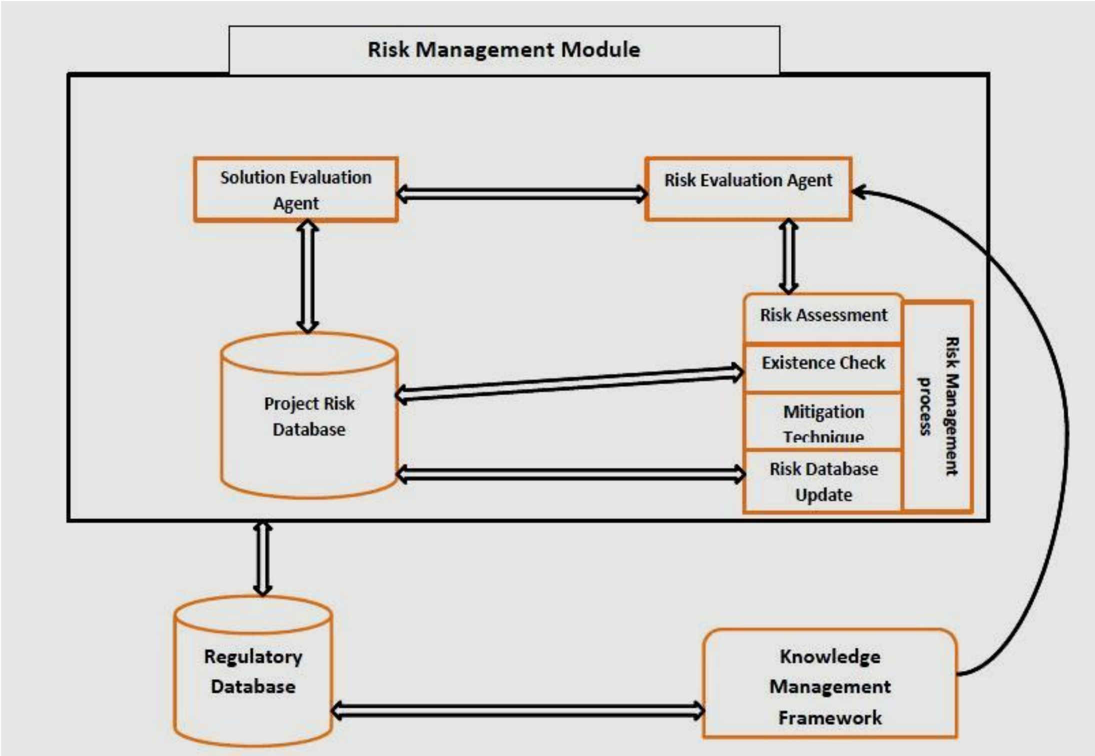

Figure 5-11: Project Risk Management Modules.

The main advantage of the proposed framework is that it is helpful in utilizing the risks and gathered knowledge on these risks to implement new and updated rules, regulations, and standards for UAV operations. Furthermore, some countries have recently started to develop and utilize UAV applications for citizen services, but they do not have standards to follow. Therefore, such framework could ease the process of developing a solid ground for UAV operations and help push the UAV business growth.

Chapter 6: Conclusions and Future Work

In this chapter we summarize the contributions of the thesis research. In addition, we include remarks about the current and future work.

6.1 Summary of Research and Contributions

In general, utilizing KM to reduce risks provides a positive value in information accuracy within the project scope. In addition, UAV is a new area of technology that requires more effort in reducing risks and delivering excellent services and applications.

The proposed framework can help developers exchange knowledge and related issues with regulatory bodies and other developers. Furthermore, the proposed framework can be customized based on developer needs and requirements because it can be helpful in case of geographically located developer teams.

In Chapter 3, we identified the challenges encountered by UAV applications development from the PM perspective. Furthermore, we divided those challenges into technical and managerial challenges. In Chapter 4, we highlighted various types of risks associated with UAV applications development. Furthermore, current techniques were addressed in the context of managing risks in UAV applications development.

In Chapter 5, we highlighted the role of KM in project environments with respect to UAV applications development projects and similar environments (such as the aerospace industry). Furthermore, we addressed the challenges encountered by KM in such environments, and the benefits of using KM also in such environments. The main advantage of the proposed framework is that it is helpful when utilizing the risks and gathered knowledge on these risks in implementing new and updated rules, and regulations and standards for UAV operations.

The proposed framework in Chapter 5 can help developers reduce risks. Furthermore, it can provide high accessibility to a wide range of information, standards, and specifications. Moreover, it can accelerate the future growth of such technology. In addition, the proposed framework can help provide a solid ground for standardizing such industry and accelerating future growth.

6.2 Future Work

Although we addressed many issues and provided solutions to some of the problems related to UAV applications development, there are still many issues to be addressed and numerous methods and approaches to be investigated and/or enhanced in order to achieve better performance in UAV applications development projects with respect to KM and other factors that might affect the growth of such technology. In this section, we propose some research directions for future work that extends our current research:

1. A comprehensive framework for developing UAV applications and services: a framework can cover different aspects of UAV platforms and system architectures with respect to all the issues addressed in the field.

2. Simulation of real scenarios and case studies from the industry: as mentioned in the Introduction, UAV civil applications are a new area of study, and hence there will be some difficulties in accessing some information from the industry. Therefore, future work will include collaboration with local UAV applications

developers and local firms to implement the framework in their firms (as an experimental work) and perform simulation and risk analysis using PM software.

3. Investigating the integration of this framework to other unmanned systems development industries: the growth of unmanned systems is arising in other means of transportation. Hence, following the same study in other unmanned systems might lead to an integrated and unique framework that can cover such unmanned systems in general (Aerial, Naval, and ground).

Bibliography

ADACORE (2011). Gnat pro safety-critical DO-178 B&C. Online web page. Retrived from www.adacore.com/gnatpro-safety-critical/avionics/do178b

Al-Jaroodi, J., & Mohamed, N. (2012). Service oriented middleware: A survey. *Journal of Network and Computer Applications, 35(1)*, 211–220.

Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). *Autonomous Vehicle Technology: A Guide for Policymakers*. Rand Corporation.

Australian Government Department of Defence (2012). *Complex Project Manager Competency Standards*. Retrieved from https://iccpm.com/sites/default/files/kcfinder/files/Resources/CPM%20Competency%20Standard%20V4.1.pdf

Bo, C., Yang, Z., Peng, Z., Hua, D., Xiaoxiao, H., Zheng, W., & Junliang, C. (2010). Development of web-telecom based hybrid services orchestration and execution middleware over convergence networks. *Journal of Network and Computer Applications, 33(5)*, 620–630.

Braga, R. T. V., Castelo Branco, K. R. L. J., Trindade Jr., O., Masiero, P. C., Neris, L. O., & Becker, M. (2012a). The prolices approach to develop product lines for safety-critical embedded systems and its application to the unmanned aerial vehicles domain. *Clei Electronic Journal, 15(2)*.

Braga, R. T. V., Trindade Jr., O., Castelo Branco, K. R. L. J., and Lee, J. (2012b). Incorporating certification in feature modeling of an unmanned aerial vehicle product line. In *Proceedings of the 16th International Software Product Line Conference, SPLC '12* (pp. 249–258). New York: ACM.

Braga, R. T. V., Trindade Jr., O., Castelo Branco, K. R. L. J., Neris, L. O., & Lee, J. (2012c). Adapting a software product line engineering process for certifying safety critical embedded systems. In *Proceedings of the 31st International Conference on Computer Safety, Reliability, and Security, SAFECOMP'12* (pp. 352–363). Springer-Verlag Berlin: Springer.

Chatzigeorgiou, A., & Stephanides, G. (2002). Evaluating performance and power of object-oriented vs. procedural programming in embedded processors. In *Reliable Software Technologies ADA Europe 2002* (pp. 65–75). Springer.

Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J. R., Mellouli, S., Nahon, K., …, & Scholl, H. J. (2012). Understanding smart cities: An integrative framework. In *System Science (HICSS), 2012 45th Hawaii International Conference on* (pp. 2289–2297). IEEE.

Christensen, K. S., & Bukh, P. N. *Knowledge management in perspectives: An analysis of project management in two companies*.

DefenceWeb/Forecast International (2014). *UAV market to see major growth in next decade forecast international*. Retrieved from http://www.defenceweb.co.za/index.php?option=com_content&view=article&id=34420:uav-market-to-see-major-growth-in-next-decade--forecast-international&catid=35:Aerospace&Itemid=107

DeGarmo, M. T. (2004). *Issues concerning integration of unmanned aerial vehicles in civil airspace*.

Dehghani, R., & Ramsin, R. (2014). An abstract methodology for developing knowledge management systems. In *Proceedings of Conference on Innovations in Information Technology 2014* (pp. 121–126). Al Ain: IEEE.

European Commission (2012). *Managing projects--The importance of project planning*.

Faris, H., Totaro, S., & Corallo, A. (2011). Framework and implementation of a knowledge management system for aerospace collaborative working environments. In *Proceedings of the 2011 IEEE 12th International Conference on Mobile Data Management, MDM '11* (pp. 92–97). Washington, DC: IEEE Computer Society.

Faughnan, M., Hourican, B., MacDonald, G., Srivastava, M., Wright, J., Haimes, Y., …, & White, J. (2013). Risk analysis of unmanned aerial vehicle hijacking and methods of its detection. In *Systems and Information Engineering Design Symposium, SIEDS* (pp. 145–150). IEEE.

Finn, A., & Scheding, S. (2010). *Developments and challenges for autonomous unmanned vehicles*. Springer-Verlag Berlin: Heidelberg.

Fito, J. O., & Guitart, J. (2014). Business driven management of infrastructure level risks in cloud providers. *Future Generation Computer Systems, 32(0),* 41–53.

For Aeronautics, R. T. C.A. (2014). RTCA-DO178B. Online web page. Retrieved from www.rtca.org

Gourova, E., & Toteva, K. (2014). Design of knowledge management systems. In *Proceedings of the 8th Nordic Conference on Pattern Languages of Programs, VikingPLoP* (pp. 3:1–3:15). New York: ACM.

Groba, C., Braun, I., Springer, T., & Wollschlaeger, M. (2008). A service-oriented approach for increasing flexibility in manufacturing. In *Factory Communication Systems, WFCS, IEEE International Workshop on* (pp. 415–422).

Harvey, D., & Holdsworth, R. (2005). Knowledge management in the aerospace industry. In *Professional Communication Conference, IPCC, Proceedings, International* (pp. 237–243).

Hu, Y., Du, J., Zhang, X., Hao, X., Ngai, E., Fan, M., & Liu, M. (2013). An integrative framework for intelligent software project risk planning. *Decision Support Systems, 55(4)*, 927–937.

Huang, L., Port, D., Wang, L., Xie, T., and Menzies, T. (2010). Text mining in supporting software systems risk assurance. In Proceedings of the IEEE/ACM international conference on automated software engineering, pages 163-166. ACM.

Idries, A., Mohammed, F., Mohamed, N., Al-Jaroodi, J., & Jawhar, I. (2015). Challenges of developing UAV applications: A project management view. In *Industrial Engineering and Operations Management, 2015 International Conference on*.

Inc, L. G. R. (2009). Project management.Online Web Page. Retrieved from http://www.letsgorobotics.com/project-management

Institute of Risk Management (2002). *A risk management standard*. Retrived from https://www.theirm.org/media/886059/ARMS_2002_IRM.pdf

Jaanus, J., & Ley, T. (2013). Aligning knowledge development between innovation-driven context and knowledge organization systems. In *Proceedings of the 13th International Conference on Knowledge Management and Knowledge Technologies, i-Know '13* (pp. 14:1–14:7). New York: ACM.

Jong, E. D. (2009). End-to-end UAV messaging over unreliable data links. *The Journal of Military Electronics and Computing*.

Karapetyan, A., & Otieno, R. (2011). *A study of knowledge management challenges in project management: Case of start-up projects in Swedish incubators*.

Kremljak, Z., & Kafol, C. (2014). Types of risk in a system engineering environment and software tools for risk analysis. *Procedia Engineering, 69(0)*, 177–183.

Kurek, K., Keller, T., Modelski, J., Yashchyshyn, Y., Piasecki, M., Pastuszak, G., …, & Bajurko, P. (2013). Integrated communications system for the remote operation of unmanned aerial vehicle. *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 7(2)*.

Laporte, C. Y. (1998). Development and integration issues about software engineering, systems engineering and project management processes. *Software Process Improvement 98*.

Liebowitz, J., & Megbolugbe, I. (2003). A set of frameworks to aid the project manager in conceptualizing and implementing knowledge management initiatives. *International Journal of Project Management, 21(3)*, 189–198.

Lobato, L. L., da Mota Silveira Neto, P., do Carmo Machado, I., de Alemida, E. S., & de Lemos Meira, S. R. (2012a). Risk management in software product lines: An industrial case study. In *Software and System Process (ICSSP), 2012 International Conference on* (pp. 180–189).

Lobato, L. L., da Silveira Neto, P., do Carmo Machado, I., de Alemida, E. S., & de Lemos Meira, S. R. (2012b). Risk management in software product lines: An industrial case study. In *Proceedings of the International Conference on Software and System Process, ICSSP '12* (pp. 180–189). New Jersey: IEEE Press.

Luley, M. (2014). *UAVs around the world, an analysis of where the growth is*.

M.H ,Inc. Embedded systems project management. Retrieved from http://novellaqalive2.mhhe.com/sites/dl/free/0070667640/607541/Web_Materail_Emb_Systesm_SWProjectMgt.pdf

Manvi, S. S. & Shyam, G. K. (2014a). Resource management for infrastructure as a service (IaaS) in cloud computing: A survey. *Journal of Network and Computer Applications*, *41(0)*, 424–440.

Marmier, F., Gourc, D., & Laarz, F. (2013). A risk oriented model to assess strategic decisions in new product development projects. *Decision Support Systems, 56(0)*, 74–82.

Melega, M., Lazarus, S., Savvaris, A., & Tsourdos, A. (2013). GPS/INS integration in a s amp;a algorithm based on aircraft performances estimation. In *Control Automation (MED), 2013 21st Mediterranean Conference on* (pp. 513–518).

MHA Consulting (2013). Four types of risk mitigation and business continuity management (BCM) governance, risk and compliance (GRC). Retrieved from http://www.mha-it.com/2013/05/four-types-of-risk-mitigation/

Mohamed, N., & Al-Jaroodi, J. (2011). A survey on service-oriented middleware for wireless sensor networks. *Service Oriented Computing and Applications, 5(2)*, 71–85.

Mohamed, N., & Al-Jaroodi, J. (2013). Service-oriented middleware for collaborative UAVs. In *Information Reuse and Integration (IRI), 2013 IEEE 14th International Conference on* (pp. 185–192).

Mohamed, N., Al-Jaroodi, J., Jawhar, I., & Lazarova- Molnar, S. (2013). Middleware requirements for collaborative unmanned aerial vehicles. In *Unmanned*

Aircraft Systems (ICUAS), 2013 International Conference on (pp. 1051–1060).

Mohamed, N., Al-Jaroodi, J., Jawhar, I., & Lazarova-Molnar, S. (2014). A service-oriented middleware for building collaborative UAVs. *Journal of Intelligent & Robotic Systems, 74(1-2),* 309–321.

Mohammed, F., Idries, A., Mohamed, N., Al-Jaroodi, J., & Jawhar, I. (2014a). Opportunities and challenges of using UAV for Dubai smart city. In *New Technologies, Mobility and Security (NTMS), 2014 6th International Conference on*, (pp. 1–4).

Mohammed, F., Idries, A., Mohamed, N., Al-Jaroodi, J., & Jawhar, I. (2014b). UAV's for smart cities: Opportunities and challenges. In *Unmanned Aircraft Systems (ICUAS), 2014 International Conference on,* (pp. 267–273).

Jafari. M., Rezaeenour, J., Akhavan, P., & Fesharaki, M. N. (2010). Strategic knowledge management in aerospace industries: a case study. *Aircraft Engineering and Aerospace Technology: An International Journal, 82(1),* 60–74.

Mutter, F., Gareis, S., Schatz, B., Bayha, A., Gruneis, F., Kanis, M., & Koss, D. (2011). Falter in the loop: Testing UAV software in virtual environments. In H. Giese, M. Huhn, J. Phillips, & B. Schatz (Eds.), *MBEES* (pp. 81–90). Munchen: fortiss GmbH.

Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. In *Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times* (pp. 282–291). ACM.

Nikolic, J., Burri, M., Rehder, J., Leutenegger, S., Huerzeler, C., & Siegwart, R. (2013). A UAV system for inspection of industrial facilities. In *Aerospace Conference, 2013 IEEE* (pp. 1–8).

Oehmen, J., & Rebentisch, E. (2010). Risk management in lean product development. *LAI Paper Series "Lean Product Development for Practitioners"*.

Office of Naval Research Science and Technology (2011). *Naval S&T strategy*. Retrieved from http://www.onr.navy.mil/About-ONR/science-technology-strategic-plan.aspx

The Royal Academy of Engineering and The British Computer Society (2004). *The challenges of complex IT projects*. Retrieved from http://www.bcs.org/upload/pdf/complexity.pdf

US Department of Transportation Federal Aviation Administration (2013). *Integration of civil unmanned aircraft systems (UAS) in the national airspace system (NAS) roadmap*. Retrieved from http://www.faa.gov/uas/media/uas_roadmap_2013.pdf

Orlic, B., Mak, R., David, I., & Lukkien, J. (2011). Concepts and diagram elements for architectural knowledge management. In *Proceedings of the 5th European Conference on Software Architecture: Companion Volume, ECSA '11* (pp. 3:1–3:10). New York: ACM.

Pinto, C. A., Tolk, A., & McShane, M. (2011). Emerging M&S application in risk management. In *Proceedings of the 2011 Emerging M&S Applications in Industry and Academia Symposium, EAIA '11* (pp. 92–96). San Diego: Society for Computer Simulation International.

PMI (2014). *A guide to the project management body of knowledge* (5th ed.). Project Management Institute.

Polyaninova, T. (2010). *Suitable knowledge management in project environment*. Master's thesis, Dublin Institute of Technology, Dublin Institute of Technology, School of Computing.

Pongracz, G., & Palik, M. (2012). *Communication issues of UAV integration into non segregated airspace*.

PricewaterhouseCoopers (2008). *A practical guide to risk assessment: How principles-based assessment enables organizations to take the right risks*. Retrieved from http://www.pwc.com/en_us/us/issues/enterprise-risk-management/assets/risk_assessment_guide.pdf

Reich, B. H., Gemino, A., & Sauer, C. (2014). How knowledge management impacts performance in projects: An empirical study. *International Journal of Project Management, 32(4),* 590–602.

Rojabanu, M. and Alagarsamy, K. (2012). A model for the proactive risk management based on the text mining classification. International Journal of Engineering Research & Technology (IJERT), 1(7):1-5.

Rosselet, U., & Wentland, M. (2009). Knowledge management framework for it project portfolio risk management. In *Proceedings of the Fifth International Conference on Knowledge Capture, K-CAP '09* (pp. 203–204). New York: ACM.

Sams, B. J. (2011). *Deriving the cost of software maintenance for software intensive systems*.

Sarigiannidis, L., & Chatzoglou, P. D. (2014). Quality vs. risk: An investigation of their relationship in software development projects. *International Journal of Project Management, 32(6)*,1073–1082.

Sharon, A., de Weck, O. L., & Dori, D. (2011). Project management vs. systems engineering management: A practitioners' view on integrating the project and product domains. *Systems Engineering, 14(4)*, 427–440.

Shihab, E., Hassan, A. E., Adams, B., and Jiang, Z. M. (2012). An industrial study on the risk of software changes. In *Proceedings of the ACM SIGSOFT 20th International Symposium on the Foundations of Software Engineering, FSE '12* (pp. 62:1–62:11). New York: ACM.

Solomon, A., Ketikidis, P., & Choudhary, A. (2012). A knowledge based approach for handling supply chain risk management. In *Proceedings of the Fifth Balkan Conference in Informatics, BCI '12* (pp. 70–75). New York: ACM.

Sousa, N., Costa, C. J., & Aparicio, M. (2013). IO-SECI: A conceptual model for knowledge management. In *Proceedings of the Workshop on Open Source and Design of Communication, OSDOC '13* (pp. 9–17). New York: ACM.

The Standish Group (2013). CHAOS manisfesto 2013. Retrieved from http://www.versionone.com/assets/img/files/ChaosManifesto2013.pdf

Taylor, G., Irving, M. R., Hobson, P., Huang, C., Kyberd, P., & Taylor, R. (2006). Distributed monitoring and control of future power systems via grid computing. In *Power Engineering Society General Meeting, 2006*. IEEE (p. 5).

Turner, N., Maylor, H., Lee-Kelley, L., Brady, T., Kutsch, E., & Carver, S. (2014). Ambidexterity and knowledge strategy in major projects: A framework and illustrative case study. *Project Management Journal, 45(5)*, 44–55.

US Army (2010). *Eyes of the Army US Army Roadmap for Unmanned Aircraft Systems: 2010-2035*. Retrieved from http://www.army.mil/standto/archive/2010/04/16/

Weinberger, S., Hambling, D., & Sweetman, B. (2012). The power challenge for small unmanned vehicle. *Aviation Week & Space Technology - Defense Technology Edition*.

Wiewiora, A., Trigunarsyah, A. B., Murphy, G., & Chen, L. (2009). *Barriers to effective knowledge transfer in project-based organizations*.

Xiao, J., Osterweil, L. J., Chen, J., Wang, Q., and Li, M. (2013). Search based risk mitigation planning in project portfolio management. In *Proceedings of the 2013 International Conference on Software and System Process, ICSSP 2013* (pp. 146–155). New York: ACM.

Xu, Y., Malisetty, M. K., & Round, M. (2013). Configuration management in aerospace industry. *Procedia {CIRP}, 11(0)*, 183–186.

Yeo, M. L., Rolland, E., Ulmer, J. R., & Patterson, R. A. (2014). Risk mitigation decisions for IT security. *ACM Transactions on Management Information Systems, 5(1)*, 5:1–5:21.

List of Publications

Idries, A., & Mohamed, N. (2015). Towards risk knowledge management in unmanned aerial vehicles applications development. *The 16th Annual Meeting, 2015 International Conference on, Atlanta, GA, USA. International Symposium on Collaborative Technologies and Systems (CTS), the Fourth International Workshop on Knowledge Management & Collaboration (KMC 2015)* [Accepted] [In Press]

Idries, A. et al. (2015). Challenges of developing UAV applications: A project management view. In *Industrial Engineering and Operations Management, 2015 International Conference on*. [In Press]

Mohammed, F., Idries, A., et al. (2015). Integrating unmanned aerial vehicles with smart cities. *Journal of Intelligent and Robotic Systems*. (Under Review)

Mohammed, F., Idries, A.et al. (2014a). Opportunities and challenges of using UAV's for dubai smart city. In *New Technologies, Mobility and Security (NTMS), 2014 6th International Conference on* (pp. 1– 4).

Mohammed, F., Idries, A., et al. (2014b). UAVs for smart cities: Opportunities and challenges. In *Unmanned Aircraft Systems (ICUAS), 2014 International Conference on* (pp. 267–273).