GICHD

GUIDE TO SYSTEMS ENGINEERING

FOR HUMANITARIAN INFORMATION MANAGEMENT

Guide To Systems Engineering For Humanitarian Information Management,
GICHD, 2021

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The Geneva International Centre for Humanitarian Demining (GICHD) is an international expert organisation based in Switzerland that works to eliminate mines, explosive remnants of war and other explosive hazards. By undertaking research, developing standards, and disseminating knowledge, the GICHD supports capacity development in explosive ordnance-affected countries. It works with national and local authorities to help them plan, coordinate, implement, monitor and evaluate mine action programmes. The GICHD also contributes to the implementation of the Anti-Personnel Mine Ban Convention, the Convention on Cluster Munitions, and other relevant instruments of international law. The GICHD follows the humanitarian principles of humanity, impartiality, neutrality, and independence.

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INTRODUCTION

In the context of rapidly unfolding humanitarian emergencies and high-risk, post-conflict environments, the effective management of information is critical. Unfortunately, information management (IM) systems can fail to meet stakeholder requirements in these contexts if they are not sufficiently understood before deployment. Humanitarian IM systems often fail to meet the needs of their users, and are regularly delivered over budget and later than expected, because of poor design and planning.

The result can be disappointment, missed opportunities and rejection of the system by users. This guide aims to prevent that, by introducing the core principles of systems-based engineering within the context of humanitarian emergencies and post-conflict environments.

When effectively applied, information management systems serve to enable a process, a capability, or a result. It is critical that an IM system comes from the part of the organisation that will benefit from it, with sponsorship or buy-in from senior leadership who sees the value in what the system will enable. When an IM system is initiated independently (such as by an IM or technology team), it is all too often destined to fail.

Systems engineering (SE) is a well-established method for improving the likelihood of success of technologically risky projects. Systems engineering seeks to understand the big picture, and to identify the cause-and-effect relationships between the various elements of any overall system. It also recognises the importance of understanding the short- and long-term consequences of any action, as well as the associated risks and costs. SE is a structured and all-encompassing design and management process, which considers both the business and the technical interests of stakeholders throughout the life cycle of any proposed system.

This guide can be used when deploying a new IM system as well as when upgrading or improving an existing system. In this publication, the GICHD introduces theoretical and practical best practices from around the world, and provides tools that will improve the success of IM systems deployed in support of mine action, peace monitoring, disaster risk reduction and other conflict and post-conflict humanitarian initiatives.

LIST OF ABBREVIATIONS

AMVA	Metropolitan Area of the Aburrá Valley (Colombia)
CDF	Custom defined field
ConOps	Concept of operations
COTS	Commercial off-the-shelf
EGIS	Enterprise geographic information system
EORE	Explosive ordnance risk education
FRA	Functional requirements analysis
FRD	Functional requirements definition
GIS	Geographic information system
GICHD	Geneva International Centre for Humanitarian Demining
IKMAA	Iraqi Kurdistan Mine Action Agency
IM	Information management
IMAS	International Mine Action Standards
iMMAP	Information Management and Mine Action Programme (an international not-for-profit organisation)
IMS	Information management system
IMSMA	Information Management System for Mine Action
MOEs	Measures of effectiveness
MOPs	Measures of performance
NASA	National Aeronautical and Space Administration (of the United States of America)

NMAC National mine action centre

NOAA National Oceanic & Atmospheric Administration (United States)

OP Open source

OSCE Organization for Security and Cooperation in Europe

SaaS Software as a Service

SE Systems engineering

SEM Systems engineering management

SIATA Sistema de Alerta Temprana de Medellín y el Valle de Aburrá (Early Warning System of Medellín and the Aburrá Valley)

SMM Special Monitoring Mission to Ukraine (OSCE)

SRD System requirements definition

TNMAC Tajikistan National Mine Action Centre

ToC Theory of change

UNMAS United Nations Mine Action Service

WBS Work breakdown structure

An exhaustive and updated list of acronyms and abbreviations related to the Systems Engineering Body of Knowledge is available at: https://www.sebokwiki.org/wiki/Acronyms.

KEY TERMINOLOGY

A number of words used in this guide have specific meanings. They include:

- Concept of operations: the overall high-level concept of how the system will be used to meet stakeholder expectations, and that serves as the basis for subsequent definition documents and provides the foundation for long-range operational planning activities.
- Engineered system: a system designed or adapted to interact with an anticipated operational environment to achieve one or more intended purposes while complying with applicable constraints.
- Stakeholders: people and organisations that have an interest in a system, or may be affected by that system. These might include internal and external users, data contributors, donors and direct / indirect beneficiaries, including communities, governments and civil society organisations.
- System: a combination of interacting elements organised to achieve one or more stated purpose.
- Systems engineering: a transdisciplinary and integrative approach to enable the successful realisation, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.

An exhaustive and updated list of terminology related to the Systems Engineering Body of Knowledge is available at:
https://www.sebokwiki.org/wiki/Category:Glossary_of_Terms.

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QUICK REFERENCE GUIDE TO IM SYSTEM DESIGN

A quick reference guide is provided with this publication as a checklist for IM systems engineers and project managers. It is recommended for use in conjunction with the detail found in this guide, and with further information available through the materials listed on this publication's resource site, https://www.gichd.org/en/seguide/.

CHAPTER 1 – RUDIMENTS OF SYSTEMS ENGINEERING & INFORMATION MANAGEMENT

1.1 SYSTEMS ENGINEERING DEFINITION

The field of systems engineering (SE) emerged in the 1940s and was first used for the robust design of complex military and energy systems. Today, SE is employed in a wide range of civilian applications, including space exploration, transportation, medicine, education, electronics, heavy industry, and information management.

SE is rooted in the concept of systems thinking, a holistic approach that considers the interdependence of various components of any system of interest. Systems thinkers seek to understand the big picture and identify the cause-and-effect relationships between the various elements of any overall system. They also recognise the importance of understanding the short- and long-term consequences of any action, as well as their associated risks and costs. (International Council on Systems Engineering, 2015) Most importantly, they know that by disassembling a complex system into less-complex subsystems, it will be easier to solve design challenges and manage project risks (strategic, technical and financial).

There are many classical and modern definitions of the term systems engineering. In this guide, we adopt the following:

> *Systems Engineering is a* ***transdisciplinary*** *and* ***integrative*** *approach to enable the successful realization, use, and retirement of* ***engineered systems****, using* ***systems principles and concepts,*** *and scientific, technological, and management methods.* (International Council on Systems Engineering, 2020)

The above quote suggests that SE is a structured and all-encompassing design and management process, which considers both the business and the technical interests of stakeholders throughout the life cycle of any proposed system.

In our context, the word ‘system’ is defined as ‘a combination of interacting elements organised to achieve one or more stated purposes.’ (ISO/IEC/IEEE 15288, 2015) These elements can be physical or conceptual, or a combination of both. (International Council on Systems Engineering, 2020) For example, an enterprise-wide geographic information system will integrate a suite of products (hardware and software), people, processes, information, services, standards, techniques, facilities, and communications in order to achieve its objectives.

The remainder of this section introduces some important foundational knowledge about SE and information management (IM); take some time to study this before beginning to apply the tools and methods explained in the rest of the publication.

1.2 CHARACTERISTICS OF AN ELEGANT SYSTEM

It is important to acknowledge that IM systems are typically composed of a single or combination of (1) open-source, (2) commercial, and (3) custom-built components. Regardless of whether an IM system is constructed out of existing or custom technologies, the goal remains the same: to implement a solution that is robust in application, graceful in operation, efficient, economical, and timely.

Ultimately, any system should be *elegant* – that is, have the qualities of being ingenious, simple, appealing, and graceful. Elegance does not preclude the need for systems to also be resilient, secure and durable – indeed, these traits are all essential to the overall outcome of any IM project. Most importantly, elegant systems are not built through chance or coincidence; they are built using an intentional process, and by a team with the necessary resources, skills, and discipline. (NASA, 2018)

But is this realistic within a conflict or post-conflict humanitarian context? The answer is YES! Even when timelines are tight, staff are overwhelmed, and funding is limited – organisations should still aim to deploy elegant IM solutions. Elegance should be considered essential to the successful deployment of any IM system. The skilled systems engineer understands how to achieve this seemingly lofty aspiration within the extreme pressures of a humanitarian emergency or a peacebuilding initiative in a fragile region.

> *'Systems engineers aren't superheroes, even though some organisations make theirs out to be! But they can achieve a lot when empowered to do so.'*
>
> Michael Johnson, SE-Training GmbH

1.3 ROLE OF THE SYSTEMS ENGINEER

Systems engineers are valuable members of a project team because they balance stakeholder interests, resolve conflicting objectives, manage risk, navigate constraints, and strive for an elegant result. The exact role and responsibility of the systems engineer may vary depending on the size and complexity of each project and from phase to phase of the project's life cycle. And, while large projects may require one or more dedicated systems engineers, smaller deployments may combine the functions of a project manager and a systems engineer, to create what might be called a 'project lead'. Except for the most basic IM deployments, it is not advisable to conflate the role of the project lead / systems engineer with that of an IM officer – these roles should ideally remain distinct until the system is fully operational.

[Note: It is quite possible for the same person to take on the role of project lead, and once the system is operational to then utilise the system in the role of IM officer. Indeed, IM officers are increasingly expected to acquire systems engineering skills, making this approach more the norm than the exception. Instead of being limited to their traditional function of providing IM products and services, the role of IM officers has shifted towards being a service enabler – a logical step towards taking on the role of systems engineer. This has significance in the context of humanitarian information management systems since it helps address the requirement for timely information in high-pressure environments. But, the perspective and responsibilities of a systems engineer are quite different to that of an IM officer, and must be respected if the same person is asked to perform both roles in an organisation.]

Specifically, the role of the systems engineer includes:

1. Leading the development of the concept of operations and resulting system architecture;
2. Creating project boundaries;
3. Defining system requirements;
4. Leading the technical planning effort;
5. Consulting key stakeholders;
6. Documenting the technical plans, requirements, specifications, and acceptance of documents.

The systems engineer is an inter-disciplinarian ‘skilled in the art and science of balancing organizational, cost, and technical interactions in complex systems’. (NASA, 2016)

So how does the role of a systems engineer fit within the overarching process of project management? As illustrated in the figure below, the systems engineer is focused on the technical aspects of a project, as opposed to the programmatic, financial, and contractual aspects of the project (collectively referred to as project planning & control). The systems engineer will have overlapping interests with other members of a project management team in common aspects such as risk management, scheduling, and stakeholder consultation.

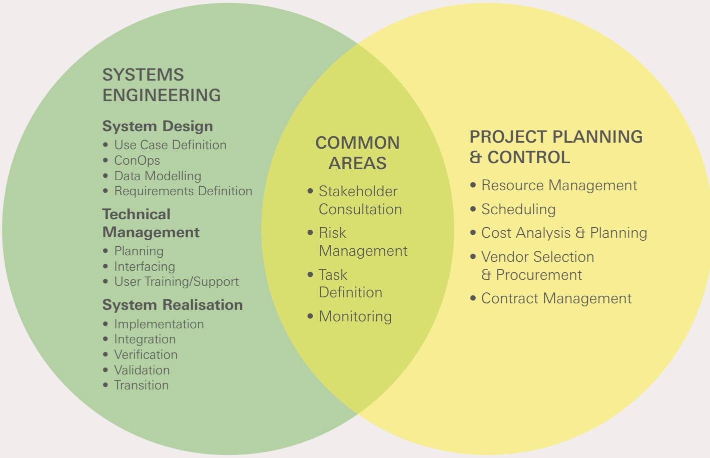


Figure 1.1 – SE in the context of overall project management (NASA 2016 & SE-Training, 2020)

As noted above, the precise role of a systems engineer can change from project to project, but his / her primary role is to support technical decision-making within the project management process. This is done according to a set of well-established principles.

1.4 THE TWELVE PRINCIPLES OF SYSTEMS ENGINEERING

The role of the systems engineer is perhaps most effectively understood by reviewing the twelve SE principles as defined by the US National Aeronautical and Space Administration (NASA):

Principle 1 – Interdisciplinarity: systems engineering integrates various disciplines with applicable budget and schedule constraints**.** The systems engineer is expected to deliver an elegant solution on budget and on time using multidisciplinary knowledge, and a wide array of tools and techniques.

Principle 2 – Manage complexity: the systems engineer must manage the complexities of an organisation's mission and the complexities of its desired system. These are interdependent and should not be managed as mutually exclusive. It is not possible to design an effective system without understanding the mission that it will support, or the stakeholders involved in that mission.

Principle 3 – Iterative and progressive: no matter how diligent the systems engineer is at the start of a project, there will still be knowledge gaps that will be filled as the system is developed; SE provides the framework to decide if and how to improve the original design, with a continuously improving understanding of requirements.

Principle 4 – Comprehensive: systems engineering has a critical role through the entire system life cycle. Starting from *conceptualising* a system based on the needs of diverse stakeholders, then *modelling* and *analysing* various designs of that system, then *building* and *testing* that system, then *deploying* and *operating* that system, and finally to *decommissioning* that system – SE supports planning from cradle to grave.

Principle 5 – Formal process based on fundamentals: systems engineering should incorporate physical, logical, mathematical, and sociological truths in the design and deployment of any system. And, because systems should respect the maturity of their users' experience, systems engineers need to enforce these fundamentals; that is, by making sure that inexperienced organisations follow more formal processes when operating their systems, as compared to experienced organisations (who may already have the same controls).

Principle 6 – Culturally respectful: systems engineering respects the discipline of interactions within the organisation, including its culture. Any system is informed by, and will ultimately mirror, the realities of the environment in which it will be used. The systems engineer must therefore help the project manager to resolve knowledge gaps or organisational barriers, to avoid flaws in system design and operation.

Principle 7 – Informed decision-making: a system will only be as good as the completeness of understanding amongst the individuals involved in the SE process; the systems engineer strives to promote informed decision-making by involving essential stakeholders and consulting best practices throughout the SE process.

Principle 8 – Legal and policy compliance: both policy and law must be properly understood to not overly constrain or under constrain system implementation. The systems engineer is obliged to understand applicable policies and laws to ensure the system is legally compliant. Policies tend to be more flexible than laws, since they are often determined by the organisation that will use the system, and can therefore be adapted around the system when appropriate and in consultation with policymakers. Laws can be more onerous, as they are unlikely to be changed to accommodate any particular system.

Principle 9 – Risk management: systems engineering decisions often have to be made with an imperfect understanding of the system context, and a recognition that there will always be knowledge gaps even as understanding improves. It is therefore critical to manage this uncertainty using risk models throughout the SE process.

Principle 10 – Verification: systems engineers are obliged to test the functionalities to ensure that they comply with the system requirements – that is, to verify that a system achieves what was operationally defined as acceptable performance.

Principle 11 – Validation: stakeholder expectations may or may not have been adequately reflected in the system requirements, and SE requires the systems engineer consult with various users before deploying any system to validate their level of acceptance.

Key point: SE distinguishes between the verification of the system requirements, and the validation of stakeholder expectations.

Principle 12 – Time sensitivity: particularly in the domain of IM systems, design decisions are very much constrained to the state-of-the-art in technology at the time of the design process. The rapid advancement of technologies may mean that the system will be out of date by the time it becomes operational. The systems engineer is aware of time frame-decision constraints, and endeavours to mitigate their impact throughout the SE process.

These twelve core principles apply to the simplest and to the most complex of systems; for an exhaustive analysis of the theoretical and practical implications of these principles, the interested reader may wish to refer to (NASA, 2018).

PRINCIPLES FOR DIGITAL DEVELOPMENT:

In addition to NASA's twelve principles of systems engineering, also consider the ICT4D[1] community's nine principles for digital development (https://digitalprinciples.org/principles):

1. Design With the User.
2. Understand the Existing Ecosystem.
3. Design for Scale.
4. Build for Sustainability.
5. Be Data Driven.
6. Use Open Standards, Open Data, Open Source, and Open Innovation.
7. Reuse and Improve.
8. Address Privacy and Security.
9. Be Collaborative.

1 ICT4D = Information and communications technology for development.

1.5 SYSTEMS ENGINEERING MANAGEMENT

Let us now explore the concept and rationale behind systems engineering management. As illustrated in the figure below, the term refers to the integration of three types of activities required to build an effective system:

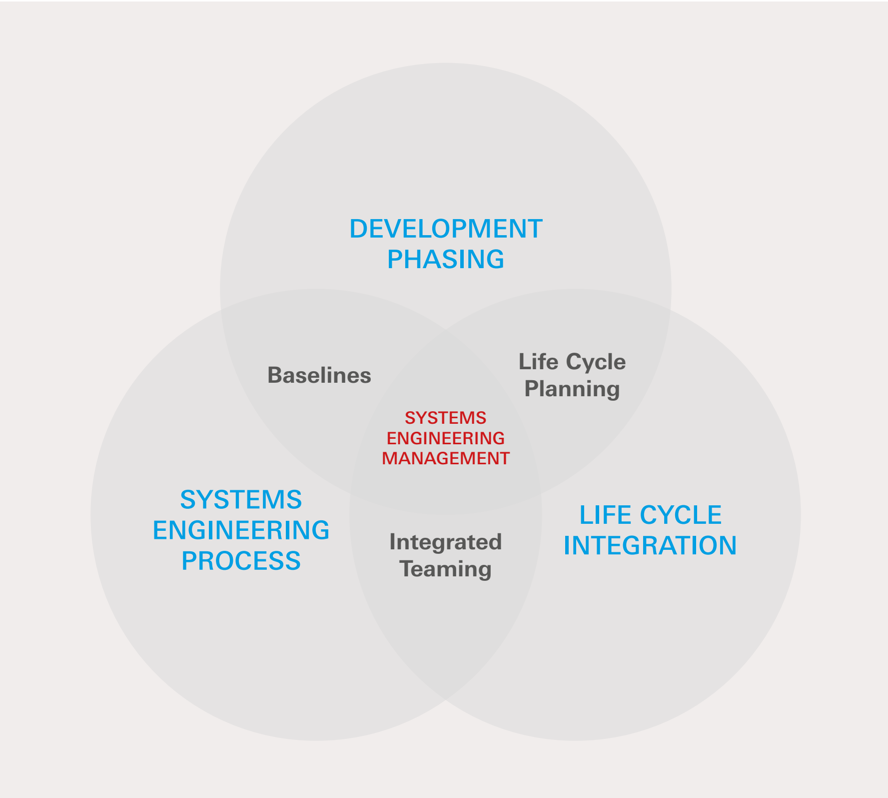
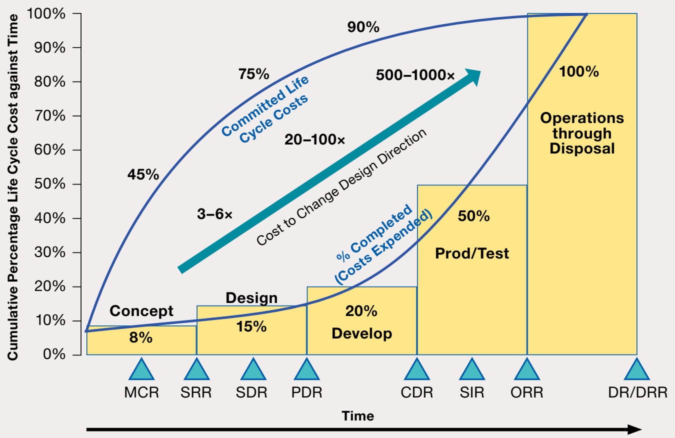


Figure 1.2 – Three activities of systems engineering management.
Figure modified by the GICHD and based on (US DoD, 2001)

Take a moment to study the figure above (which is referred to as a three-set Venn diagram), and you will observe that:

- ***Development phasing*** controls the design process and provides baselines that coordinate design efforts. It serves two major purposes: (1) to control the design effort (by baselining each level of development), and (2) to connect the technical management effort with the overall acquisition effort (by defining the event milestones and deployment timelines).
- ***Systems engineering process*** refers to the comprehensive, iterative, and robust problem-solving techniques that aid in developing a system which will meet stakeholder needs.
- ***Life cycle integration*** ensures that a system is designed to remain viable throughout its life. The eight primary life cycle functions of SE are: development, production, deployment, operation, support, disposal, training, and verification.

Collectively, the intersection of these three activities is defined as systems engineering management (SEM). The economic argument for employing SEM is compelling, since multiple studies have shown that because the life cycle cost of most projects is usually determined by the design stage, the cost to change the system design becomes progressively more expensive later in the life cycle. As the cost curves in the figure below illustrate, only a small percentage (approx. 15% on average) of overall project cost is incurred during the conceptual stage and design of a typical system but, at the same point in time, a large percentage (more than 75%) of the overall cost will be committed / determined. It is therefore very cost effective to apply SEM from the very initial stages of a project. As a general rule of thumb, the more complex and essential a system is to a group of stakeholders, the more rigorous and justifiable is the application of SE management.



MCR	Mission Concept Review	**CDR**	Critical Design Review
SRR	System Requirements Review	**SIR**	System Integration Review
SDR	System Definition Review	**ORR**	Operational Readiness Review
PDR	Preliminary Design Review	**DR/DRR**	Decommissioning/Disposal Readiness Review

Figure 1.3 – Life cycle cost from early phase decision-making. (NASA, 2016)

Even in a relatively basic deployment of off-the-shelf IM solutions within the humanitarian context, the cost curves will look the same as above. **Yet, projects sometime begin with the acquisition of hardware and software, the delivery of training, and the collection of data – *not* with the disciplined design of system requirements!** SEM strives to ensure that functional requirements determine technological procurement, and not vice versa, to avoid the costs associated with partial or total system failure.

There is an optimal amount of investment in SEM for a project, and up to a 7:1 return on investment in SE. That is, for each dollar invested in SEM, there can be up to $ 7.00 in savings. Research also shows that the optimal investment in SEM for a typical system is about 14% of overall project cost, as illustrated in the figures below.

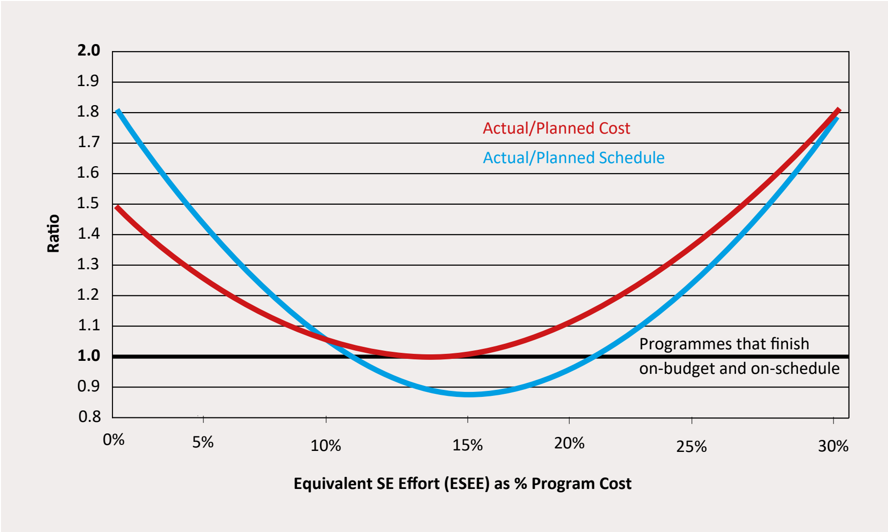


Figure 1.4 – Correlation of SEM effort as % of programme cost. (Honour, 2013)

While the optimal ratio of investment in SEM will vary from project to project, there are significant returns with committing appropriately to a systems-based approach; it is possible to overdo systems engineering! The goal is to make the right level of commitment during the conceptualisation and design stages, to manage project risk *before* the project team attempts to deploy their system. This commitment to SEM then supports the team throughout the life cycle of the system, improving the likelihood that it will be completed (a) on budget, (b) on time, and (c) with high levels of user acceptance.

Bear in mind the definition, principles, roles and management of SE as you study the rest of this guide. This section concludes by defining IM within the context of SE, and comparing two common forms of system development.

1.6 DEFINITION OF INFORMATION MANAGEMENT

There is a wide variety of definitions of the term information management. The Cambridge Business English Dictionary defines it simply as, 'the process of collecting, organizing, storing, and providing information within a company or organization.' (CUP, 2021) IM requires the ongoing collection, analysis, and timely provision of valuable information for a defined set of stakeholders. This information contributes to the understanding of, and the ability to make, decisions regarding:

- The nature and characteristics of an organisation's operational environment and its rate of change;
- The implications of the operational environment for an organisation's stakeholders (e.g. affected populations, partner organisations and governments);
- The needs, requirements and preferences of stakeholders;
- The status of an organisation's assets and ability to act;
- The prioritisation of actions and allocation of resources; and
- The progress towards the achievement of targets.

Information management (IM) in mine action refers to the process of defining and continually improving information requirements from all relevant stakeholders and to the subsequent collection, validation, storage, analysis and dissemination of timely, accurate and easy-to-access information that meets these requirements.

The ultimate goal of IM is to deliver information products to stakeholders. To be effective, IM therefore depends on the close collaboration and involvement of all stakeholders, both internal and external, with an interest in the mine action programme.

Source: UNMAS 2020 https://www.mineactionstandards.org/fileadmin/user_upload/IMAS_05-10_Ed2-Am1_02.pdf

Understanding who needs what information, how they will analyse it and what they intend to do with it, is essential to the success of any IM system. Different users may need the same data for different purposes. This in turn may influence the accuracy, frequency and format in which data is collected and reported. IM is not the sole responsibility of an IM department. Responsibility lies with those who will use the resulting information (and who must specify their information requirements), those who collect it (and who must comply with requirements), those who store, secure, analyse and disseminate it, and those responsible for designing, maintaining and overseeing the overall IM system.

Ineffective IM can force decision-making based on intuition rather than evidence. A lack of information may discourage decision makers from taking efficient decisions, steering them towards unnecessarily cautious positions. An inability to measure performance impedes transparency and opens the door to corruption and inefficiency.

WHY IM MATTERS

Creating an effective IM system in humanitarian action can serve to increase efficiency, strengthen operations, enable better decision-making, and ultimately, contribute to improved outcomes.

It is important for all stakeholders, including senior management, to invest time to understand the merits of an effective IM system and set organisational parameters that will enable its success. IM systems all too often fail during implementation or uptake or come in over budget. Indeed, the CHAOS report 2015 showed that only 30% of all technology projects succeed. This percentage is even lower for bigger projects. (The Standish Group, 2015) Furthermore, the majority of large technology projects tend to run 45% over budget and 7% over time. (Bloch, Blumberg, & Laartz, 2012) To reduce the risk of incurring extra costs, it was demonstrated that there is an inverse relationship between time spent on systems engineering and cost overruns. (SEBok, 2021) More up-front preparation, planning, and design on a project will reduce future expenditure as the cost of making changes increases exponentially in the later stages of a project.

To mitigate these costs and risks, buy-in from and active engagement of senior management to set a clear strategy is critical to successfully delivering a quality IM system.

While the aforementioned points apply across sectors, the humanitarian sector has its own particularities. Information management systems for humanitarian action have evolved a lot during the last 20 years but some work is still needed, especially in the exchange of information between headquarters and the field. Due to the urgency of many humanitarian settings, having already allocated time and resources in order to have a robust IM system, will contribute to a more efficient and cost-effective response. (Schofield, 2003)

IM is commonly and mistakenly seen as an isolated task belonging to the IT department – limited to hardware and software maintenance and data archiving. Instead, IM should be understood as a basic function of every decision maker at every level in an organisation.

All data is collected for a purpose. If it does not satisfy that purpose, then the system fails. Combining operational, quality and information management as facets of a single activity is increasingly recognised within mine action programmes and humanitarian initiatives in general. The future will see an increasing emphasis on a common understanding of the interconnectedness of these functions and the need for humanitarian managers to understand, and apply, principles of all three (operational, quality, and information management) throughout their work.

1.7 WATERFALL VS AGILE METHODS OF SYSTEM DEVELOPMENT

Before concluding this review of the rudiments of systems engineering and information management, we shall explore the two most common approaches to system development: waterfall vs agile. Although these development models are primarily employed within the context of software engineering, they are equally relevant in the wider context of systems engineering. And irrespective of which model is employed, the SE process is neither static nor inflexible; indeed, the process must always be responsive to change, where practicable.

The waterfall method is sequential in nature and requires a development team to advance to the next phase of development or testing *only if* the previous step has been completed successfully. So, if a project's system requirements are stable and well defined, the waterfall method is typically preferable. This is the traditional form of system development and is known to deliver results that are robust, fully documented, and resistant to 'mission creep' (overexpansion of original system requirements). Especially because a new system will have complex interdependences with other systems, the waterfall method is often preferable in order to guarantee compatibility.

The agile method is iterative in nature and allows a project team to undertake system development and testing activities concurrently. When the system requirements are constantly evolving and cannot be fully defined at the start of the project, the agile method is preferable. Because it is particularly client oriented and capable of accommodating changing needs during the development cycle, it is best suited to dynamic environments.

There has been an unmistakable trend towards greater use of agile versus waterfall methods. (Dima & Maassen, 2018) While there are many reasons for this, one that is particularly relevant to the humanitarian sector is the growing maturity of modular technology components. Such components can be configured and adapted to fit specific needs without necessarily requiring complete custom development. The ability to configure system requirements allows for a more adaptable and more agile approach to systems engineering.

The table below summarises the key differences between the agile and waterfall system development methods, extracted from (GURU99, 2021):

AGILE	WATERFALL
Separates the project development life cycle into segments called sprints.	Development process is divided into distinct phases.
Follows an incremental approach.	Waterfall methodology is a sequential design process.
Agile methodology is known for its flexibility.	Waterfall is a structured software development methodology so at times it can be comparatively less responsive to real-time project dynamics.
Can be considered as a collection of many different projects.	Will be completed as one single project.
Quite a flexible method allowing changes to be made in the project development requirements even if the initial planning has been completed.	There is a rigorous change control process in cases where requirements must change after development starts.
Follows an iterative development approach. Because of this, planning, development, prototyping and other development phases may appear more than once.	All the project development phases such as designing, development, testing, etc. are completed only once in this model.
The test plan is reviewed after each sprint.	The test plan is rarely discussed during the test phase.
A process in which the requirements are expected to change and evolve.	Ideal for projects which have definite requirements and where changes are not expected.
Testing is performed concurrently with development.	The testing phase comes after the build phase.

AGILE	WATERFALL
Introduces a product mindset where the product satisfies the needs of its end customers and changes itself as per the customer's demands.	This model shows a project mindset and places its focus completely on accomplishing the project.
Works exceptionally well with time & materials or non-fixed funding. It may increase stress in fixed-price scenarios.	Reduces the risk in firm fixed price contracts by getting risk agreement at the beginning of the process.
Prefers small but dedicated teams with a high degree of coordination and synchronisation.	Team coordination / synchronisation is very limited.
Requirements are prepared by the product's owner and their team on a daily basis during a project.	Requirements are prepared by a business analyst before the start of the project.
The test team can take part in changes to the requirements without a problem.	It is difficult for the test team to initiate any change in requirements.
Description of project details can be altered any time during the process.	A detailed description is needed to implement this software development approach.
Team members are interchangeable; as a result, they work faster. There is also no need for project managers because the projects are managed by the entire team.	In this method the process is always straightforward, so the project manager plays an essential role during each stage.

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CHAPTER 2 – SYSTEMS ENGINEERING-BASED DESIGN PROCESS

Designing an information management system is a process that is multidisciplinary, iterative, and highly consultative, and is supported by specific activities related to project management, monitoring and evaluation. This chapter explores the systems engineering (SE)-based design process within the context of humanitarian information management (IM) systems, such as those described in the final chapter of this guide.

This process is – as the reader would expect – quite systematic! Systems engineers like to stress the need for:

- Adopting an interdisciplinary approach to designing a new system;
- Understanding the user requirements fully before attempting the design process;
- Testing the system to ensure stakeholder satisfaction;
- Considering the complete life cycle of the system, including operations and decommissioning;
- Providing full documentation to the system operators.

These critical elements are achieved through effective:

1. Project management.
2. Analysis of user requirements.
3. Definition of functional requirements.
4. Definition of system requirements.

Collectively, these process elements allow systems engineers to attain a good design. These are now discussed in more detail.

2.1 PROJECT MANAGEMENT

As noted in Chapter 1.3, the field of systems engineering is quite distinct from that of project management. Systems engineers are nevertheless responsible for a range of technical project management and planning considerations. This section reviews some of the most common considerations; however, the reader is also advised to consult donor-specific project management requirements where applicable.

A. THEORY OF CHANGE

If you are deploying a donor-funded system, you will probably need to develop or use a theory of change to plan and then evaluate your system's success. Increasingly, government agencies, international non-governmental organisations (NGOs), UN agencies, and other major humanitarian organisations have started to align the theories of change of their interventions with 'systems thinking'.

A theory of change (ToC) is a specific and measurable description of an initiative that forms the basis for strategic planning, ongoing decision-making, and evaluation. It requires participants to clearly articulate long-term goals, define measurable indicators of success, and identify what actions are needed to achieve the goals. A well-developed ToC can help a systems engineer understand how to deliver a successful solution, and to acknowledge underlying assumptions as well as the risks therein. Ultimately, a ToC should be plausible, feasible and testable, in order to serve as a framework for implementing a new system. (Center for Theory of Change, 2020)

Establishing a clear ToC before beginning to design a new IM system is fundamental to the ultimate success of that system, since:

> *'Every program [and project] is based on a "theory of change" – a set of assumptions, risks and external factors that describes how and why the program [or project] is intended to work. This theory connects the program's [or project's] activities with its [expected ultimate outcome]. It is inherent in the program [or project] design and is often based on knowledge and experience of the program [or project design team], research, evaluations, best practices and lessons learned.'* (Global Affairs Canada, 2016)

Consider the approach illustrated below within the context of your IM project:

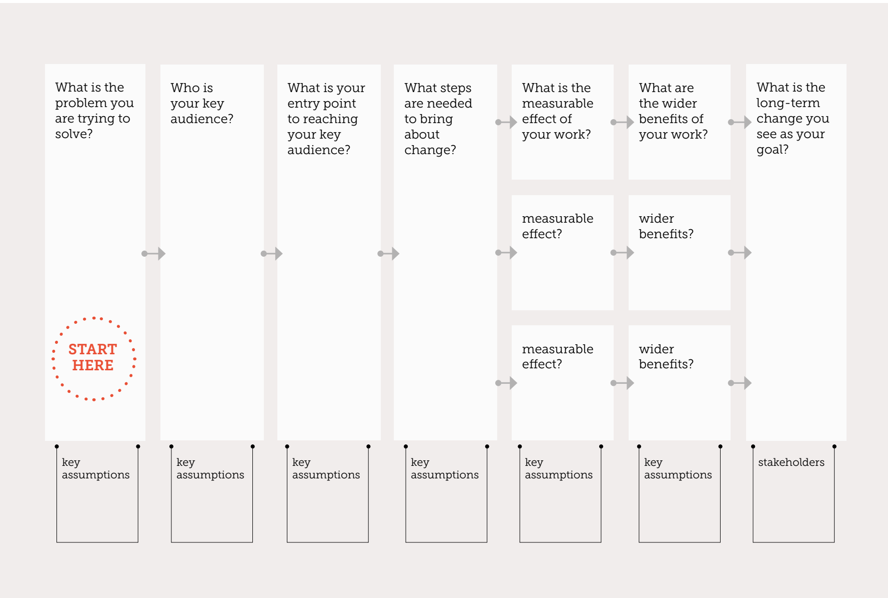


Figure 2.1 – Defining a theory of change (Nesta DIY Toolkit 2014)[2]

2 https://diytoolkit.org/tools/theory-of-change/ (Retrieved July 15, 2020)

With other members of your project team, start on the left side of the figure by defining the problem(s) that your IM system must solve. Then, identify the key stakeholders (users, beneficiaries, administrators, supporters) of the system, as well as the way that diverse stakeholders will interface with the system. You can do this at a high level for your ToC, and then very precisely in your system requirements definition (Section 2.5). Continuing to work from left to right, identify the progress indicators that will define success for your system, and establish the wider benefits and long-term impact that is envisioned. At every step, take note of key assumptions and how they might create risk or opportunities for your project.

Critical elements of such a process include making sure that the right stakeholders are in the conversation, that there is active participation, and that there is space to draft, iterate and refine ideas. These results should then be converted into a concise, written document that clearly states the following for your project:

1. **Outcomes** (situated along causal pathways).
2. **Interventions** (or activities), that will achieve the Outcomes.
3. **Assumptions**, which underly any element of your ToC.
4. **Rationales**, explaining why the interventions will be impactful.
5. **Indicators**, to measure your success in a S.M.A.R.T.[3] manner.
6. **Narrative**, to provide context and additional explanatory detail to your ToC diagrams.

The ToC document should then be reviewed by all project stakeholders, to confirm common understanding and agreement of the project before a detailed system design is attempted.

Finally, your ToC is the foundation of a results-based management (RBM) framework, which has emerged as the preferred approach for managing donor-funded initiatives. RBM promotes realistic, measurable, and impactful outcomes over the entire project life cycle.

3 S.M.A.R.T. = Specific, Measurable, Attainable, Relevant & Time-bound.

Logical framework analysis (LFA, or logframe): it is possible that a logical framework has already been developed for your project. Logframes employ a well-established implementation theory, but they can lack an underlying theory of change. A ToC begins with a participatory and inclusive process to clearly define desired outcomes, by first working out programme goals or desired impact and then working backwards on outcome pathways. Instead of a conventional forward-oriented, reasoned ‘so that’ argument (e.g. donors should fund a new system *so that* a humanitarian organisation can gather field information more efficiently *so that* analysts can identify trends in a conflict *so that* diplomats are better informed *so that* peace agreements are enforced), a ToC, by contrast, begins with a long-term goal and outcomes and then works backwards (in time) to the earliest changes that need to occur. Only when the pathway has been developed is it time to consider which interventions will best produce the outcomes in the pathway (this avoids the classic error of selecting an IM system or software solution before completing a functional requirements analysis).

B. SYSTEMS ENGINEERING PROCESSES

The technical and management processes that enable systems engineering to be so effective are summarised in the figure and table below. In general, these processes aim to ensure a system’s requirements are developed according to well-defined needs, and that the system remains effective throughout its design lifetime. These classical processes resemble the sequential approach that is now commonly referred to as waterfall methodology, in contrast to a more iterative approach referred to as agile methodology (see Section 1.7 for a comparison of their advantages and disadvantages). The SE ‘V’ diagram, which is associated with the waterfall methodology, is often used to depict the key processes from the planning & monitoring phase to the disposal phase.

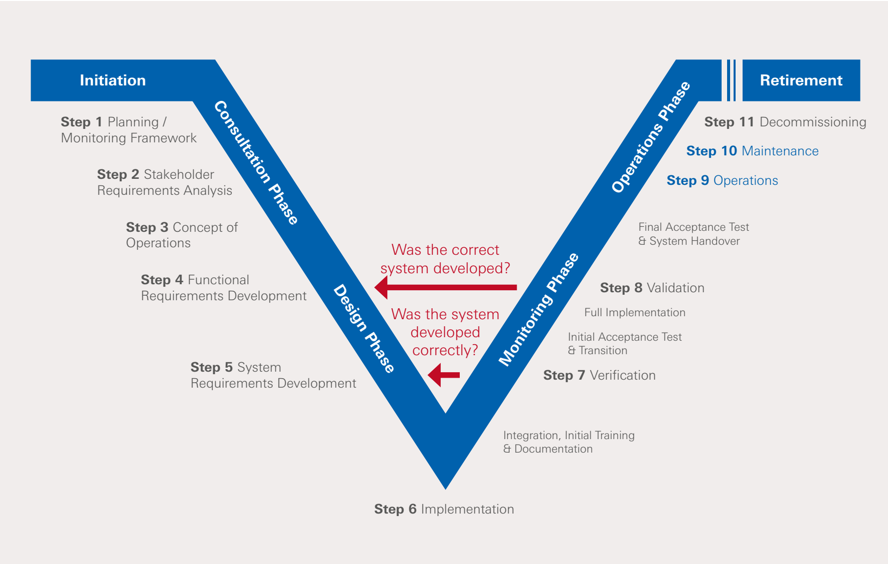


Figure 2.2 – Systems engineering process, the SE 'V' diagram

Table 2.1 – Step-by-step summary of SE processes

NAME OF PROCESS		RESULT / DESCRIPTION
Step 1	Planning & monitoring process	Theory of change and results-based monitoring framework (see Section 2.1A above), co-developed with and accepted by key stakeholders, to guide the systems design and implementation.
Step 2	Stakeholder consultation & user requirements analysis	Comprehensive set of use cases (see Section 2.2 below), which describe the specific functional needs of each user group in non-technical, user-oriented language.
Step 3	Enterprise-level ConOps process	Concept of operations (see Section 2.3 below), based on high-level organisational requirements, to describe how the various subsystems of a system will work to achieve the desired results, and how various stakeholders will interact with the system.

NAME OF PROCESS		RESULT / DESCRIPTION
Step 4	Functional requirements definition (FRD) process	FRD documentation (see Section 2.4 below), developed by the project team, which describes the system in a technologically agnostic manner. FRD should provide hardware and software vendors, and system integrators, with a clear picture of organisational needs so that they can propose their solutions.
Step 5	System requirements definition (SRD) process	SRD documentation (see Section 2.5 below), developed by the project team, which technically defines the system criteria needed to satisfy the functional requirements of each user group. SRD should also include a monitoring plan and an acquisition & operation budget. Developed by the project team, in consultation with subject-matter specialists as well as commercial / non-commercial solution providers.
Step 6	Implementation & integration process	Configuration of the selected system architecture in accordance with the SRD, by the project team, as well as initial training, system-user documentation, and setting of baseline metrics for monitoring plan.
Step 7	Verification process	Initial acceptance test which provides objective evidence that each system element fulfils its specified system requirements (according to the measures of performance criteria).
Step 8	Validation process	Final acceptance test, which provides objective evidence that the system, after sufficient test usage (qualification period), fulfils all stakeholder requirements specified in the concept of operations (according to the measures of effectiveness criteria).
Step 9	Operation process	Full-scale deployment and adoption of the system.
Step 10	Maintenance process	Sustained performance of the system through installation of software updates, replacement / upgrade of hardware, retraining of users, updating of documentation, etc.
Step 11	Decommissioning process	Safe retirement of the system at the end of its life, either through redeployment into a different environment, or demobilisation (secure archive and equipment disposal).

Following the step-by-step approach described above will ensure you design, deploy, and operate an effective system. For a more robust discussion about each of these processes, consult the sections indicated, as well as the INCOSE Systems Engineering Handbook. (International Council on Systems Engineering, 2015)

C. PROJECT TEAM COMPOSITION

The capacity to implement the aforementioned SE technical and managerial processes comes from the project team. It is important to aim for diverse representation in the team, and although every project will have a unique team composition, there are certain roles and responsibilities that are common in almost every project. The following table summarises the inactive and active players in most humanitarian information management system projects – of course, one person may serve in more than one role, and larger projects will justify more team members than smaller projects.

	ROLE	RESPONSIBILITIES / ACCOUNTABILITY	NOTES
inactive	Sponsor	The person responsible for committing funding and resources to a project to meet specific strategic objectives.	The sponsor (e.g. donor, grants officer, finance director) is a key stakeholder, but not an active member of the project team.
inactive	Programme manager	The person responsible for initiating, evolving, and closing projects.	The sponsor may be supported by a more technical manager to assist with fund administration, monitoring and evaluation. **May be an active member of the team.**
inactive	Steering committee (SC)	The senior managers of the host organisation responsible for enabling the project team, ensuring policy compliance, and promoting adoption of the new system.	Composed of a chairperson and managers from Operations, IT, Communications, HR, Admin / Finance, and other relevant units from within the host organisation (and, optionally, external stakeholders). Most SC members will not be active members of the project team, but essential to its success.

	ROLE	RESPONSIBILITIES / ACCOUNTABILITY	NOTES
active	Project lead	The person responsible for (1) planning, assessing and controlling the project, (2) obtaining a product or service in accordance with the organisation's requirements, and (3) eliciting, defining and analysing the stakeholder and system requirements.	Combines the SE roles of systems engineer, project manager and requirements manager, and is accountable for overall project success.
	Solution designer	The person responsible for defining and analysing the system architecture, and for planning, procuring, and leading the configuration of management activities.	Can also combine the SE roles of configuration manager and procurement manager.
	Monitoring specialist	The person responsible for planning and leading the verification and then the validation activities.	Combines the roles of verification lead and validation lead.
	Infrastructure manager(s)	The person(s) responsible for ensuring that the organisation is provided with the necessary facilities, tools, and communications and information technology assets consistent with business needs.	Typically, one or two infrastructure managers from the host organisation's IT, IM/GIS, and/or Operations units.
	Implementation team members	The persons authorised to implement the project under the direction of the other team members.	Technical specialists who are assigned tasks by the project lead, solution designer, monitoring specialist, and infrastructure manager(s). Examples include GIS officers, IT specialists, project support officers, etc.

Adapted from Guide to SEPM Roles and Responsibilities
(INCOSE UK & APM, 2017)

Consider these various core roles and responsibilities when building your project team, and if necessary, modify the team's composition based on the complexity of your proposed system. Finally, recognise the importance of establishing some form of project governance, such as a steering committee, at the earliest stages. In addition to ensuring broad institutional ownership, a well-structured form of governance will help the team navigate the various challenges that are inherent in deploying their system and empower the project lead to be as successful as possible.

D. EMPLOYING CRITICAL PATH & GANTT CHART ANALYSES

Critical path and Gantt chart analyses will help promote the completion of your project on time, on budget and within scope (of importance, since some project managers argue that any increase in one of these factors will invariably affect the other two, the so-called triple constraint theory). Both are standard tools in the project management toolkit and although they can be done manually, consider using a software package like Microsoft Project or OpenProject for instance, to develop your work breakdown structure (WBS) (such as tasks, sub-tasks, scheduling, resource allocations), and to track and report your progress once you get started.

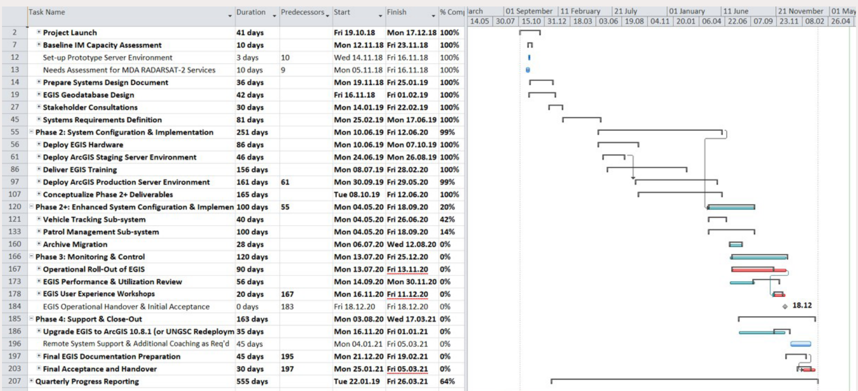
Critical path analysis is a modelling technique that uses the following values to calculate the longest path to the end of a project:

1. A list of all tasks and sub-tasks required to complete the project;
2. The time (in days or weeks) that each sub-task will take to complete;
3. The dependencies between the tasks and sub-tasks; and
4. Logical end points such as milestones or project deliverables.

Mapping out these values also provides an indication of the earliest and latest that each activity can start and finish without making the project longer; it then becomes clear what tasks are 'critical' (i.e. on the longest path) and which have 'total float' (i.e. can be delayed without making the project longer).

Gantt chart analysis provides a visual representation of tasks over time, as well as their interdependencies. Tasks are shaded in proportion to the degree of their completion, so a task that is 25% completed is one-quarter shaded. Resources can also be linked to each task in project management software, creating powerful analytical, planning and reporting options for the project team.

The figure below illustrates the combined use of these two forms of project analysis. Note how the critical path links those tasks in the Gantt chart that determine the duration of the project (from the GICHD's Work Plan (as of June 2020) for the Enterprise GIS project in Ukraine):



	Task Name	Duration	Predecessors	Start	Finish	% Comp
2	Project Launch	41 days		Fri 19.10.18	Mon 17.12.18	100%
7	Baseline IM Capacity Assessment	10 days		Mon 12.11.18	Fri 23.11.18	100%
12	Set-up Prototype Server Environment	3 days	10	Wed 14.11.18	Fri 16.11.18	100%
13	Needs Assessment for MDA RADARSAT-2 Services	10 days	9	Mon 05.11.18	Fri 16.11.18	100%
14	Prepare Systems Design Document	36 days		Mon 19.11.18	Fri 25.01.19	100%
19	EGIS Geodatabase Design	42 days		Fri 16.11.18	Fri 01.02.19	100%
27	Stakeholder Consultations	30 days		Mon 14.01.19	Fri 22.02.19	100%
45	Systems Requirements Definition	81 days		Mon 25.02.19	Mon 17.06.19	100%
55	Phase 2: System Configuration & Implementation	251 days		Mon 10.06.19	Fri 12.06.20	99%
56	Deploy EGIS Hardware	86 days		Mon 10.06.19	Mon 07.10.19	100%
61	Deploy ArcGIS Staging Server Environment	46 days		Mon 24.06.19	Mon 26.08.19	100%
86	Deliver EGIS Training	156 days		Mon 08.07.19	Fri 28.02.20	100%
97	Deploy ArcGIS Production Server Environment	161 days	61	Mon 30.09.19	Fri 29.05.20	99%
107	Conceptualize Phase 2+ Deliverables	165 days		Tue 08.10.19	Fri 12.06.20	100%
120	Phase 2+: Enhanced System Configuration & Implemen	100 days	55	Mon 04.05.20	Fri 18.09.20	20%
121	Vehicle Tracking Sub-system	40 days		Mon 04.05.20	Fri 26.06.20	42%
133	Patrol Management Sub-system	100 days		Mon 04.05.20	Fri 18.09.20	14%
160	Archive Migration	28 days		Mon 06.07.20	Wed 12.08.20	0%
166	Phase 3: Monitoring & Control	120 days		Mon 13.07.20	Fri 25.12.20	0%
167	Operational Roll-Out of EGIS	90 days		Mon 13.07.20	Fri 13.11.20	0%
173	EGIS Performance & Utilization Review	56 days		Mon 14.09.20	Mon 30.11.20	0%
178	EGIS User Experience Workshops	20 days	167	Mon 16.11.20	Fri 11.12.20	0%
184	EGIS Operational Handover & Initial Acceptance	0 days	183	Fri 18.12.20	Fri 18.12.20	0%
185	Phase 4: Support & Close-Out	163 days		Mon 03.08.20	Wed 17.03.21	0%
186	Upgrade EGIS to ArcGIS 10.8.1 (or UNGSC Redeploym	35 days		Mon 16.11.20	Fri 01.01.21	0%
196	Remote System Support & Additional Coaching as Req'd	45 days		Mon 04.01.21	Fri 05.03.21	0%
197	Final EGIS Documentation Preparation	45 days	195	Mon 21.12.20	Fri 19.02.21	0%
203	Final Acceptance and Handover	30 days	197	Mon 25.01.21	Fri 05.03.21	0%
207	Quarterly Progress Reporting	555 days		Tue 22.01.19	Fri 26.03.21	64%

Figure 2.3 – Example of a simplified SE-based work plan (OSCE SMM 2020)

E. MANAGING PROJECT RISK

One of the most critical functions of the project team is to manage risk, and to have contingency plans to mitigate the impact of various threats to its success. While there are various approaches to assessing risk and developing such plans, the overall goal should be to be as proactive as possible, by:

- Questioning planning assumptions by continuously asking 'what if <scenario> happens?';
- Constantly anticipating the impact of external events on the project, and having a plan to respond;
- Informing other stakeholders of identified risks and response plans, so that their expectations are realistic and calibrated;
- Establishing a team culture that promotes risk consciousness;
- Mitigating the impact of external dependencies on system implementation, so that even if the project team has limited ability to control them, these external dependencies have a minimal effect on the team's plan;
- Developing formal and informal contingency plans for all significant risk, including:
    - Procurement delays;
    - System failure and cyberattack;
    - Community lockdown / inability to come on-site;
    - Staff turnover / capacity constraints;
    - Delays that affect the float or critical path of your project (see Section 2.1D);
    - Funding shortfalls;
    - Changing user needs and requirements;
- Other organisational-specific approaches as appropriate.

While every member of the project team should be involved in managing uncertainty, it is the ultimate responsibility of the project lead to ensure that strategic, technical, financial, administrative, political, environmental, and human risk is constantly monitored and, whenever possible, mitigated through effective contingency planning and decision-making.

The project lead should constantly consider when and how to engage other stakeholders effectively in managing risk and in making decisions, and remember that there are typically four types of decisions: (1) unconscious decisions, (2) conscious decisions needing a quick answer, (3) conscious decisions needing a more extensive answer, and (4) extensive decisions needing full stakeholder participation. (SE-Training, 2020)

2.2 STAKEHOLDER CONSULTATION / USER REQUIREMENTS ANALYSIS

Even when the need for a new or improved IM system is obvious, it is important to invest the time in consulting the stakeholders of that system, to understand their needs and concerns. This is also an essential part of building a sense of ownership, or buy-in, for them to the proposed system when it is implemented.

As a first step, the process begins with mapping out all the various stakeholders inside and outside the host organisation. External stakeholders, such as donors, beneficiaries, and partner institutions, should also be identified and prioritised as part of this process.

Typically, a user requirements analysis involves a series of consultations, composed of presentations, brainstorming sessions, and open discussions across the spectrum of stakeholders. These consultations may be with individuals, small teams, or large groups, and are intended to inform the system requirements. Use cases define the individual functional requirements of the proposed system, and a sophisticated system may have dozens of unique use cases that represent the full scale of capability expected from the system.

The figure below shows an example of a use case worksheet for the GICHD's Enterprise GIS (EGIS) project in Ukraine. This worksheet defines the basic requirements for one specific functionality needed by the organisations's image analysts and was one of nearly 70 use cases prepared during the consultation process. A blank template of this worksheet can be downloaded from the following SE guide's resource website, at: https://www.gichd.org/en/seguide/

OSCE Organization for Security and Co-operation in Europe Special Monitoring Mission to Ukraine — **SMM EGIS Use Case Worksheet** — GICHD — esri

Date	Name of Lead User	Use Case Title (or Short Description)	Reference #
29-Jan-2019	Firstname Lastname	Rapid Access Archive of Observed Violations using Thumbnail Images	UC- IMC001

User Stories

1. As a Image Analyst, I want to quickly validate any prior observation, so that violations of the Minsk Agreement are always accurately reported.

2. As a Head of SMM's ITC Dept, I want to efficiently, securely store imagery data, so that the demand on ITC budget, personnel and infrastructure is manageable.

Actors / Roles / Responsibilities

1. IMC Imagery Analysts will be required to digital archive thumbnails of each violation as part of their observation reporting process.
2. ICT will be required to maintain and expand digital storage of data servers to ensure sufficient high-availability access to the archive.
3. ICT will be required to improve network performance to ensure timely archiving and recovery of imagery/video clips.

This Use Case is:

- ○ Required
- ◉ Desired
- ○ Optional / Not Urgent

Info Sources & Data Inputs

1. All Mid-mini UAV Images
2. All LR UAV Images
3. All Satellite Images
4. Associated metadata
5. Associated UAV flightpaths

Assumptions, Risks or Dependencies

1.This functionality would be for future observations only, and not pre-2019 iml

2. IT/Data storage capacity will be expanded as required by SMM.

Actions (Workflow / Process Map)

Step 1: Conduct Image Analysis as per SMM Standard Operating Procedures

Step 2: When a Minsk Violation is observed in any UAV/Satellite image, the analyst will save a thumbnail with all associated metadata, and hyper-linked to the relational database used to document such observations.

Step 3: If that observation needs to be re-examined in the future, the analyst can immediately access that thumbnail without requiring ICT to recover backup tape archives.

Step 4: If that observation needs to be compared with other within a specific geographic area or time period, all observations will be accessible within a few minutes of being requested from EGIS Image Server.

Output(s)

On-the-fly recovery of any archived thumbnail, in any supported file format, with all associated metadata including flight-paths and SMM's original violation report.

This capability should be accessible within the Observation Database environment, ideally with embedded links to the image thumbnails of observed violations.

A new reporting function for Validation of Prior Observations should allow the Imagery Analyst to officially confirm or change a prior observation record in the Database.

Relevant SMM SOPs

This is a new functionality (No Existing SOP)

List of References / Attachments

n/a

Data File Locations [and Formats]

Drive:\....\.....\....\ Weekly Imagery [JPEG, EXIF]

Drive:\....\.....\....\ . Satellite Imagery [GeoTIFF]

Additional Notes / Comments

Figure 2.4 – Example of a use case worksheet (OSCE SMM 2019)

Once all user requirements are documented as specific use cases, they are reviewed and approved by relevant stakeholders and then used to define the functionality of the proposed system. Chapter 4 of the guide describes the EGIS project in more detail, together with several other case studies featuring SE-based design.

INFORMATION MANAGEMENT SYSTEM FOR MINE ACTION (IMSMA)

Stakeholder consultations have shaped the development of the latest generation of IMSMA – IMSMA Core – and guided the design of everything from the underlying data schema to its various forms and dashboards.

The importance of stakeholder consultations continues each time IMSMA Core is deployed to a new organisation. Early in the deployment process, it is advisable to organise a stakeholder workshop. This is ideally a one-week gathering of representatives from the national mine action centre (NMAC) and other stakeholders, to determine the IM needs, requirements, and priorities. In addition, it is an opportunity to identify areas for improvement and standardisation which stakeholders can agree upon. To begin this process, first identify the broad range of stakeholders that need to be consulted. For example, an overseas donor might be interested in the number of square metres of cleared land, whereas a local NGO working in explosive ordnance risk education (EORE) might need information tools to prioritise and assess EORE activities.

At least one capable representative should be identified from each stakeholder organisation, through a process referred to as stakeholder mapping. This process identifies entities that are part of the mine action programmes and other relevant humanitarian / development actors, that represent those who use IM or could benefit from IM products supported by the NMAC. With each identified stakeholder organisation, map out their activities and identify candidates to represent each of them.

Encouraging diverse representation in terms of who is consulted will help ensure that different perspectives on information requirements are reflected. Those who conduct the work will always know in more detail what the processes and workflows are, and how these relate to their information needs and requirements. Examples of workflows and roles include:

- EORE – educators, coordinators, head of programme;
- Victim assistance – medical staff, field teams, coordinators, head of programme;
- Implementing partners – IM, field operators, coordinators;
- Donors – country liaison;
- Decision makers – government officials, NMAC officials, community leaders.

Identification and review of potential stakeholder representatives must occur in cooperation and active participation with the NMAC. Take note of and be sensitive to the cultural hierarchy in which you will be working.

Stakeholder pre-assessment

Once stakeholders are identified, prepare a questionnaire for them to fill out. This will offer a guide for them on what will be discussed in the workshop, as well as provide an initial understanding of stakeholder expectations. This pre-assessment must be done by all stakeholder representatives. Some may prefer to have different questionnaires for different stakeholders, such as technical, operations, and management. With IMSMA Core deployments it has been found to be effective to use a generic set of questions that serve to open dialogue and guide further conversations.

Suggested questions for a pre-assessment:

1. What are five key things you need information on to conduct your activities?

2. Are you currently able to get information on these five key things?

3. Do you currently use information / data provided by the IM service of the NMAC? If **yes**, check the items below:
    - Maps
    - Statistics
    - Information dashboards
    - Reports
    - Other (elaborate)

4. Where in your operations are these information / data products used?
    - How frequently are they used?
    - Are you able to easily access these when needed?
    - Is enough information provided? If **no**, what should be added?

5. What would you suggest could be improved?

6. On a scale of 1 (low confidence) to 5 (high confidence) what is your level of confidence in the quality of data?

7. Do you / your organisation currently submit data to the NMAC?
    - If **yes**: on a scale of 1 (inefficient) to 5 (efficient), how efficient is the data submission process?

8. Do you use survey forms provided by the NMAC? If **yes**, which survey forms do you use?

9. Do you conduct field data collection on mine action activities? If **yes**, please describe.

A. Gathering user requirements

Presentations

Prior to the workshop, advise each stakeholder that they will be invited to present their current, as well as proposed, way of working with information, and with the NMAC. This is an opportunity for them to show what their IM needs and requirements are, as well as what they hope the new IM system will achieve for them. Suggest they structure their presentation to include:

- Introduction of their organisation;
- Ongoing activities (including who is conducting IM in country and how);
- How data is submitted to the NMAC;
- How information / data is retrieved from the NMAC;
- Needs / requirements of stakeholders and the NMAC.

Together with the stakeholders, identify the users / roles within their organisation. In some cases, this will need to be done in collaboration with the NMAC. As the NMAC is typically the primary client for whom IMSMA is being deployed, make sure to always consult with them before any independent outreach to stakeholder groups.

User stories

In the stakeholder workshop, ask participants to identify types of users and each user's needs as part of an exercise. This will engage the stakeholders and encourage them to think in the framework of identifying and understanding users and their requirements. See an example of an exercise prompt for user roles / needs below. Throughout this engagement it is important to keep in mind the needs of related areas / sectors such as education, protection, health, and others. At the stage of defining user stories, it is again important to be sure applicable groups have a voice among the stakeholders.

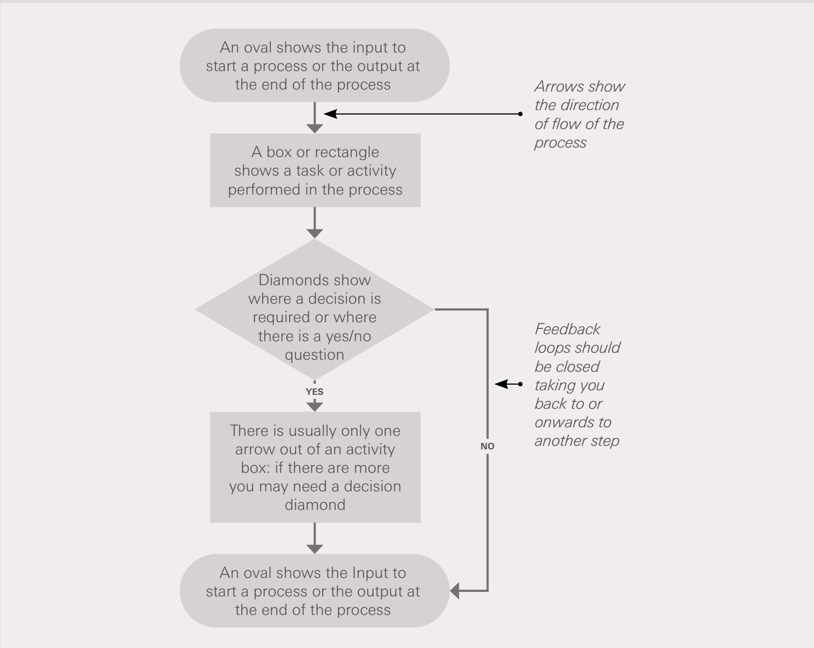
Identifying Users and User Needs

For this exercise choose a minimum of two types of Users (Actor/Role). Then identify the following:

1. As an (actor/role)___________
2. They need to know__________
3. In order to________________
4. To provide________________

Workflows and processes

In the stakeholder workshop, the exercise on workflows and process mapping will be key in showing stakeholders what information you will need from them. For this exercise, introduce stakeholders to the principles of process mapping and conduct a group exercise creating process maps of workflows for various activities in mine action relating to data and information.



Example of an introduction to process mapping visualisation

It is recommended to divide stakeholders into their user / role groups. For example, all EORE stakeholders in one group, land clearance operators in another. The best approach is to have them create a minimum of three process maps for three different roles within their thematic group. If time allows, ask these groups to continue making process maps for all users / roles in their focused theme. Continue to move through the groups, observing their progress and providing direction and clarification as needed. Remember, what they produce is what will guide your design approach. Ensure they are providing you with all the information you need during this process.

After the workshop is completed, request that stakeholder organisations (who submit data to, or use data from the NMAC) provide process maps or workflows specific to their organisation on where data is: data used from the NMAC (including forms), and data collected and submitted to the NMAC.

[Note: Work directly with a stakeholder organisation to get a clear mapping of their workflows and processes.]

B. Lead user engagement

It is important to keep stakeholders involved in the development process to gain their feedback and monitor whether solutions being developed are effectively addressing user needs and requirements.

Identify a lead user (or focal point):

- Identify focal points within each stakeholder organisation. Discuss with the stakeholder organisation who their lead user will be;
- Maintain regular contact with the lead user and ensure their satisfaction with the system requirements by providing regular updates on development progress and seeking their feedback.

IMSMA Core progress meeting:

- Hold a regular progress meeting with stakeholders and the NMAC;
- Review progress on development;
- Discuss road map / timeline of project;
- Any potential delays should be made clear to stakeholders in these meetings;
- Discuss stakeholders' feedback and / or concerns.

2.3 CONCEPT OF OPERATIONS

The completion of the stakeholder consultations and use cases should permit the development of a conceptual view of a proposed system. At a minimum, this includes a high-level block diagram showing the functional elements (or subsystems) that must be integrated, in order to achieve a set of clearly defined performance requirements or objectives, supported by sufficient narrative to enable the reader to clearly conceptualise the key elements of the system.

> *A concept of operations (ConOps) 'is a user-oriented document that describes systems characteristics for a proposed system from a user's perspective. A CONOPS also describes the user organization, mission, and objectives from an integrated systems point of view and is used to communicate overall quantitative and qualitative system characteristics to stakeholders.'* (IEEE, 1998)
>
> *A ConOps 'describes the overall high-level concept of how the system will be used to meet stakeholder expectations, usually in a time sequenced manner. It describes the system from an operational perspective and helps facilitate an understanding of the system goals. It stimulates the development of the requirements and architecture related to the user elements of the system. It serves as the basis for subsequent definition documents and provides the foundation for the long-range operational planning activities.'* (NASA, 2016)

The ConOps is needed in order to obtain preliminary consensus amongst all the stakeholders *before* committing to detailed systems design. In other words, it precedes – and once approved, it shapes – the development of the SRD. The SRD provides a comprehensive, technical explanation of a system based on user requirements which are identified during stakeholder consultations and represented by the concept of operations.

The process of defining use cases helps to describe stakeholder expectations. The ConOps should therefore include specific measures of effectiveness (MOEs), that can be employed to ensure satisfactory achievement of stakeholder expectations during the validation stage of system delivery.

MOEs are the measures of success designed to 'correspond to accomplishment of the system objectives as defined by the stakeholder's expectations. They are stated from the stakeholder's point of view and represent criteria that are to be met in order for the stakeholder to consider the project successful. As such, they can be synonymous with mission / project success criteria'. (NASA, 2016)

MoEs should also provide a results-based monitoring framework to assess the longer-term impact of any system. The need to baseline and monitor progress through indicators linked to outcomes and goals linked to a theory of change is essential, to provide an onwards diagnostic on implementation issues as well as providing evidence of the benefits of the investment in due course. Being able to demonstrate that more effective decisions taken, based on the improved system, saved time, money or lives, is highly relevant to senior managers, donors and others.

As illustrated in the figure below, the translation of user requirements into functional requirements, and then into the final design solution, is iterative – the project team must be willing to periodically test their progress against the ConOps (and if necessary, specific use cases) to ensure the final design of its system fulfils all of the criteria for success defined by its stakeholders.

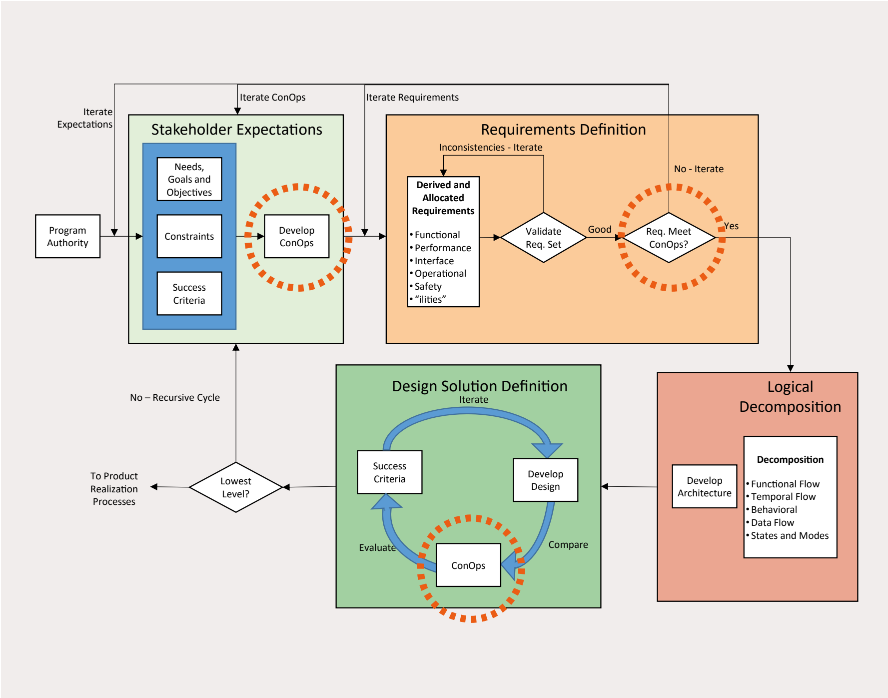


Figure 2.5 – Interrelationships between system design processes (NASA, 2016)

Once the ConOps has been reviewed and accepted by the stakeholders of a new system, the project team can proceed with the development of the functional requirements of that system, and then with the system architecture. At each step, the ConOps is consulted to ensure the ultimate design will meet user needs.

There are examples of how to draw a ConOps system diagram in the EGIS and SIATA case studies found in Section 4. These diagrams, combined with a short description of how each of the subsystems are expected to work, are sufficient to transition to the next stage of the SE design process – the functional requirements analysis.

2.4 FUNCTIONAL REQUIREMENTS ANALYSIS

In order to translate a ConOps into system requirements, an intermediate step – functional requirements analysis (FRA) – is employed to describe the system requirements from the host organisation's perspective. The FRA is a detailed, function-by-function description of how the system will ultimately satisfy its user requirements.

Ideally, the FRA should avoid favouring specific hardware and software solutions, and be as ambivalent to specific technologies as possible. For example, if an organisation requires a certain type of dashboard to be accessible to a group of users, the FRA should describe as clearly as possible the data, analysis and display formatting of the dashboard, and avoid referring to a specific commercial off-the-shelf (COTS) / software-as-a-Service (SaaS) solution that might bias or constrain the potential ways to achieve these functional requirements.

BENEFITS OF WELL-WRITTEN REQUIREMENTS

In the stressful, dynamic reality of almost any humanitarian emergency, following system design processes like FRA might seem like a luxury when people's lives are at risk. A hastily deployed IM system might be easier to justify than a properly-deployed system that takes more time to design and implement.

Employ a pragmatic approach, and balance good practices with the realities on the ground. When a proposed IM system involves significant user expectation and / or cost, there needs to be an equally significant commitment to ensuring its design will meet those expectations. When a system involves little investment and low user expectation, a correspondingly lower commitment to its design may be defensible.

For mission-critical IM systems, the effort invested in preparing well-written design requirements will reduce technical and financial risk and will improve the likelihood that user needs will be met. Such a system will be more effective, durable, and successful, and will be cheaper and less prone to delays. **Most importantly, once deployed, this system is more likely to be employed and supported by various stakeholders, since they will have been given the opportunity to contribute to its design.**

Benefit	Rationale
Establish the basis for agreement between the stakeholders and the developers on what the product is to do	The complete description of the functions to be performed by the product specified in the requirements will assist the potential users in determining if the product specified meets their needs or how the product should be modified to meet their needs. During system design, requirements are allocated to subsystems (e.g., hardware, software, and other major components of the system), people, or processes.
Reduce the development effort because less rework is required to address poorly written, missing, and misunderstood requirements	The Technical Requirements Definition Process activities force the relevant stakeholders to rigorously consider all of the requirements before design begins. Careful review of the requirements can reveal omissions, misunderstandings, and inconsistencies early in the development cycle when these problems are easier to correct thereby reducing costly redesign, remanufacture, recoding, and retesting in later life cycle phases.
Provide a basis for estimating costs and schedules	The description of the product to be developed as given in the requirements is a realistic basis for estimating project costs and can be used to evaluate bids or price estimates.
Provide a baseline for verification and validation	Organizations can develop their verification and validation plans much more productively from a good requirements document. Both system and subsystem test plans and procedures are generated from the requirements. As part of the development, the requirements document provides a baseline against which compliance can be measured. The requirements are also used to provide the stakeholders with a basis for acceptance of the system.
Facilitate transfer	The requirements make it easier to transfer the product. Stakeholders thus find it easier to transfer the product to other parts of their organization, and developers find it easier to transfer it to new stakeholders or reuse it.
Serve as a basis for enhancement	The requirements serve as a basis for later enhancement or alteration of the finished product.

Figure 2.6 – Benefits of well-written requirements (NASA, 2016)

The table above summarises the principal arguments in favour of formal SRD documentation. The development of this documentation includes a thorough analysis of system requirements, which begins with understanding its functional, physical and operational views.

A. UNDERSTANDING FUNCTIONAL, PHYSICAL AND OPERATIONAL VIEWS

The SE design process begins with the development of a ConOps, and then the decomposition of that system conceptualisation into functional, physical, and operational views. The **functional view** describes *what the system must do* to produce the required operational behaviour. It is exclusively motivated by user requirements, and not the availability of any potential commercial solutions; in fact, it should be agnostic of such solutions. This way, the functional requirements (in combination with the physical requirements shown below) serve as the primary determinant of the final system specifications. Functional view information includes:

1. System functions;
2. System performance:
   a. Qualitative (how well it performs, measured through user feedback and reported levels of satisfaction);
   b. Quantitative (how much it can perform, measured through system analytics);
   c. Timeliness (how often it can perform as expected, measured through availability metrics);
3. Tasks or actions to be performed;
4. Inter-functional relationships;
5. Hardware and software functional relationships;
6. Performance constraints (e.g. field workers without mobile data access, or unable to safely use certain technologies in active conflict zones);
7. Interface requirements including identification of potential open-system opportunities (potential standards that could promote open systems should be identified);
8. Unique (i.e. function-specific) hardware or software; and
9. Verification and validation requirements (see Section 3.6).

Once the ConOps has been used to derive the functional view of a new system, the project team can begin to decompose it into a **physical view**, to focus on *how the system will be constructed*. This will also define the physical interfaces between various users and equipment, and technology requirements. Physical view information would normally include:

1. Configuration of system:
    a. Interface descriptions;
    b. Characteristics of information displays and operator controls;
    c. Relationships of operators to system / physical equipment; and
    d. Operator skills and levels required to perform assigned functions.
2. Characterisation of users:
    a. Handicaps (special operating environments); and
    b. Constraints (movement or visual limitations).
3. System physical limitations:
    a. Physical limitations (capacity, power, size, weight, etc.);
    b. Technology limitations (internet bandwidth, power requirements, language, etc.);
    c. Database models and archives;
    d. Existing and legacy systems;
    e. Custom vs commercial-off-the-shelf requirements;
    f. Reusability and disposal requirements; and
    g. Legal or institutional policies / standards.

Finally, the project team must consider the system's **operational view**, or *what it will allow its users to do, and how*. This is not the same as the concept of operations, and is better understood instead as an operational concept, since it includes:

1. Operational needs definition;
2. System mission analysis;
3. Operational sequences;
4. Operational environments;
5. Conditions / events to which a system must respond;
6. Operational constraints on the system;
7. Mission performance requirements;
8. User and maintainer roles (defined by job tasks and skills requirements or constraints);
9. Structure of the organisation that will operate, support and maintain the system; and
10. Operational interfaces with other systems.

Adapted from (US DoD, 2001)

As shown in the figure below, the iterative decomposition of the user requirements into functional, physical and operational views also involves consideration of interfaces, or the boundaries between various internal and external elements that when working together create the desired system.

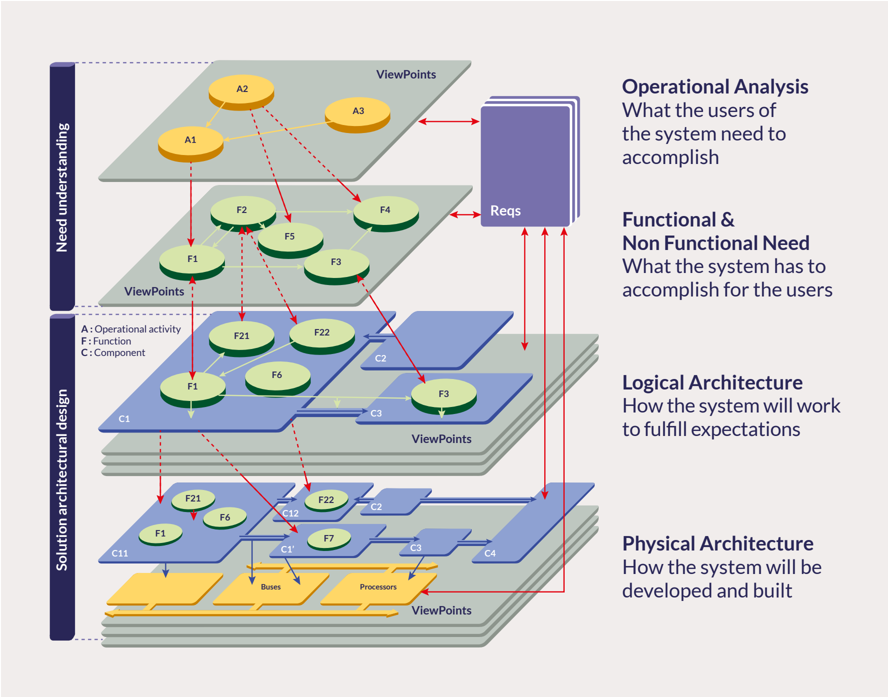


Figure 2.7 – Logical decomposition of system conceptualisation (PPI 2020)[4]

Map out the functional, physical and operational views of your proposed system *before* deciding what commercial or open-source solutions are advisable to prevent design or technology bias; user needs should always dictate the solutions employed, *not* the availability of any specific solution. Indeed, the drafting of the functional requirements should exclude solutions providers, who should be engaged only once it is time to design the system requirements (see Section 2.5).

The exception, of course, is when an organisation has already invested in a particular technology which must be employed to achieve as many of the functional requirements as possible. This is not ideal but also not unusual, and the skilled project team will maintain an open mindset when forced to accommodate an existing technology platform.

4 https://www.ppi-int.com/ppisyen70/

B. DATA & LEGACY SYSTEMS CONSIDERATIONS

You may have noted that existing database and legacy systems are important physical view considerations if they need to be replaced by – or connected to – a new system. Almost every organisation must deal with how to rebuild or migrate their existing capabilities to an upgraded system. This is an essential activity during the functional requirements design phase, as it forces the project team to consider important questions such as:

- Should we retain the data model that organises our current database, or is this the time to re-engineer our data model to support future IM systems growth?
- Do we need to migrate data archives to the new system's database, to permit longitudinal or big data analytics as well as rapid recovery of historical data?
- Can our current hardware continue to meet the performance requirements of the new system, should we upgrade our local infrastructure, or should we move to cloud-based hosting solutions?
- Are there application programming interfaces for external systems that need to interface with the new system?
- Can our legacy system meet user requirements without being replaced? If so, are there other reasons which might justify replacing it versus retaining it within the new system architecture?
- Is the legacy data suitable for use in the new system? Does it pass the fit-for-purpose tests to justify migration of the legacy data to the new system, or do we need to migrate selected data records and attributes only?

As you can easily imagine, a careful and comprehensive analysis of all of an organisation's relevant databases and legacy systems is a prerequisite to finalising the functional design of a new system. Your project team should engage existing users of those databases and systems, as well as potential solution providers if required, to prevent mistakes, oversights or false assumptions creating points of failure in the final design of your new system. Section 3.1 below explores data and legacy systems in further detail.

C. PERFORMANCE

To determine the optimum system architecture, it is necessary to clearly specify its performance targets using a set of measurable, objective indicators. If performance specifications aren't defined at the functional design stage, the project team cannot be certain the system will support key factors such as:

- Response time (latency, or user wait times for each process or interaction with the system, at various times of the day);
- Workload (processing time, or throughput, at various periods of the work cycle);
- Scalability (ability to grow to support usage and technological advancement over time);
- Availability (percentage on time, or recovery time objective in case of system failure or breach, where high availability systems involve additional investment in redundant infrastructure in order to minimise the risk of system failure);
- Data resilience (acceptable loss of data, or recovery point objective in the case of a system failure or breach);
- Security (user authentication protocols, authorisation / accessibility protocols, external and internal threats and sensitivities, etc.).

These are often referred to as non-functional requirements. Consideration of both functional and non-functional performance requirements will help you to define system attributes based on your stakeholder consultations, and to ensure that system security, reliability, performance, maintainability, scalability, and usability aren't overlooked in the design process. For most organisations, this could result not only in non-compliance with legal and policy requirements, but unacceptable outcomes once the system is deployed.

2.5 SYSTEM REQUIREMENTS DEFINITION

The final step in the design process is to convert the functional requirements definition into a detailed, technical vision that can be implemented by the project team. In other words:

> *The purpose of the System Requirements Definition process is to transfer the stakeholders, users-oriented view of desired capabilities into a technical view of a solution that meets the operational needs of the users.* (ISO/IEC/IEEE 15288, 2015)

Up to now in the system design life cycle we intentionally refrained from discussing specific commercial or open technology solutions. In the system requirements analysis, we research, compare, select, and decide how to integrate specific technologies to achieve the stated functional (and non-functional) requirements. Then, the process of implementation is defined in a detailed work plan that includes a final budget as well as a clear assignment of roles and responsibilities. And lastly, the SRD includes the minimum criteria with which system acceptance will be verified. [Note: *validation* is based on the ConOps, but *verification* is based on the SRD's criteria as indicated in table 2.1.]

Although every SRD will be unique, it is helpful to consider the following points before deciding how your project team should structure its SRD documents:

- Market analysis – even if the project's sponsor has identified a specific type of solution prior to launching the project, it is still advisable to survey various open-source, COTS and SaaS options before determining how best to meet the system requirements. An updated understanding of these options often increases the confidence that the proposed system reflects the best possible approach to achieving its defined – and undefined / future – requirements.

- Research & development (R&D) considerations – although it is unlikely that a significant amount of R&D will be feasible in the context of an urgent humanitarian IM systems deployment, take a moment to identify opportunities or challenges that may justify such an effort, either internally or by a partner institution that specialises in the area(s) of the proposed R&D.

- Cost analysis – system budgeting should include procurement, operational costs including maintenance of software, hardware, communication services and databases. Cost analysis should also include initial and ongoing user training, security, continuity of operations, and contingencies.

- Verification criteria – while the measures of effectiveness define the criteria for meeting stakeholder expectations, and were included in the ConOps, measures of performance (MOPs) define a system's operational performance requirements. MOPs are derived from the MOEs, and reflect the technical, quantifiable, and measurable system characteristics deemed necessary to achieve the more qualitative MOEs (NASA, 2016).

- Data management – for most humanitarian organisations, the collection, storage, maintenance, and access of data in a secure, efficient, and reliable manner is a core challenge, and a primary objective of adopting a new IM system. The SRD should address this matter thoroughly. Data modelling, archive migration, metadata (information about each data file), and data recovery / resilience are essential considerations in any new IM system design.

- Subsystem approach – a well-structured SRD will describe a complex system architecture using the system of systems model proposed by the ConOps. The technologies and integration of various subsystems (data generation, storage / management, analysis, display, communications / reporting, etc.) can still be used to ensure that the SRD is a useful, navigable document. The reduction of systems into subsystems helps to simplify and explain how a broader vision will be achieved, on time, on budget and within scope.

- Partner engagement – the functional requirements definition is intended to communicate the operational what of a system, and the SRD should provide the technical how, when and how much of that system. Very few humanitarian organisations have the internal expertise to develop their SRD without engaging system integrators, equipment suppliers and other external service providers. These partners may be selected because of historical relationships, trusted referrals, commercial marketing or open bids (request for proposals).
- Tasking and scheduling – each activity can be broken down into tasks, or work packages. These are basic elements in the WBS that show the hierarchical order of work needed to complete the system. This chronological approach to developing the WBS guides the development of the cost breakdown structure, which identifies the cost for each stage of the system life cycle. Collectively, the project management professional completes these activities in order to understand the life cycle cost of the system, and to schedule associated resources.

The approach described in this section may seem overwhelming or even excessive to some readers. You may have thought, 'We're not launching rockets into outer space or developing a nuclear power station, we just need a better way of managing our information, and we need it now!' The level of investment in the design and planning of a project is always contextual, and every organisation needs to consider its system requirements, given its realities. Be assured that an effective SRD doesn't need to be a thousand-page document – it can be a short, precise document of just a few pages, particularly for a standard deployment of a COTS / SaaS-based system that presents little risk or cost for an organisation. It will obviously need to be more robust for a system of systems involving complex integration of a wide range of functionality at significant cost. Take the appropriate amount of time to consider what level of effort should be invested in defining system requirements before you begin system implementation. The next section provides some important strategic considerations for implementation.

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CHAPTER 3 – IMPLEMENTATION STRATEGIES

Once the design of a new information management (IM) system has been approved by stakeholders, it is time to implement the system. In some cases, a new system will replace one or more existing (legacy) systems and may therefore require the migration of original data and functionality to the new system. In other cases, an organisation may have very little existing data, software, hardware, or processes that are relevant to a new system.

This chapter describes key considerations in data and legacy systems migration, and then explores the sequence of activities that characterise the deployment, validation, and delivery of a new system.

3.1 DATA AND LEGACY SYSTEM MIGRATION

Humanitarians and members of peace missions rely on the use of different application software to fulfil daily tasks and reporting. These usually include Word documents, Excel spreadsheets, Outlook emails, Adobe Acrobat files and readily available software. With access to fast internet connectivity, organisations can also use cloud-based digital platforms such as Google Drive and Esri's ArcGIS Online that allow easy sharing with others and, for basic use, do not require a complex setup. Medium and large programmes lean towards using custom-built or configured software, tailored to service their operational demands, and that standardise workflows.

Technology constantly evolves. Software requires maintenance and upgrades to keep up with security standards, operating systems, new hardware, and changes to systems it may interact with. Sometimes, replacement with a new system is more fitting and cost effective than maintaining applications and systems built using outdated technologies.

Many organisations cannot update or adapt new systems and the reason is not only the cost of developing a new system, but the high level of complexity of migrating historical data to the new system. Data does not have a price tag as its use defines its value. Losing data can lead to noticeable financial and reputational damage for an organisation and means interruption to its work. That is why it is vital for stakeholders to have full access to their historical data even when using a new system.

From an information management perspective, we use the term ‘migration’ to describe the moving of data and processes from one locality (system) to another locality (system) and integrating the historical data in the new system environment.

The migration process requires a successful transfer of the data, information, processes, and business logic to the new system. To maintain accuracy of and credibility in the system, it is critical to ensure that no data is unintentionally lost or incorrectly changed during this process.

A failure in migration is a failure in new system implementation. Legacy and new systems should only run in parallel until the migration process and testing has been completed, after which the legacy system must be decommissioned and properly backed up in case it needs to be inspected later.

We can complete a successful migration in a consolidated one-time effort, or we can divide it into different stages as the development of the system progresses. Start by migrating parts of the system for certain operational divisions, as long as it does not affect the whole of the IM system. This will allow you to start using the migrated components and benefit from the new system sooner. There are various factors that affect migration, and these include:

1. **Time:** system migration is time consuming, regardless of the system formats and the skilled resources available. Copying data from one table to another is fast, but the validation of the data requires a considerable amount of time, and an ill-prepared migration can hide data issues until much later in the process, requiring a considerable amount of extra work at later stages.

2. **Technical differences**: systems generally don't communicate well with each other due to the different technology platforms in use, and thus require regulations or protocols that standardise and govern the communication process between the systems. Defining the use cases, or business logic, of the new system allows you to define test cases for the new system and compare the results with the old system to ensure a successful data migration, and that the new system delivers accurate and reliable output.

3. **Technical resources**: we cannot implement a migration without having the proper technology and human resources in place. A system migration requires a lot of technical knowledge of both the old and the new systems. It requires an understanding of the functionality, technology components, end user requirements, testing procedures, etc., and in certain situations requires advanced programming skills. It is important to collaborate with experts in your team, project, or peer group and exchange knowledge and experiences, sharing different solutions, in order to identify the most effective solution for the migration by having the right resources in place.

4. **Training:** during the migration, we will see the first signs of user acceptance and resistance. Many features designed in the system will differ from the way it was implemented in the legacy system due to improvements in end user interface design, technology changes and even the development of new digital platforms. This creates what appears as a shift in the business logic when migrating existing processes to the more efficient new system, as the implementation of the business logic differs from the legacy system. Training helps to mitigate user resistance by providing explanations for the improved implementation of the business logic and speeds up the adoption process. Resistance to change is normal behaviour, but by identifying and demonstrating the reasons for and benefits of the changes, we will lower user resistance to the adoption of the system; this helps users adapt to the new processes and to overall acceptance of the new system by the user. In addition, training increases the level of trust in the new system by providing users with the knowledge and skills required to effectively use the new system and by indicating the gaps existent in the legacy system, and how they are addressed in the new system.

5. **User validation and acceptance:** a new system will either replicate the legacy system functionality and produce output faster, or extend the legacy functionality. It is therefore important to ensure that we confirm that we do not lose functionality or data in the migration to the new system, unless it is explicitly required and defined in the system design process. User acceptance testing is the final step in ensuring that we have developed the users' skills sufficiently in using the new system effectively and, through the test cases, ensures that we have covered all the functionality required of the new system. In a phased approach, we apply the test cases and user acceptance testing following the migration of each component to ensure that the new component works as needed before moving to the next component. The different components will likely have an impact on each other during the migration process, so it is wise to conduct a final user validation and acceptance test to confirm that the migration process has been completed successfully and that all components interact as required.

6. **Data fitness for purpose:** before migrating legacy data to a new system, consider its fitness for purpose and its quality. Fitness for purpose is the affordance of data to be interpreted and used in a context that permits its effective usage. Data quality is the discrepancy between the fitness for purpose of optimal data versus actual data – quite simply, how closely the available data resembles the theoretical ideal of that same data. (Mocnik, Fan, & Zipf, 2017)

   There are six dimensions to data fitness:

   1. Completeness: the proportion of data that is captured and stored against the potential of 100%;
   2. Correctness: the degree to which the data is 'true';
   3. Timeliness: the degree to which the data represent reality from a required point of time;
   4. Uniqueness: refers to data that must not lose their unique field values (such as victim or employee records, village identifiers, etc.);
   5. Validity: the degree to which data conform to the required format, type and range (also known as syntax);
   6. Acceptability: the degree to which data is acceptable to end users and stakeholders (perhaps the most important dimension!).

3.2 INFORMATION TECHNOLOGY CONSIDERATIONS

There are several questions which must be answered when determining how to satisfy the requirements of a new IM system: what is the right package (hardware and software) for my project? Which software, hardware, and mobile devices are best suited for the purpose? Is an on-site platform needed or should it be cloud-based? Should a stand-alone app or software suite be used? Should open-source or commercial off-the-shelf (COTS) software be used? Should an on-premises installation be used, or would it be better to subscribe to a cloud-based Software as a Service (SaaS) solution?

WHAT IS OPEN-SOURCE SOFTWARE?

Open-source software is software that freely shares the underlying source code so that anyone can inspect, modify, and enhance it.

(Adapted from opensource.com)

BUY VS BUILD

Should we buy the system and adapt it to our needs, or should we develop it? Buying may seem preferable in many cases, however there is no guarantee that COTS or open-source solutions will satisfy your functional requirements. The cost of buying and then configuring such systems can be significant, especially when there are unique or highly specialised requirements. Maintenance and administration can also be challenging, especially with poorly supported non-commercial packages. The alternative to buying an existing solution also needs to be carefully considered, since the risk and cost of building custom solutions can be even more formidable for most humanitarian organisations.

COST

Software procurement is not the only factor that determines the total cost of ownership of a system. It is necessary to also consider the procurement of hardware (stand-alone computers and servers, storage, security systems and infrastructure), labour (staff costs are a major consideration and escalate rapidly when on-premises infrastructure is run well), training and maintenance (planning for disaster recovery, securely, keeping up to date with patches, monitoring, etc.). Staff costs are typically the greatest expense until the scale of enterprise systems overshadow human resources. In humanitarian contexts, where IT staff capacity is typically limited, it is important to consider whether on-premises (local) systems can be managed effectively; if not, the organisation could become exposed to security vulnerabilities, data loss, and system unavailability. A full explanation of calculating total cost of ownership is beyond the scope of this guide but many resources exist on this topic. A good introduction is at https://www.cio.com/article/3005705/calculating-the-total-cost-of-ownership-for-enterprise-software.html.

CLOUD-BASED VS ON-PREMISES SYSTEMS

Before exploring the merits of employing cloud-based versus on-premises (locally-hosted) systems, it is important to clarify that there are different models of cloud computing. For example, some cloud providers give access to their already deployed software and applications, for example ArcGIS Online. In this case, we refer to the cloud service as Software as a Service. Others provide software and hardware that serve as a foundation to build upon and we refer to this type of cloud as Platform as a Service. Another type of cloud service is Infrastructure as a Service, which provides flexible access to remotely-hosted computing infrastructure with servers, operating systems and storage to build upon. Lastly, there are other cloud computing models that pair with locally installed systems. Each option has its own advantages, characteristics and limitations. Some of the largest commercial providers include Amazon Web Services, Google Cloud Platform, and Microsoft Azure; each offer a mix of Software, Platform and Infrastructure as a Service.

Let us consider some noticeable features between on-premises and cloud systems.

Connectivity

Cloud-based systems provide on-demand access with real-time communication for teams and project management in different locations regardless of the distance. This requires having reliable and high-speed internet access. An on-premises system will probably not provide that level of accessibility to those without direct access to the in-house network. Allowing external access to an in-house network requires a stable internet connection and establishing a secure access method such as a virtual private network. A cloud-based system provides on-demand access as well as real-time communication for teams, but loss of physical control over equipment. It also offers the possibility of administration from different locations. Internet connectivity and bandwidth are critical considerations when using a cloud-based provider, since users working in environments that have unstable internet access, limited bandwidth or a total lack of access in the field, will need to be able to work while disconnected from cloud-based services.

Scalability

Upgrading a cloud server is just a matter of a few clicks and maybe a restart of the server. Upgrading disk space, memory, CPU capacity and bandwidth is relatively easy, fast, and requires no actual installation of hardware. The major cloud service providers offer control panels that allow system administrators to manage and monitor their instances (servers). Alternatively, when using on-premises servers, upgrading the disk space, memory or processors requires buying the right hardware, installing it and mounting it in the intended machine. It requires knowledge of the hardware and operating system in order to successfully achieve the required result. There is also the risk of compatibility and availability issues with regards the hardware, especially in hard-to-reach areas.

Security

If there is a need to control and limit access to certain users of the system, a stand-alone option is very secure, by installing the system in your premises and allowing individual access through secure machines, especially if it is not connected to the internet. Alternatively, many cloud-based systems provide robust security, maintained by extensive teams of staff with specialised skills. Large cloud providers invest heavily in their system and security. It is important to recognise the fact that an on-site system requires ongoing access for skilled staff to ensure it is properly patched, upgraded and maintained, to stay up to date with security threats and vulnerabilities.

In the following table are some cost drivers for on-premises and cloud systems.

ON-PREMISES	CLOUD-BASED
Capital expenditure typically required to obtain the assets (hardware and software).	Low initial expenditure (operational expenditure vs CapEx).
Fixed monthly cost.	Variable monthly cost.
Off-site backups have a cost implication.	Off-site backup cost is comparatively low.
Increased maintenance and operational costs related to power consumption, system backups (if on-site), IT staff, etc.	Relatively low operational costs as provider supplies IT staff, the pay-per-use model, lower / shared power consumption.
Cost of maintaining skilled IT staff to ensure a secure system is a considerable expense.	Competent IT staff supplied at comparatively low cost due to economies of scale and included in monthly fee.

The shift towards cloud computing picked up rapidly from around 2010. By 2020, the majority (60%) of servers sold were to cloud providers rather than to individual organisations for use in their own data centres. (Carey, 2021)

To summarise cloud versus on-premises considerations:

- Cloud tends to be advantageous for cost, uptime, scalability and ease of use;
- On-premises tends to be advantageous for localised control.

OTHER CONSIDERATIONS

Beyond the choice between buy vs build system, open source vs commercial, on-premises vs cloud and cost considerations, other points are also important to keep in mind when choosing the right system for your needs.

Accessibility

There is the question of accessibility regarding otherwise enabled people (reading, typing challenges), as well as cultural barriers and preconceptions regarding system usage and the diversity of system user groups (such as gender, age, literacy and education level, language, and symbology use).

Support

With any system, support will be needed at some point. It will usually be a mix of in-house staff and technology provider support, depending on the complexity of the issue. Proprietary systems will usually have a defined support mechanism in place, but open-source systems may or may not have an active community that can help. In either case, it is necessary to have in-house capacities to at least help with the implementation of solutions.

Localisation and geographic reach

When choosing the right technology, it is necessary to think about the localisation of the implementation. Indeed, some programmes may not be available in some parts of the world or may not be used (and thus harder to implement). Furthermore, technologies have different capacities in adapting to different regional and national contexts. These may include being able to integrate different character sets, time zones, currencies, data formats, language translations and even different printing paper sizes.

Transferability and interoperability

Most of the time, the data that you input into a system will be needed in other systems. You want to be able to easily transfer data between platforms, systems and even between different institutions. The feasibility and cost of transferability is crucial to consider when choosing a system.

3.3 SYSTEM RISK MANAGEMENT

Managing system risk begins with identifying all the possible risks involved in the development, deployment, use and failure of the system, and then developing suitable responses to these risks. The responses may be pre-emptive so that we remove or reduce a risk, or may consist of one or more steps to take when something goes wrong. To manage the risk effectively, we need to identify the risks with our stakeholder group, determine the impact that each risk will have for the different stakeholders and then identify the steps needed to mitigate the risk. An adverse event such as the loss of access to the system may have different levels of impact on different stakeholders, so we need to tailor our responses accordingly. Potential positive events such as increases in project staff or funding need to be considered as well, to ensure that we identify all possible sources of uncertainty related to the project and can plan for them.

The risk assessment needs to include all the system components, including the system environment, with detailed attention given to protecting the data we are using in humanitarian responses, as misuse of the data could endanger the population. The extent of a risk assessment needs to match the size of the project and can range from a simple matrix as shown below, to a dedicated team project with multiple documents.

LOW	MEDIUM	HIGH	EXTREME
• Acceptable • Ok to proceed	• As low as reasonably practicable • Take mitigation measures	• Generally unacceptable • Seek support	• Intolerable • Place event on hold

LIKELIHOOD	SEVERITY			
	ACCEPTABLE *Little to no effect on event*	**TOLERABLE** *Effects are felt, but not critical to outcome*	**UNDESIRABLE** *Serious impact to the course of action and outcome*	**INTOLERABLE** *Could result in disaster*
IMPROBABLE *Risk is unlikely to occur*				
POSSIBLE *Risk will likely occur*		Inability by NMAA to maintain the OS	Unauthorised system access Improper system maintenance	Data loss System failure
PROBABLE *Risk will occur*		DB schema change after data ingestion	Continued system changes	

Figure 3.1 – Risk assessment matrix

The International Standards Organization provides widely-employed risk assessment techniques and offers the following risk assessment process:

1. Plan the assessment – define the purpose and scope of the assessment, understand the context of the assessment, engage with stakeholders, define the assessment objectives, consider the human, organisational and social factors that impact the project, and lastly, review the criteria for the decisions taken.

2. Collect and analyse data and develop a model reflecting the project environment.

3. Apply risk assessment techniques – identify risk, determine sources, causes and drivers of risk, investigate the effectiveness of existing controls, understand the consequences and likelihood of the risks, analyse interactions and dependencies, and lastly, understand the measures of risk.

4. Review the analysis – verify and validate results, conduct uncertainty and sensitivity analyses, carry out monitoring and a review of the risk and assessment.

5. Apply results to support decisions – these are decisions about the significance of the risk, and decisions that involve making a selection between options.

6. Record and report the risk assessment process and outcomes.

Refer to (ISO/IEC 31010:2019) for a collection of techniques to apply in the risk assessment, ranging from brainstorming to surveys, checklists, scenario analysis and many more. There are numerous techniques available for conducting a risk assessment, but again it is critical to ensure that the assessment scope and detail match with the size of the project to ensure the effective use of resources and management of risk; a small project, therefore, does not warrant a 3-month risk assessment and neither does a multi-year project deserve a two-day risk assessment.

The risk management plan must clearly communicate the risk, associated impact and the responses that will be activated, along with the response time, so that stakeholders have a clear understanding and realistic expectations of the mitigation measures. It is important to balance the costs of the mitigation measures with the financial and / or operational impact of the risk. For example, it could be decided that up to 15 minutes of access issues per day, due to internet connectivity loss in the field, does not warrant the deployment of alternative internet connections at all field office locations, as this additional cost will not be outweighed by the loss of productivity.

3.4 FUNCTIONAL DEPLOYMENT

A new system's functionality, originally defined as individual use cases and then deployed in the form of requirements, should be iterative, graduated and targeted to specific user groups. That is, a smaller test group of volunteers should be identified and engaged through the deployment cycle, to debug and improve functionality before it is gradually rolled out across an organisation.

Deployment of each subsystem will involve significant overlap with legacy systems, which may need to be employed in parallel until user confidence allows for full cutover. Create multiple communication channels for users to provide feedback during deployment – some will prefer ad hoc emails, others pop-up survey forms, and others in-person meetings / workshops.

Be disciplined whenever there may be a need to deviate from the system requirements definition, since changes after their acceptance can have significant risk to the overall success of the new platform. And be sure to implement and follow a change control process to ensure that any deviations from the approved requirements are reviewed carefully before being adopted. Quality assurance processes (ISO/IEC/IEEE 15288:2015) will guide implementation, a key part of the life cycle of a new system, and should involve checklists, audits and root cause analysis (as required) until the system is fully operational.

Track usage patterns to see if the system is used to its full capacity, but ensure that your organisation acts on the insights gained from the analytics to ensure that the system adds value to the organisation. (Marchand & Peppard, 2013) Use a development environment in custom development, where the development environment fully replicates the production environment, to reduce issues arising from differences between the two environments.

3.5 ORGANISATIONAL CHANGE MANAGEMENT

The decision to introduce a new system should be driven by organisational stakeholders who will benefit from it. The decision should not be made solely by technologists or systems engineers who would then need to 'sell' it to users.

Because systems engineering engages stakeholders very early in the design process, they should feel a sense of ownership when the system is finally implemented. Nevertheless, there is always going to be some resistance to change, especially when major leaps in the use of technology are involved. Therefore, sustained engagement with department managers and senior leadership across an organisation is essential to (a) ensure consistent messaging about the implementation and operational use of a new system; (b) address stakeholder concerns; (c) deliver user-specific and general training; (d) encourage, collect and apply user feedback; and (e) minimise disruption at each stage of implementation.

Systems engineers should actively engage human resources (HR) management throughout their projects. For example, a new system may require an initial orientation and regular training / re-training of employees. Unless these employees are contractually obliged to complete the training, a new system becomes vulnerable to (a) the opting out of intended users, and (b) misuse due to skills deficiencies of users.

HR departments are the entry point of new personnel to an organisation; if the standard protocol for new employee orientation includes a mandatory type of systems training, it will ensure that a new system does not become vulnerable to staff turnover / attrition over time. Engaging with organisational stakeholders at the onset of the process ensures the buy-in of the different stakeholders and helps them take ownership of the development and implementation process, which reduces the resistance to change that is inevitably encountered with all organisational changes. It is imperative to outline the common goals of the new system and distinguish the benefits that will be realised by each stakeholder or group of stakeholders (user types) so that they have a clear understanding of the reason for the change. This eases the change from the current state to the desired end state.

3.6 VERIFICATION AND VALIDATION TESTING

As explained earlier in this guide, verification is the process of confirming that a system (or a system element) fulfils its specified measures of performance (MOPs), whereas validation is the process of confirming that it fulfils stakeholder needs in an operational context according to specified measures of effectiveness (MOEs). Verification can be performed by objectively testing MOP criteria included in the system requirements definition, whereas validation may be more subjective, and therefore require an independent assessment of user satisfaction as defined by the MOEs. A peer group selected from operational users at various levels of seniority can be an excellent strategy to validate a system once it has been deployed.

The process for acceptance testing will be dictated by the system requirements documentation, and any modifications that may have occurred since the completion of the design phase.

3.7 FINAL DOCUMENTATION

One of the greatest strengths of systems engineering-based design is its disciplined approach to documentation. Whilst it doesn't necessarily need to be excessive or too onerous, documentation should ensure a sufficient record of the design and implementation decisions, acceptance criteria, as well as initial operations guidance. The system design and implementation documentation should include some or all of the following components:

- **Concept of operations**, providing a high-level description of the system;
- **Functional requirements definition**, containing the functional and non-functional requirements as well as use cases / user stories identifying the implementation of the required business logic;
- **System requirements definition,** that may include a:
    - **Detailed deployment plan** for each subsystem of the overall solution being deployed or integrated;
    - **Data migration plan** with the data structure for the legacy and new systems, as well as the data field mappings and migration test cases;
    - **Work breakdown structure work plan** with task scheduling and resource assignments;
    - **Budget** with contingencies for life-cycle costing;
- **Verification acceptance criteria** (quantitative measures of performance) based on operational technical requirements;
- **Validation acceptance criteria** (qualitative measures of effectiveness) based on stakeholder requirements;
- **Security and risk management plan**, with specific and general strategies to achieve the performance criteria established by the system requirements;

- **Recommendations for future enhancement**, to capture any desirable research, development and functionality that was identified during the design process but that was excluded in the current system requirements;
- **System user guide** for front-end users and administrators;
- **Data management and system management guides** for administrators;
- **Continuity of operations plan** for incident responders and administrators.

3.8 CONCLUSIONS

This guide has hopefully provided the reader with a broad understanding of how to apply systems engineering within the context of humanitarian information management. The design and implementation of systems in complex environments is challenging even for the most seasoned IM specialists: an SE-based approach ensures sufficient stakeholder ownership of those systems, as well as robust stakeholder satisfaction in those systems.

Chapter 4 provides a number of case studies which show how the tools and methods outlined in this guide have been used around the world.

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CHAPTER 4 – **CASE STUDIES**

4.1 SISTEMA DE ALERTA TEMPRANA DEL VALLE DE ABURRÁ, COLOMBIA

PROJECT CONTEXT

The decades-long armed conflict between the Revolutionary Armed Forces of Colombia and the Colombian government forcibly displaced millions of citizens throughout the country. Some seven million Colombians (approximately 15% of the total population) became internally-displaced persons (IDPs); many sought safety in peri-urban slums, like those which climb up from the steep valley that cradles the city of Medellín. Not only did IDPs flee from rebel-held areas in remote jungles, but also from drug-related violence, which by the early 1990s had made Medellín one of the most dangerous cities in the world.

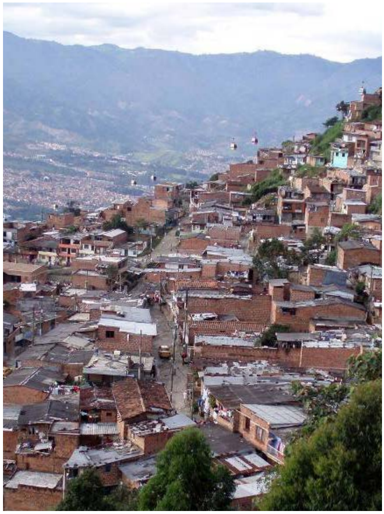

Figure 4.1 – View of Santo Domingo, Medellín (© Firoz Verjee)

The valiant effort to break the grip of local drug lords – as well as to negotiate a peace accord with the rebels – began to show promise in the early 2000s. The proud, industrious people of Medellín were keen to start a new chapter in their history, and quickly began to promote the disaster resilience, environmental quality and economic development of the region. Local authorities recognised that improved environmental awareness and natural hazard forecasting was going to be key to addressing the socio-economic vulnerability of local populations and, therefore, to sustaining the long-term conditions for peace.

Figure 4.2 – Aftermath of flash flooding in Medellín (© Firoz Verjee)

In 2007, at the request of the regional government (AMVA, or Área Metropolitana del Valle de Aburrá), the US National Weather Service (a part of the US National Oceanic and Atmospheric Administration, or NOAA) began to design an integrated early warning system to improve the health and safety of at-risk populations, and to promote the economic development of the region. The design goals of the Aburrá Valley Natural Hazard Early Warning System (AVNHEWS, and now known as Sistema de Alerta Temprana del Valle de Aburrá, or SIATA) were to:

1. *Promote* peacebuilding and disaster-resilient development;
2. *Reduce* the loss of life and suffering caused by floods, flash floods, debris flows, etc.;
3. *Enhance* water reservoir management practices related to hydro-energy production;
4. *Improve* local weather forecasting;
5. *Monitor* air quality, and promote respiratory health; and,
6. *Inform* local research, development and education.

In close consultation with local project stakeholders, NOAA defined and then used these goals to design an integrated information management (IM) solution using a classic systems engineering (SE)-based approach. The deliverable was a concept of operations and system requirements document, which would then be used by a consortium of public authorities, private companies, academic institutions, and civil society organisations, to procure, configure and operate within three years. The long delivery time frame was needed to procure and install modern weather radars, computer infrastructure, environmental sensors, and other technologies, and to complete required staff training and institution building.

The figure below details the sequence and timelines of the design and building milestones.

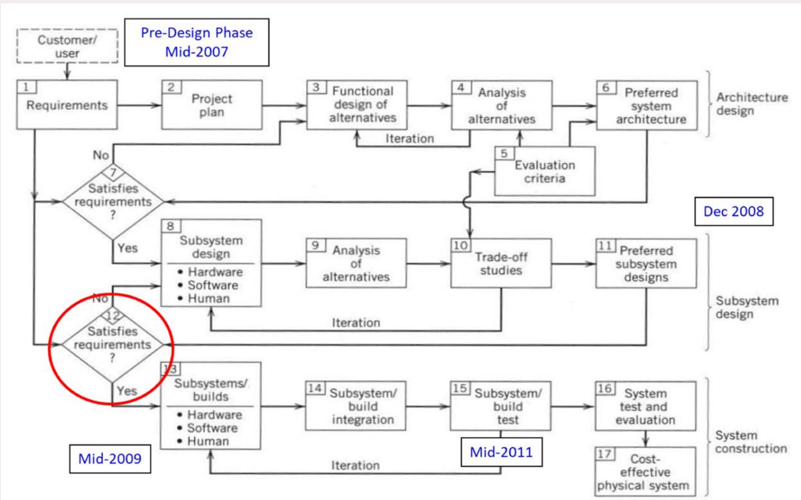

Figure 4.3 – A systems-based approach (source: NOAA)

The project began with a pre-design process, which then guided the development of a detailed design of the main system and each subsystem. The resultant concept of operations (ConOps) and system requirement definition (SRD) were then employed to build, commission and operate SIATA.

A decade after it became operational, SIATA is a remarkably successful example of SE-based design. New subsystems have recently been added to the original system design, allowing stakeholders to:

1. *Monitor* seismic events and support earthquake research;
2. *Manage* wildfire risk; and
3. *Develop* locally-engineered sensor technologies, with a view to commercially producing and exporting these technologies to other regions of South America.

SIATA provides an inspiring example of how the systems-based approach has been used to design an IM system in a peacebuilding / post-conflict context. Here is a brief summary of the strategies employed by the project team to lay the foundations for SIATA's success:

Pre-design concept planning – when NOAA's expertise was initially requested by AMVA, the project requirements were not specific enough to begin detailed design of the desired system. This is quite normal with complex systems, and so a four-month process of pre-design was undertaken without any future commitment of resources. This was sufficient time to complete a round of introductory meetings with key stakeholders in Medellín, a review of background reference materials, and to prepare an inventory of available skills, equipment, data and funding sources. The pre-design conceptualisation of SIATA also helped to calibrate stakeholder expectations, and confirm that the project partners understood their roles as well as the project goals, timelines, and so forth, of a more detailed design process.

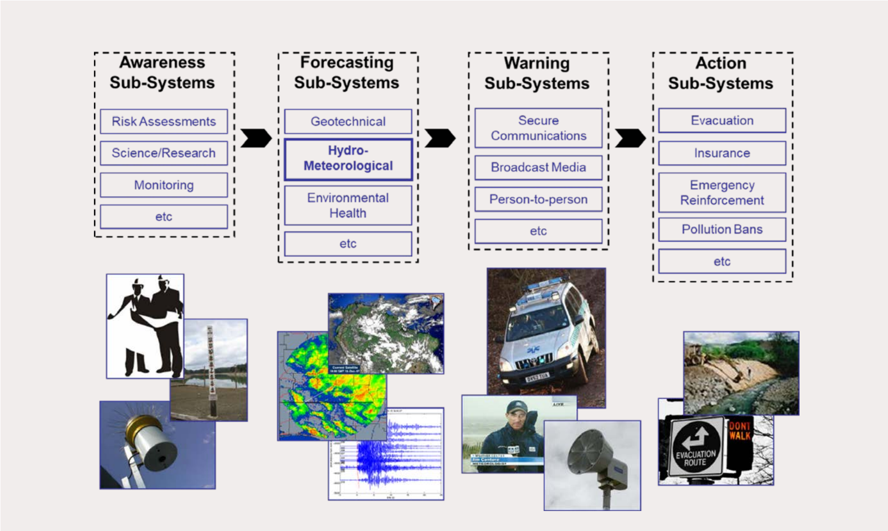

Figure 4.4 – Elements of an effective early warning system (© Firoz Verjee)

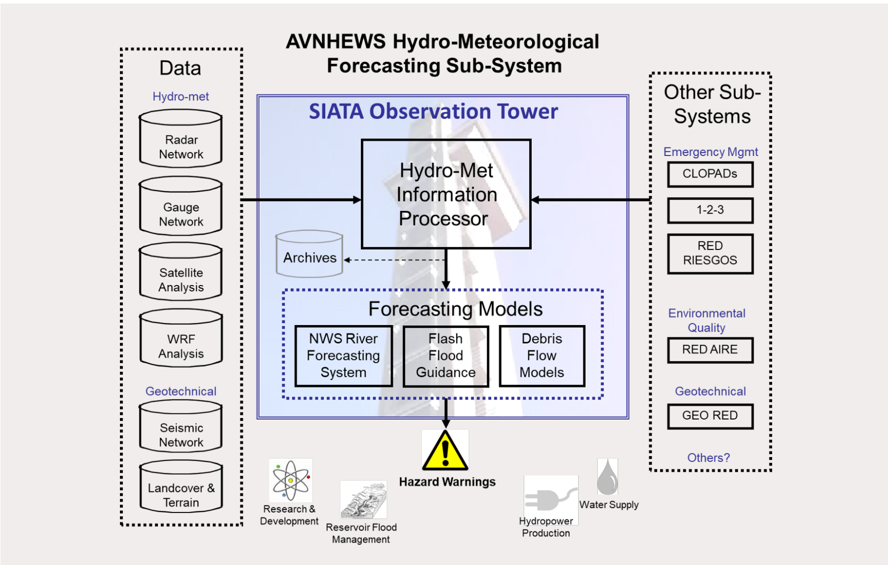

Figure 4.5 – SIATA's hydro-meteorological forecasting sub-system elements (source: NOAA)

Project ownership & funding – SIATA's (a) design, (b) construction, and (c) operation was 100% funded by AMVA and its project partners, which guaranteed strong local buy-in, and ensured the focus of the stakeholders on the project. The US government did not contribute financially to the project, although it is extremely common for IM projects to be entirely funded by donors to the developing world (even a shared contribution between a donor and recipient is preferable, and should be pursued even in fragile, post-conflict situations). In addition to relying solely on local money, the project team integrated the capacity of local institutions whenever possible, and only recommended external skills, methods or technology when there was no alternative. This not only improved long-term sustainability, it also increased stakeholder commitment and reduced technology-transfer risks.

Extensive stakeholder consultation – although NOAA has leading expertise in hydro-meteorological forecasting and environmental forecasting, its engineers and scientists did not attempt to design the various subsystems of SIATA without undertaking many months of strategic and operational consultations with the project partners. This involved a series of technical seminars, field visits, data / system analyses, and meetings with each project partner at their respective facilities in Medellín and Bogotá. The consultation process later grew to include high-profile press events, political and diplomatic exchanges, and only then the production of the SIATA SRD for peer review and final acceptance. Whilst expensive and time consuming, these consultations were an indispensable source of indigenous knowledge, scientific data, functional needs and other critical types of design inputs.

Figure 4.6 – Various examples of stakeholder engagement during SIATA's design phase (© Firoz Verjee)

Subsystem design – the figure below illustrates how SIATA was designed as a system of subsystems, built out of smaller subsystems. Each primary subsystem was engineered by specialists in the required disciplines, who then produced a subsystem design plan based on their consultations, research, and analysis. These plans were structured as follows:

1. Statement of purpose of subsystem;
2. Design criteria;
3. Description of existing capabilities;
4. Description of proposed capabilities;
5. Qualifications & methods;
6. Implementation plan:
    a. Implementation activities (by task and sub-task);
    b. Schedule (timeline of each task and sub-task);
    c. Roles & responsibilities (by task);

7. Required resources;
8. Human resources training & development plan;
9. Quality assurance;
10. Risks & assumptions;
11. Estimated budget (by task and by type of expense);
12. Conclusion & recommendations;
13. Appendices:
    a. Recommended reading;
    b. Design planning & analyses reports;
    c. List of solution providers / commercial vendors.

Integration of each subsystem design plan into a single, holistic system design plan very quickly revealed inefficiencies and synergies between the subsystems, and confirmed the priorities for long-term investment in the expansion of SIATA. A consolidated description of overall activity, timelines, costs and stakeholder roles was then presented by NOAA to the project consortium as part of the final deliverable of the design process.

Given the serious funding implications of the project, English and Spanish executive-level presentations were also delivered so that senior decision makers could understand and be confident about supporting the initiative.

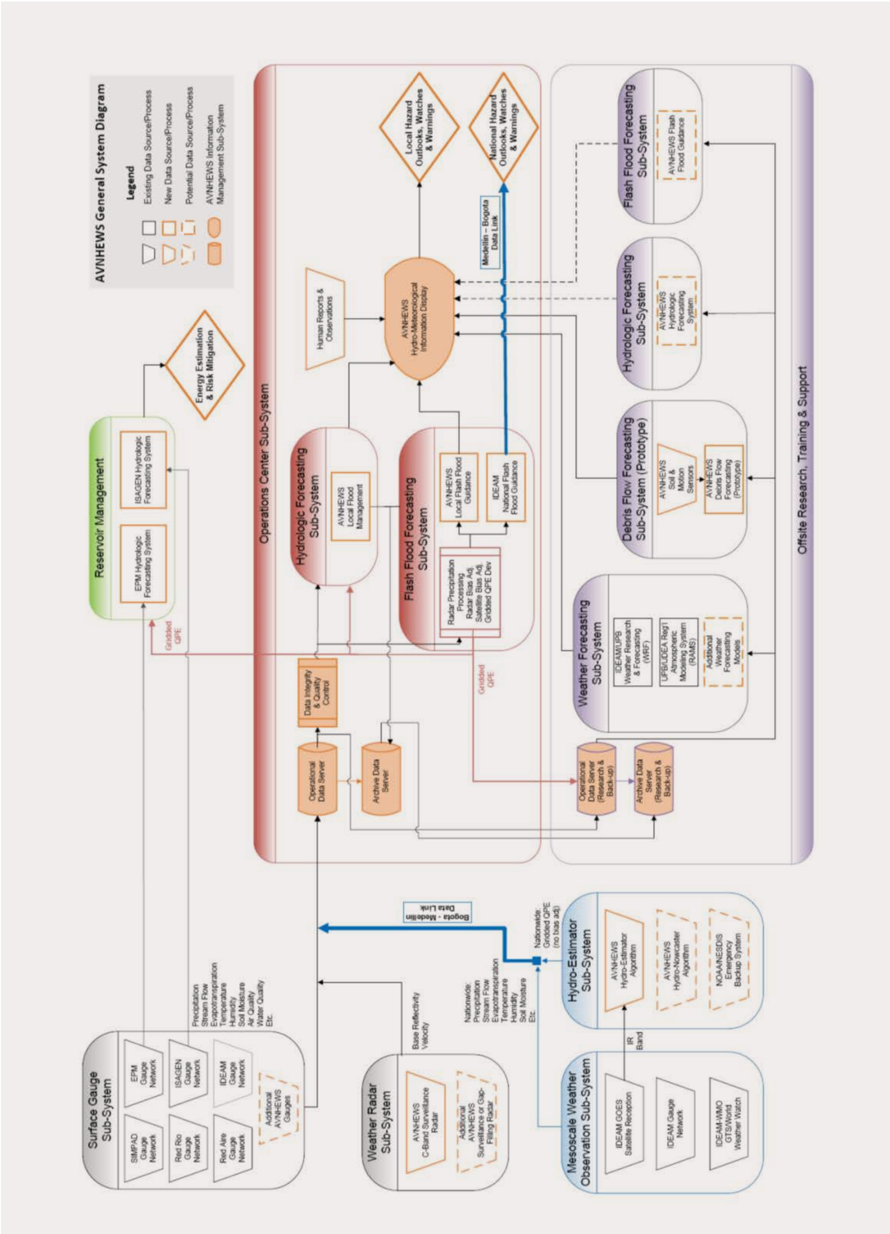

Figure 4.7 – SIATA's hydro-meteorological forecasting subsystem elements (source: NOAA)

Partnership diversity – although the consortium seemed overly complex during the initial phase of the project, in retrospect it was the broad level of interest in SIATA that enabled its success. Whilst not all partners were expected to contribute equally, the large enterprise formed by governmental, academic, non-profit and commercial institutions created extraordinary project resilience, self-perpetuation, and impact.

KEY LEARNINGS:

- Stakeholder engagement must begin on Day 1, and when effective, can result in extraordinary success even in complex environments;
- Civil society, academia and public-private sector partnerships are crucial for long-term sustainability, and inclusive outcomes;
- Empowerment of a wide range of users / stakeholders is a key role for the systems engineer from start to finish;
- Modular design, involving an array of subsystems, enables complicated systems to be successfully deployed as resources permit, and adapted as requirements evolve;
- Even with best practices in SE design, guidance by an experienced partner during the design phase is indispensable to the long-term impact of any IM system.

USEFUL LINKS

The SIATA project is an outstanding example of sustainable technology transfer and systems engineering. Visit the following links to learn more about the project:

https://www.semana.com/contenidos-editoriales/valle-de-aburra-sin-fronteras/articulo/el-sistema-de-alerta-temprana-del-valle-de-aburra-ayuda-a-evitar-tragedias-medioambientales/545058 (in Spanish)

https://use.metropolis.org/case-studies/siata-early-warning-system-of-the-aburra-valley

Channel:

https://www.youtube.com/user/siatamedellin (in Spanish)

Programme Description:

https://www.youtube.com/watch?v=TnpA8R5YTTY (in Spanish)

https://www.youtube.com/watch?v=akPCfLYPcog&list=PLbNSqpW6pxUfh-ku9gYjgmSacoDFCuCxYd (in Spanish)

https://www.youtube.com/ watch?v=bWJ1xVepVTM&list=PLbNSqpW6px-Ud9ehBvsoZpSMEIOhnzGr6n (in Spanish)

Interviews:

https://www.youtube.com/watch?v=LDK5aroA230 (in Spanish)

4.2 ENTERPRISE GIS FOR OSCE SPECIAL MONITORING MISSION TO UKRAINE

BACKGROUND

The OSCE Special Monitoring Mission to Ukraine (SMM) was deployed on 21 March 2014, following a request to the OSCE by Ukraine's government and a consensus decision by all 57 OSCE participating States. The SMM is an unarmed, civilian mission, present on the ground 24/7 in all regions of Ukraine. Its main tasks are to observe and report in an impartial and objective way on the situation in Ukraine; and to facilitate dialogue among all parties to the crisis.[5]

Figure 4.8 – OSCE SMM patrol vehicles, Ukraine (OSCE SMM 2018)

The SMM produced a range of public and internal reports based on field observations generated by hundreds of monitoring officers located across the country. Because its mission grew quickly and without a robust, modern IM strategy, the SMM struggled with the efficient collection, storage, analysis, dissemination and reporting of data generated by its unmanned aerial vehicles, cameras, and monitoring teams.

5 "OSCE Special Monitoring Mission to Ukraine," OSCE, https://www.osce.org/special-monitoring-mission-to-ukraine

The benefits of migrating to an enterprise-wide geographic information system (GIS) were increasingly obvious. Donor support was secured in 2017 and in September 2018, under US government funding, the GICHD and Esri began a multi-year project to modernise and integrate the SMM's IM practices. In addition to transforming data management systems, the project also aimed to improve the situational awareness, communications, security, and safety of SMM employees working in the conflict zone.

Figure 4.9 – OSCE SMM observers with Ukrainian-led forces (OSCE SMM 2019)

WHY SYSTEMS-BASED DESIGN?

An SE-based approach was required because of the complex, dynamic nature of the SMM's workflows and its reliance on mission-critical legacy systems. Maintaining operational continuity and managing the risk associated with transition to a new, fully integrated IM system were strong arguments for using a systems-based approach for the design and implementation of the SMM's Enterprise GIS (or EGIS).

ROLES & RESPONSIBILITIES

Bureau of Conflict and Stabilization Operations

US government **(donor)**: the US State Department's Bureau of Conflict and Stabilization Operations was the sponsor of the project; it hoped to not only reduce the SMM's IM challenges in Ukraine, but to develop a replicable model for assisting with other missions elsewhere around the world.

OSCE Organization for Security and Co-operation in Europe
Special Monitoring Mission to Ukraine

The OSCE Special Monitoring Mission to Ukraine (**beneficiary**): as the host organisation and primary user of EGIS, it was critical for the SMM to play a central role in the design, development, and deployment of the platform across its units. This ensured ownership and long-term sustainability and reduced some of the project risks. The SMM's information management department was the primary stakeholder within the SMM, and its GIS coordinator served as its EGIS project manager. The project manager was supported by a small ad-hoc team from the SMM's IM, IT and Operations departments.

GICHD

The GICHD (**grantee**): as noted in Section 2, the complementary roles of a systems engineer and a project manager can be combined when projects don't require dedicated specialists to serve in each role. Therefore, the GICHD's systems engineer served as the EGIS project lead, providing overall management of technical and financial matters, as well as work plan scheduling, monitoring, and donor communications. The project lead was assisted by a full-time project support officer, with primary responsibility for contract administration, but also many other responsibilities as required, including multilingual research and communications.

Esri (**contractor**): Esri is the world's leading GIS solutions provider, and is highly qualified in deploying enterprise systems. Because the SMM was already a user of Esri's ArcGIS software, the project partners adopted ArcGIS-based solutions by default when defining the functional requirements of the desired IM system (Non-Esri solutions were employed only when a suitable capability was not already available within ArcGIS.) Esri then translated them into system requirements, addressing ArcGIS software, other commercial off-the-shelf (COTS) software, hardware and services. Esri's team included an EGIS senior project consultant, system architects, software developers, application specialists, instructors, and contract managers, as well as sub-contractors like MDA (satellite imagery solutions provider), Hewlett-Packard (hardware provider) and several COTS software providers.

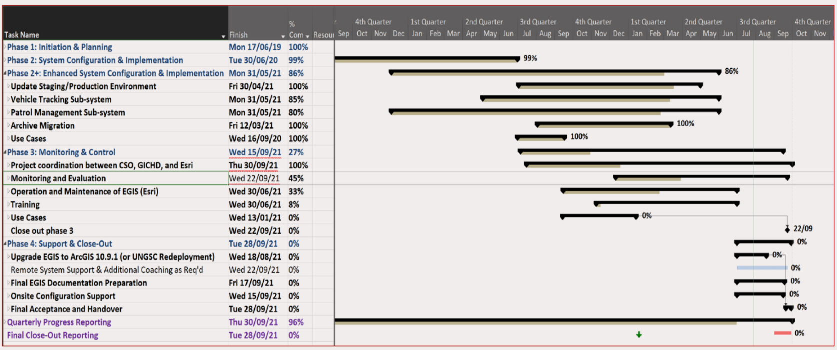

Figure 4.10 – Planning to operationalisation: SE phases of EGIS with completion levels (source: SMM 2020)

PROJECT WORK PLAN

As indicated in figure 4.10, the EGIS project the EGIS project was originally structured in four phases. These phases serve as the basis for Esri's contractual task orders and represent the EGIS work breakdown structure (WBS) at its highest level.

The EGIS work plan illustrates the lengthy timelines that can be required to successfully deploy a custom IM system, even when there is no custom software development. The following section highlights each of the five project phases.

PHASE 1 – INITIATION & PLANNING (SEPTEMBER 2018 – MARCH 2019 / MONTHS 1–7)

Despite the understandable pressure to deploy the new IM system as quickly as possible, all parties agreed that no implementation could begin until the SRD had been officially approved. This avoided the classic error of procuring technology prior to (a) securing stakeholder buy-in, and (b) designing an effective solution around the specific functional requirements of those stakeholders. It may be tempting, however, to impose a solution on users of an IM system in order to show immediate results, but building agency-wide ownership before deployment through SE processes is essential. In complex environments like that of the EGIS project, nearly seven months were required for the project kick-off, to complete stakeholder consultations and finalise the SRD.

This included the time required to negotiate partnership agreements, secure data / system access privileges, and establish project management protocols – prerequisites for most IM projects but often underestimated in the work plan.

Project launch – the EGIS project partners started with preparing for, and then hosting, a high-profile kick-off event to launch the initiative at the SMM's headquarters in Kiev, Ukraine. The objective was to introduce the team's leadership, set realistic expectations, generate excitement, establish a broad level of host-agency support, and identify potential concerns. While such events can be purely symbolic, they can provide a systems engineer with a unique preview of the project environment and the needs of various stakeholders.

Protocols – institutional necessities like partnership memoranda, non-disclosure agreements, monitoring plans, terms of reference, IT clearances / access privileges, legal and taxation consultations, etc. involved substantial effort during and even after Phase 1 of the project. Ultimately, it is the project lead's duty to satisfactorily complete these protocols if they have not been addressed prior to the initiation of the project.

Governance – soon after the project launch, the SMM created a steering committee to provide oversight and to support to their EGIS project manager. The steering committee was composed of a senior executive (SMM's deputy chief monitor), the managers of the IM, IT, Operations, HR / Finance and Security & Safety departments, as well as personnel as required. The committee met monthly to review the project, resolve problems, and provide guidance to the SMM's project manager throughout the duration of the project.

Stakeholder consultations – the project team documented each of the use cases defined during the stakeholder consultations using the worksheet illustrated in Chapter 2 and available from the guide's resource website (https://www.gichd.org/en/seguide/). This tool was used to capture the functional requirements of various stakeholders in simple, user-oriented phrasing. Some 48 formal consultations were conducted by the team across the SMM during Phase 1, resulting in 63 unique EGIS use cases. Particular effort was made to avoid biasing the outcome of these consultations and to apply a user-centric (not a technology-centric) approach in order to extract the needs of each user group. Consultations typically involved a combination of brainstorming sessions, demonstrations, and iterative development of each use case until it was satisfactorily completed.

Functional requirements analysis – once it was clear that the consultative process was sufficiently exhaustive, the project team began to transform the use cases into a formal set of functional requirements. These were technical but made no reference to specific technologies, to ensure they represented the host agency's priorities without bias to any commercial solutions provider. Even more importantly, the EGIS functional requirements were initially drafted by the SMM and not the GICHD or Esri, to ensure they correctly represented the host agency's priorities, organisational culture, and operational structure.

Concept of operations – once the functional needs were defined, it became possible to develop a ConOps. For EGIS, this was a high-level description of what was envisioned as a system of systems. The ConOps offered a simplified operational picture of how EGIS was going to be used to connect hundreds of end users located in the field, regional offices and headquarters, by integrating a variety of specialised subsystems through a common IM platform.

As illustrated in figure 4.11 below, the ConOps schematic shows how a multiple *data source* subsystem would feed monitoring information into several *administration* subsystems. These hosted the data, services and technology to support user-oriented *visualisation / analysis* subsystems. Collectively, these subsystems needed to create a common operating picture, to generate various types of reports, and to inform the SMM's *mission planning* subsystems. These subsystems guided the collection of more data by the SMM's monitoring teams in the field, creating a cycle of IM activities supported by a new enterprise geographic information management system (EGIS).

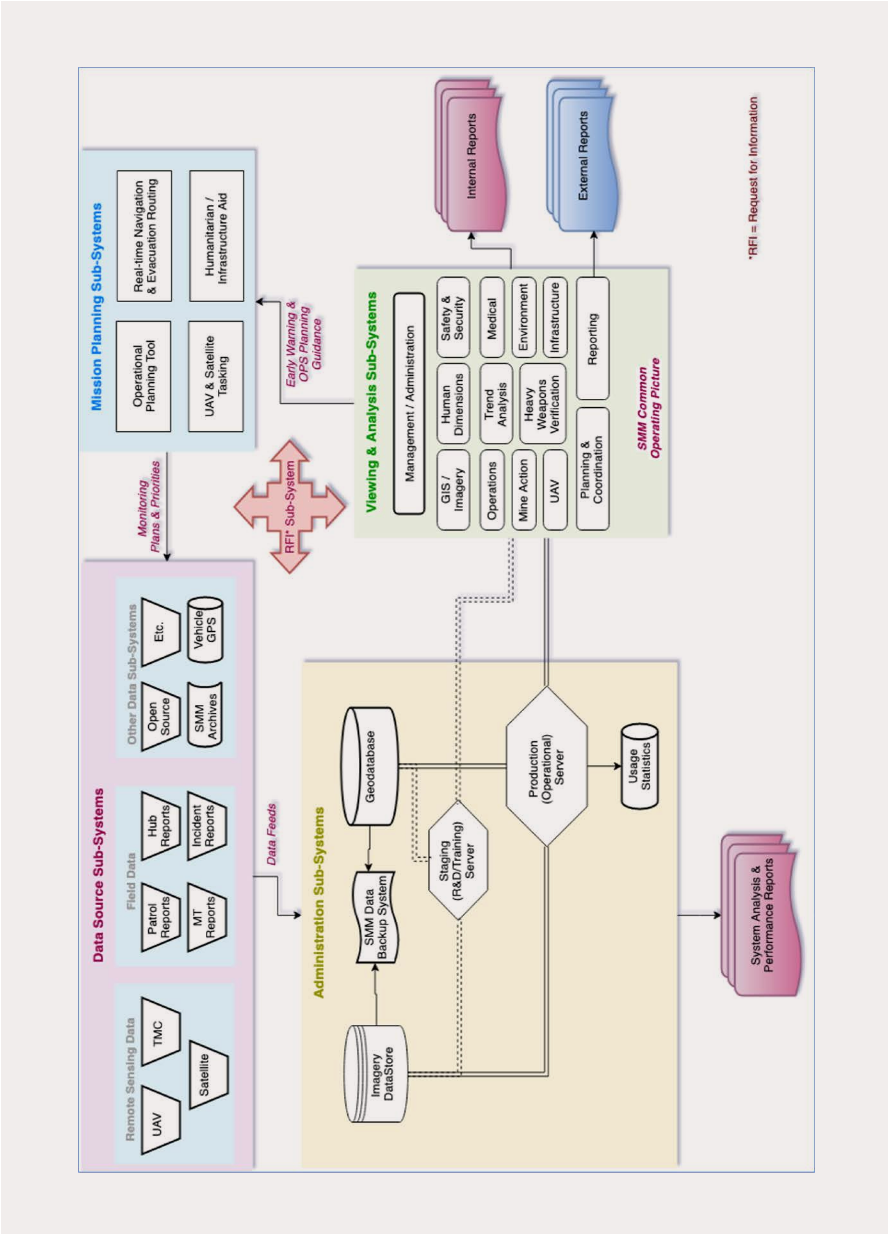

Figure 4.11 – Concept of operations diagram (SMM 2019)

System requirements document – the final design was defined through the preparation of an SRD, by Esri (the selected solutions provider). The SRD converted the functional requirements and ConOps into a clearly defined set of specifications for all software and hardware technology (including enterprise-wide licencing requirements), services, capacity development, testing, and long-term operational maintenance of EGIS. It contained detailed system architecture maps, and explained how the operational performance criteria would be achieved (high availability of critical functionality, recovery point objective, recovery time objective, etc.).

Formal acceptance of the EGIS SRD by the project team leadership marked the completion of Phase 1, and their readiness to begin procurement, configuration and training activities.

PHASE 2 – SYSTEM CONFIGURATION & IMPLEMENTATION (MARCH 2019 – APRIL 2020 / MONTHS 7–16)

The SRD should provide a clear road map to a project team, but the project team was braced for design detours after they transitioned to Phase 2. This is normal, especially within the context of humanitarian operations, and a systems-based approach is particularly helpful when conditions are unpredictable and dynamic:

Essential vs non-essential functionality – each functional need was determined to be either (a) required, (b) desired, or (c) optional. This was done in consultation with the SMM's various users, and it helped the project team focus on delivering core capability before enhancing EGIS with interesting but less critical functionality.[6]

6 Required = essential to mission. Desired = non-essential but unquestionably helpful to mission. Optional = non-essential but potentially helpful to mission.

Use case tracking – in order to monitor completion progress, the EGIS project team used various Microsoft tools to track each use case as they progressed from backlog to completion.

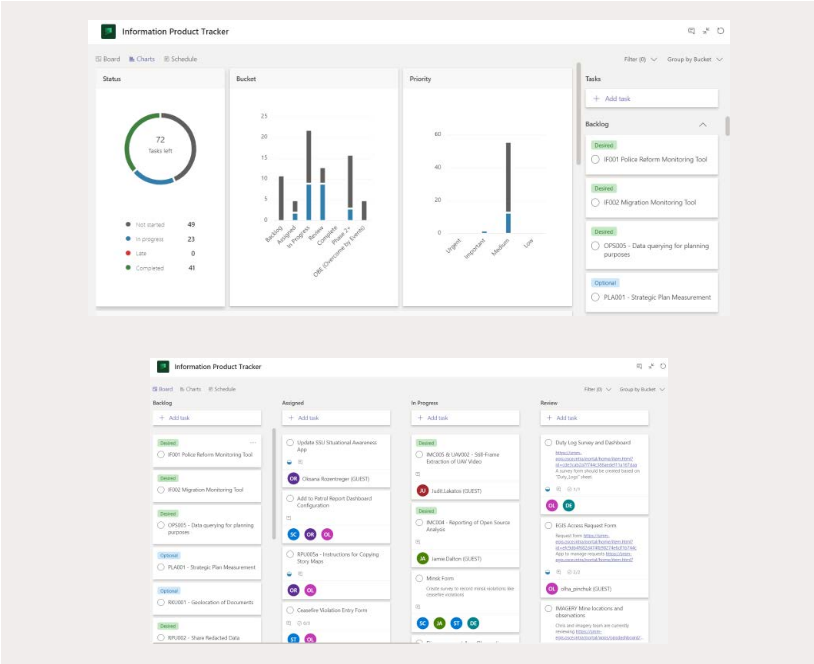

Figure 4.12 – Use case tracking dashboards

Modified agile approach – although the SRD was quite thorough, it did not attempt to be overly prescriptive. The SMM's realities changed daily, and some functionality was redesigned during Phase 2 using an iterative agile-like approach; that is, a minimum viable product was developed for an SMM user group to test and to react to, before additional effort was invested. While it is the most commonly-used approach and can be the default approach for some IM system deployments, it was primarily used by the EGIS team in cases in which the end users could not be expected to adequately articulate their needs during Phase 1.

Addition of new phase in work plan – the original EGIS work plan had only four phases, but the growth in the scale of the project, due to unplanned requirements, and the availability of funding provided justification to add a new phase, called **Phase 2+ – Enhanced system configuration & implementation** (May 2020 – August 2020 / Months 17–23). The creation of a separate phase for development of the EGIS platform ensured that core system functionality was satisfactorily completed before enhancements were attempted. The new phase was clearly defined by a new work package, and concluded with the signing of operational acceptance documents by the project leadership.

PHASE 3 – MONITORING & CONTROL (JULY 2020 – NOVEMBER 2020)

With the completion of system development and training, the project team was ready to deploy the platform to each user group. Operational roll-out included (a) **system monitoring** using back-end specialised software (ArcGIS Monitor) installed during Phase 2, and (b) **satisfaction monitoring**, based on statistical usage reporting, feedback surveys, and user experience workshops. The team found it important to build in a sufficient period for monitoring to allow the project team time to address system deficiencies, deliver additional training / coaching / support, and confirm IM system acceptance before close-out.

PHASE 4 – SUPPORT & CLOSE-OUT (NOVEMBER 2020 – DECEMBER 2021)

EGIS was built from COTS technology that was well documented, but the project team still allocated a significant period of time to develop custom references for the SMM's various stakeholders. And although system documentation should be continuously updated throughout a project, the final phase of EGIS IM involved formal publication of the following user references by the project team:

- Group-specific user references / standard operating procedures.
- Database administration manual.

- System architecture & maintenance manual.
- IT continuity of operations plan / incident management plan.
- In-house training curricula, videos & materials.

These types of references promote the long-term sustainability of a new IM system, and should be concise, factual, understandable and accessible. Well-documented systems have a much better chance of surviving the impact that skills attrition and staff turnover will have over time; the systems engineer should therefore insist on robust references to minimise dependence on the project team *after* it completes the delivery of a new system.

KEY LEARNINGS

This case study has hopefully illustrated how IM systems can be deployed in the peacebuilding context using a systems-based approach. The project shows that:

- Conflict-related deployments are unpredictable and require both discipline and agility;
- Risk management is a key role for the systems engineer from start to finish; and
- COTS and professionally-hosted solutions are generally (but not always) preferable, especially when IT capacity is constrained, and sustainable, scalable solutions are required.

4.3 INFORMATION MANAGEMENT SYSTEM FOR MINE ACTION

TAJIKISTAN INFORMATION MANAGEMENT SYSTEM FOR MINE ACTION (IMSMA) CORE IMPLEMENTATION

BACKGROUND

At the end of 2017, the Republic of Tajikistan had just under 7.46 km^2 of mine contamination across 153 confirmed hazardous areas, and almost 1.35 km^2 of suspected hazardous area (SHA) across 59 unsurveyed minefields. The 59 SHAs equate to 45 remaining tasks to be surveyed, as some tasks contain multiple minefields, potentially laid at different times during different conflicts and because minefields are counted separately if they are more than 500 metres apart. The mined areas are located in 13 districts in three provinces of Tajikistan.

The overall baseline contamination at the end of 2017 was a small reduction compared to the end of the previous year (7.76 km^2 of confirmed contamination and 1.97 km^2 of suspected mined area).

Mine contamination remains in the provinces of Khatlon and the Gorno-Badakhshan Autonomous Region along the Afghan border (reported to contain 60,357 anti-personnel mines), as well as in the central region. Shamsiddin Shohin district (formerly known as Shuroobod district) in Khatlon province is the most heavily mined district. Mines were laid in and around military positions on hilltops overlooking the Panj river valley, mostly delivered remotely by helicopter or laid by troops who were moved in and out by helicopter. Consequently, there are no established roads or tracks to access the minefields for survey or clearance.

The battle areas in question are mainly recorded as hazardous areas due to past accidents involving unexploded ordnance or reports from local communities. Resurvey of most of these areas is required to determine whether further evidence of explosive remnants of war exists, including cluster munition remnants.

WHY SYSTEMS-BASED DESIGN?

The Tajikistan National Mine Action Centre (TNMAC) began development and implementation of a priority setting-based approach to identify contamination and plan tasking clearance. To make this effective, a robust IM system which can aid in visualising, modelling, and clearance efforts was necessary. To develop this, an SE-based approach was required due to the complex social, environmental, and geographical nature of the contamination. As Tajikistan nears completion and moves into the long-term risk management phase, it was necessary to provide tools which interactively visualise potential residual contamination risk for ongoing development initiatives.

ROLES & RESPONSIBILITIES

TNMAC is the **mine action authority** which all operators report to. TNMAC owns, manages and is responsible for the national database, tasking and standardisation.

The GICHD: as noted in Chapter 2, the complementary roles of a systems engineer and a project manager can be combined when projects don't require dedicated specialists to serve in each role. Therefore, the GICHD's systems engineer served as the IMSMA Core project lead, and provided overall management of technical as well as financial matters, in addition to work plan scheduling, monitoring, and donor communications. The project lead was assisted by a part-time consultant with primary responsibility to assist in the development of the IMSMA Core system as required – including the development of custom tools.

IMSMA Core is a system of tools and processes that can be configured to fit national programmes' specific operational and reporting requirements, which provide access to information for a wide range of stakeholders, foster information sharing and provide near-real time maps and reports on the extent of land contamination. It is a knowledge base for the use of GIS in mine action, designed so that mine action actors can contribute to it and continuously improve it over time. IMSMA Core is the next generation of IMSMA, developed and supported by the GICHD.

PROJECT WORK PLAN (FEBRUARY 2018 – DECEMBER 2019)

The Tajikistan IMSMA Core was structured in four main phases over two years:

1. IM stakeholder workshop (review of IMSMA Core, identify stakeholder and user needs / requirements):
    - Information requirement discussion;
    - Define groups and permissions;
        - Used to define user access and structures.
    - Review of currently used forms;
    - Define process maps;
        - Used to define workflows.
2. Preparing the national database for migration and designing the IMSMA Core database:
    - Address database issues / errors and backlog;
    - Adapt data entry to Survey123 form;
    - Test Survey123 form;
3. Workflow design:
    - Develop workflows (maps and apps created);
    - Test workflows;
4. Go live.

PHASE 1 – IM STAKEHOLDER WORKSHOP

In order to carry out a full and unified consultation with stakeholders and the national authority, a stakeholder workshop was organised to understand the current IM systems in place and define the requirements of the new IMSMA Core system. Group activities and a series of brainstorming sessions were facilitated, with all results being recorded and used to guide the IMSMA Core design.

PHASE 2 – PREPARING THE NATIONAL DATABASE FOR MIGRATION AND DESIGNING THE IMSMA CORE DATABASE

Preparing the national database for migration:
The first task was to prepare the existing national database for migration to IMSMA Core. A full review of the data geometry, duplicate entries, missing or incomplete entries, calculation errors and identification of all custom defined fields (CDFs) actively being used in IMSMAng vs ones no longer needed or in use. This review also provided a list of items for review and correction in the database, giving the initial guide for preparing the database for a migration to IMSMA Core. In addition, completing all data backlogs of reported data in the national database was necessary. A GitHub was created where issues could be detailed, and progress could be tracked. Using GitHub proved to be an invaluable tool for collaboration between the GICHD and the TNMAC and as a repository for solutions.

Designing the IMSMA Core database:
Through the process of preparing the national database for migration, a clear understanding of the database structure, workflows and current data collection methods were identified. Throughout the data preparation process there were discussions on how to improve the data schema, data collected and how to enter data in the national database. These discussions led to a plan on how best to approach the development of the IMSMA Core database. Improvements were identified, which could be implemented in the IMSMA Core system, as well as identification of where the database could be updated in accordance with International Mine Action Standards (IMAS) recommendations.

Adapting the forms for IMSMA Core:
During the data preparation process, a review of the data collection forms was carried out. This required identifying the number and types of forms that are in active use and would need to be migrated to IMSMA Core. Like the database preparation process, the survey forms were reviewed, identifying areas for improvements and potential updates following IMAS recommendations. All necessary CDFs were also identified, and non-essential or redundant CDFs were noted. Following the review, all actively used forms were adapted to Survey123 which turned paper forms into electronic survey forms connected directly to the IMSMA Core database. Improvements and updates were incorporated into the Survey123 forms as well. Once the first draft of the new survey forms was completed, a full test of the forms was implemented. Through the process for adapting the forms to IMSMA Core, the database schema was developed and prepared.

PHASE 3 – WORKFLOW DESIGN[7]

Using guidance from the results of the IM stakeholder workshop, and through discussions conducted during the data preparation process and adaptation of the forms for IMSMA Core, workflows were updated. Improved process maps were made for the data collection, entry and validation processes. While seemingly more complex, the updated process improved the delegation of tasks and efficiency (see Figures 4.13 and 4.14).

A workflow process involving the use of ArcGIS Pro, web applications and Survey123 was designed in IMSMA Core to facilitate more efficient data entry and validation, as well as minimising the potential for human error. Task workflows were designed in ArcGIS Pro for TNMAC IM officers, providing an easy guide to the tools and tasks for each stage of the data entry and approval processes. The workflows give guidelines on the order of steps to take and present tools for use in each of these steps.

7 Subsequent implementations of IMSMA Core have had database design and workflow design occur in tandem rather than sequentially, as depicted in this example.

Information dashboards were also designed to support the reporting requirements of the TNMAC to stakeholders. Once all workflows and dashboards were completed, a full testing was carried out, and the necessary adjustments made.

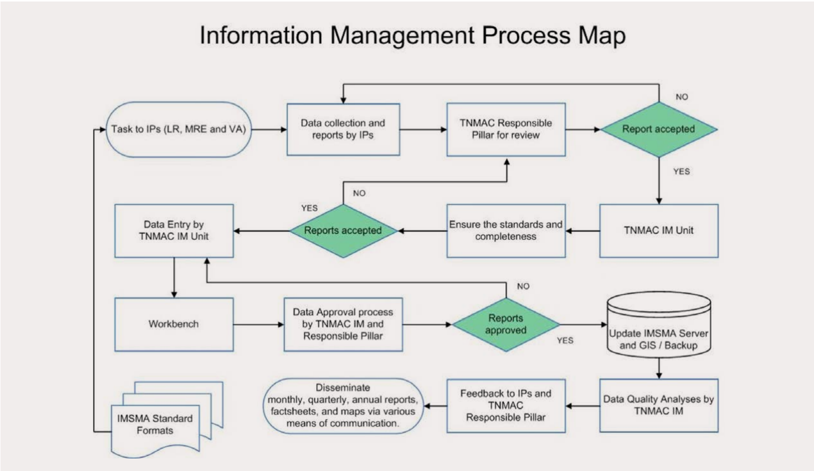

Figure 4.13 – IMSMAng process map #1 (GICHD 2019)

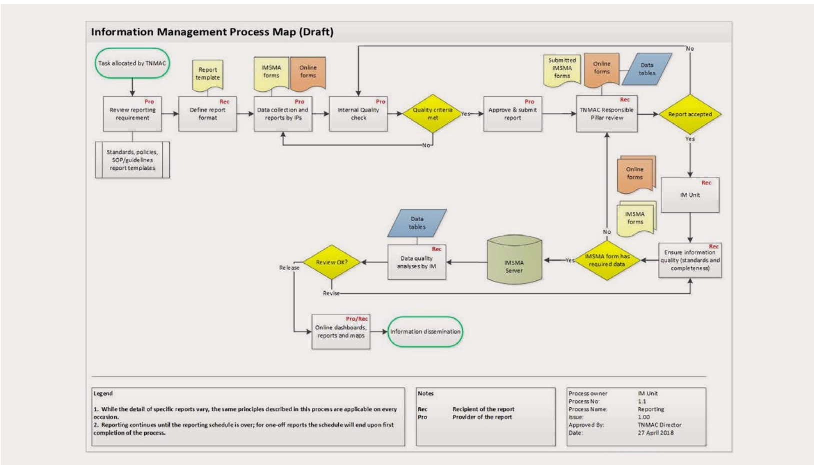

Figure 4.14 – IMSMAng process map #2 (GICHD 2019)

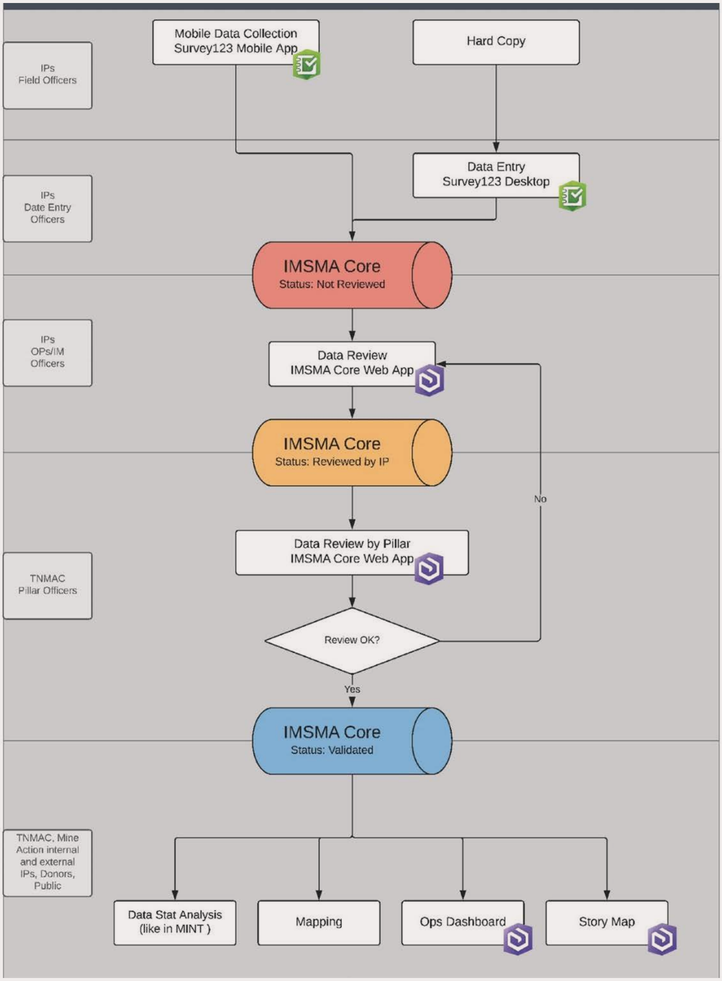

Figure 4.15 – IMSMAng process map #3 (GICHD 2019)

PHASE 4 – GO LIVE

In December of 2019, IMSMA Core was officially launched in Tajikistan. The national database was migrated to IMSMA Core, with workflows, applications and information dashboards in active use. Throughout the process, the TNMAC operated with their legacy database and IMSMA Core in parallel. As elements of the workflows, forms and data were ready for use in IMSMA Core, the TNMAC moved the related activities into operation in IMSMA Core. This parallel operation process provided for a disruption-free process, where operations could continue without interruption.

LESSONS LEARNED:

- Parallel operation of IMSMAng and IMSMA Core throughout the development process provides **little to no disruption** to operations. This parallel approach also allows for a gradual testing of elements in the IMSMA Core design with **no risk** to the national database or ongoing operations.
- **Clear planning** and **identification of needs** for the IMSMA Core system must be completed in the first phase of development. Any large design changes midway through the project can cause long delays which may ultimately increase the projected timeline by months.

DRC IMSMA CORE IMPLEMENTATION

IMSMA Core was also implemented as a pilot project in the Democratic Republic of Congo (DRC) for the United Nations Mine Action Service (UNMAS). UNMAS DRC carries out explosive ordnance disposal and explosive ordnance risk education, reporting to the national authority, but owning and managing their own database. They are currently updating their IMSMA Core to UNMAS standards.

Prior to IMSMA Core, UNMAS forms were in Excel and Word, with their database hosted in Excel / Access. National data standards were being reviewed, which meant that at some point an adaptation of the database and forms would be needed to reflect new UNMAS standards. While this did not occur during the initial development of IMSMA Core, the system was updated to reflect new UNMAS and International Mine Action Standards after launch.

As in the case of Tajikistan, information gathered through an initial stakeholder workshop, and from discussions carried out during the data preparation process, as well as through adaptation of the forms for IMSMA Core, led to workflows being updated accordingly. In this case, workflows were created with a trigger system alerting those responsible for various tasks. The triggers were designed as email alerts connected to the database. Using a custom script, database triggers indicated the start or end of a specific task within various workflows such as managing workflow status and notifications of activities. Each trigger was sent to the individual responsible.

IMSMA Core went 'live' for UNMAS DRC in 2019, and the following year further database and reporting updates were made to enable easier maintenance and updates.

LESSONS LEARNED

The lessons learned from the implementation of the DRC programme were the following:

- **Regular communication** within the project team is critical during iterative design.
- Due to changes in the composition of the project team during the life cycle of the implementation, the importance of **clear documentation** for both processes and design, as well as the recording of issues, was highlighted, to support the handover of responsibilities.
- As the IMS was rolled out to additional programmes, **minimum data standards** were required to allow data to be consolidated on a global scale. These minimum data requirements were then extended to meet local information needs.
- Missions to DRC by the GICHD and UNMAS teams highlighted the importance of identifying the most productive means of working and communicating with in-country staff. In DRC, an **in-person approach** was significantly more effective than remote support.

Following a systems engineering approach, the global information management system based on IMSMA Core is now being implemented across all UNMAS operations. Adopting the lessons learned from the pilot project, the programme is being delivered in partnership with United Nations Office for Project Services (UNOPS) who serve as the project lead.

4.4 OPEN-SOURCE IMS FOR MINE ACTION

BACKGROUND

The Iraqi Kurdistan Mine Action Agency (IKMAA) is responsible for the following tasks:

1. Clearing all areas of the Kurdistan Region of mines and explosive hazards;
2. Promoting mine risk awareness and educating the people of the Kurdistan Region through different media outlets and school programmes;
3. Providing the necessary assistance to mine victims;
4. Cooperating and contributing to the prohibition of the use of anti-personnel mines and participating in international conferences and workshops related to mine action;
5. Coordinating and cooperating with organisations and centres with the same mandate, within and outside of the Kurdistan Region, which helps the agency achieve its goals.

WHY DID IKMAA REQUEST AN OPEN-SOURCE IM SYSTEM?

IKMAA increasingly struggled with the limitations of their legacy, stand-alone system, as its programme grew to include multiple locations for data entry across Kurdistan. This resulted in inefficient and time-consuming data synchronisation between these locations. IKMAA required an online, web-based centralised IM system that would have lightweight internet connectivity requirements and would contain basic spatial data visualisation capabilities. IKMAA requested the Information Management and Mine Action Programme (iMMAP), in 2021, to develop such a system for them, with the provision that most of IKMAA's spatial data analyses would continue to take place offline using GIS desktop software.

ROLES AND RESPONSIBILITIES

IKMAA is the mine action authority in the Kurdistan Region of the north of Iraq, and all operators report to them. IKMAA has complete control over the new open-source IM system and issuing tasks for implementing partners.

GICHD

IKMAA requested GICHD involvement in the system development processes. The GICHD is providing guidance and support to IKMAA and iMMAP in the development of the IMS based on IMAS 05.10 Information Management for Mine Action, and experience gained in the development of the IMSMA software.

iMMAP

IKMAA tasked iMMAP with the development of the open-source IM system as part of its project funded by the U.S. Department of State Bureau of Political-Military Affairs, Office of Weapons Removal and Abatement, to develop the IM and GIS capacity of the Iraq mine action authorities. The new IMS is being developed in-house by iMMAP staff based in Erbil, using only open-source components to ensure minimal financial requirements for the continued deployment of the IMS.

PROJECT WORK PLAN (MARCH 2021 – DECEMBER 2021)

The open-source IMS was requested by IKMAA from iMMAP with the involvement of the GICHD to ensure the integration of best practices from both organisations in the development of the system. The project follows the waterfall software development methodology, as most of the system requirements could be defined at the onset of the project, and consists of the following phases:

1. Workshop with IKMAA, the GICHD, and iMMAP to clarify the following:
    - System requirements (functional and non-functional);
    - New features required from the open-source IMS;
    - Offline or online use of the system?
    - Technology components of the new system;
    - Stakeholder roles of IKMAA, the GICHD, and iMMAP.
2. Designing and developing the open-source IMS, to include:
    - Designing the new system according to the system requirements;
    - User-friendly data entry form design;
    - Dashboards for each humanitarian mine action activity and for the overall system;
    - Using PHP and PostgreSQL to develop the new system to have a relational database management system (RDBMS) that is compatible with IMSMA Core and thus simplify any future data migration;
    - Robust data validation and verification;
    - Chain of action or business logic for all procedures;
    - Using OpenLayers for the GIS component of the system;
    - Deploying the system on IKMAA's existing server;
    - In-house training of IKMAA staff on using the new system.
3. Migration of IKMAA data to the new system and training in the system:
    - Mapping all data to fit the new system's data structure;
    - Finding a suitable solution for IMSMA version data;
    - Checking and entering data into the system with all IKMAA offices;
    - Training IKMAA staff with different user levels, i.e. users, administrators, and decision makers.

PHASE 1 – WORKSHOP WITH IKMAA, THE GICHD AND IMMAP

This workshop was the start of work with IKMAA, to discuss the open-source IM system for mine action and included the three stakeholders, to facilitate and direct the system development process.

This phase focused on collecting the system's requirements and capturing the system's required business logic. The breakdown below lists the main steps and outputs:

- In-house interviews with the technical and information management staff;
- In-house knowledge with similar software to be used as a valuable reference for all challenges and problems;
- Generation of all the required documents to clearly explain the system's requirements, such as use case diagrams, functional and non-functional requirements, etc.

Functional requirements

1. Creating and designing data entry forms and related tables dynamically, according to the users' requirements;
2. Supporting granular permissions by allowing users to access the data sets and functionalities according to the privilege granted by the system administrator;
3. Supporting a multi-language interface with the ability to add new languages when required;
4. Tracing historical data and logs for each field report;
5. Providing the following GIS functionality:
    - Visualising data on the map;
    - Supporting online and offline maps;
    - Enabling the addition and removal of record geometries such as points, polygons and polylines;
    - Providing a tool to measure area size and distances;
    - Providing map printing as PDF files.

6. Importing data from data sources such as MS Excel, Comma Separated Values (CSV), etc.;
7. Exporting data as MS Excel workbook files;
8. Providing tools for basic data analysis and visualisation;
9. Optional integration with mobile data collection tools such as KoBoToolbox and Survey123;
10. A content management system to manage user profiles, form permissions, country structure and auxiliary data;
11. An email notification system to notify users of updates and to send weekly and monthly reports to stakeholders and decision makers;
12. Supporting the printing of single reports or batches of reports.

Non-functional requirements

1. Response time for creating a form not exceeding five minutes, based on the current data entry forms used by IKMAA;
2. Accessing forms restricted to a specified group, allocated in the system's permissions table, and accessing authorisation for management down to a specific field level;
3. Providing a tool to translate terms, keywords and technical vocabulary from English to all other languages that are configured in the system;
4. A web map tool allowing for the customisation of the geometry themes and labels;
5. A web map tool allowing for the transformation of geometry coordinates from longitude and latitude to the military grid reference system;
6. A web map tool enabling the automated submission of geometries into the database by importing the report data in bulk from external resources such as CSV files or using bearing and distance measurements for polygons and polylines;
7. Ability for the system's backup and recovery mechanism to restore the system back to a specified date within 15 minutes.

System component selection approach

The overarching considerations for the selection of the component technologies were based on the following criteria:

- Direct cost in terms of initial purchase, ongoing maintenance (upgrades and support of the software) and indirect cost in terms of labour required for system maintenance (user base size, access to support documentation and prevalence of technically focused fora / knowledge repositories). All the components selected are either freeware or open source, except for the Windows operating system.
- Performance, scalability, and security – Apache, PostgreSQL, and PHP can run with their default configurations on a mid-range laptop for web apps to a maximum of 100 simultaneous users. These apps can easily be tweaked to improve performance, or be migrated to a Linux-based environment for additional performance gains. Software bundles such as WAPP (Windows, Apache, PostgreSQL, and PHP) provide a mix between the Windows open-source (OS) platform that most end users are familiar with, and the Apache, PostgreSQL, and PHP components, for an easily manageable platform that can scale to meet demands. Additionally, PostgreSQL provides support for spatial data types, which simplifies the storage of the HMA spatial data.
- Cross-browser and device compatibility – HTML5, which includes JavaScript and CSS3, is the global web content rendering standard and by using PHP to generate HTML5 standard code on the server side, the system will be usable across a wide range of desktop and mobile devices. The GeoJSON data format similarly provides compatibility with a wide range of web platforms, thus providing the opportunity to integrate with other systems in the future.
- Ease of use and troubleshooting – with a WAPP foundation, the solution would run on the familiar Windows platform and provide system administrators with easy access to the component configuration files, source code, and logs generated by the Apache server and PHP interpreter.

- Lastly, the primary technical requirement for the system was that it must allow IKMAA to adapt the database structure and the web application components independently following the completion of the system development process. The use of these mature and widely used technologies ensures that IKMAA can use a large number of websites and online communities that provide support for users of these technologies, and with the plain text file-based configurations used by these components, whilst editing the components and the source code will not pose a problem.

PHASE 2 – DESIGNING AND DEVELOPING THE OPEN-SOURCE IMS

1. Design: the design of the database included the following:

- Designing and modelling the system's database conceptual and logical schema. See Figure 4.16, below, for the conceptual diagram of the database schema;

- Selecting suitable technologies for the software and hardware components such as the web app development language, database, etc. The following were defined as the preferred technology components:

    - Back-end technologies: PHP (version 7) as the server-side scripting language, PostgreSQL (version 10) as the database platform, Apache (version 4.2) as the webserver, the OS platform being either Windows or Linux, and GeoJSON as the main format for spatial data representation;
    - Front-end technologies: HTML5 which includes JavaScript and CSS3, Metronic UI package for themes and layout rendering, OpenLayers (version 6) for spatial visualisation, thus providing support for the mainstream web browsers, i.e. MS Edge, Google Chrome, and Firefox.
- Defining the system's architecture pattern;

- Generating the software's development documentation, i.e. the system sequence diagram, entity relation diagram, state machine diagram, etc.

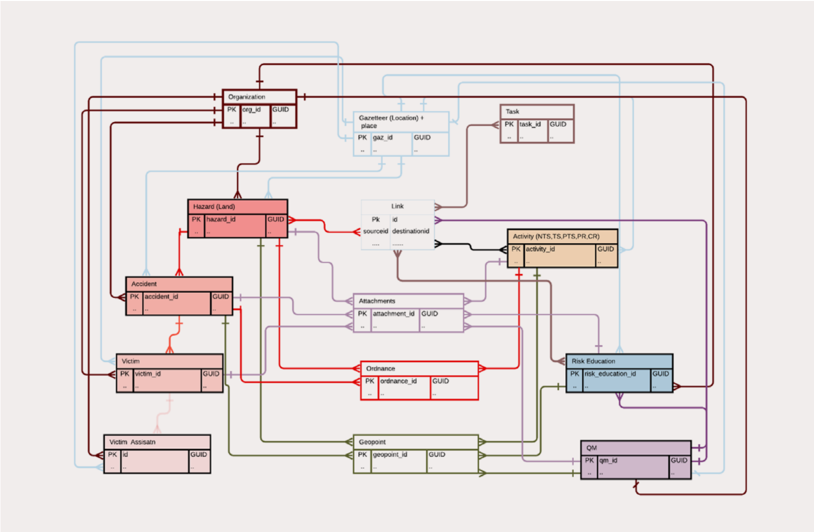

Figure 4.16 – Open-source IMS database conceptual schema (iMMAP 2021)

2. Development: all the solutions and models from the design phase were implemented in the system database and web application development.

3. Testing and verification: testing the completed IM system as a whole and through the verification process to ensure that the final system meets the client's requirements and specifications in terms of business logic and functionality.

4: Deployment: iMMAP deployed the pilot system to the production environment at IKMAA's offices in Erbil to facilitate testing of the new IMS by different user types in IKMAA. Deployment of the pilot system aids in the identification of additional functional and non-functional requirements that did not surface during the initial system design. IKMAA staff received initial training in the use of the new system, with additional users to be included in Phase 3.

5. Maintenance: following up users' requirements after system deployment and applying code updates as needed for issues discovered following the deployment.

PHASE 3 – MIGRATION OF IKMAA DATA TO THE NEW SYSTEM AND TRAINING IN THE SYSTEM

In this phase, we start with the main data migration process, as during Phases 1 and 2 we migrated the IMSMA auxiliary data to the new system, which are labelled as support tables in the new IMS. The migration process focuses on mapping the extensive data tables and CDFs in the IKMAA IMSMAng database to a more streamlined database architecture in the new system. The data migration will include the migration of the IMSMAng Info versions of data to the new system's record change tracking mechanism.

A monolithic system architecture was selected for the new IMS, which means that the user interface and data access / manipulation code are combined in a single package, as opposed to abstracting the data access and manipulation code from the user interface code. However, the system functions are logically grouped and thus see the component units isolated according to the tasks' focus, with the application settings and configuration files separated from the main package to restrict access to the relevant user permission level.

The following user types are designed to operate in the system in its entirety with specific roles designed for each user type:

1. System administrator
    - Create new user and modify existing users;
    - Grant permissions for system users;
    - Import data from external data sources;
    - Export data from the system.
2. System super administrator
    - This user type has all the system administrator permissions, in addition to:
    - Changing system configurations and settings; and
    - Creating new projects.
3. Form creator
    - Creating new data entry forms and deploying or activating the forms for general use;
    - Modifying or deactivating existing forms.

4. Form supervisor
    - Reviewing and approving newly added records;
    - Reading and writing access to all records belonging to users under their supervision.
5. Form data entry
    - Adding new records to the forms that they have permission to access;
    - Editing and disabling all existing records that they have permission to access.

Following on from the completion of the pilot phase with the IKMAA Erbil offices, the system will be made available to the remaining IKMAA offices spread across the region and user training will be provided to the new users. Whilst it is expected that the increase in system users will lead to the identification of improvements or refinements to the business logic, these are not expected to have a critical impact on the base system and will be reviewed with all the stakeholders prior to implementation.

LESSONS LEARNED

In selecting the system components, it was found that while IKMAA staff have strong technical foundations in RDBMS and the overall management of IT and IM systems, the use of a Windows-based web application hosting platform would simplify the management and maintenance of the system components.

The limited funding available to IKMAA for the implementation of new IM systems dictated a pragmatic approach to the selection of the system components, hardware requirements, and the tools required by IKMAA to manage the system components and the source code. The selected components can be administered easily using an advanced text editor such as Notepad++, while the source code can be updated with a freeware integrated development environment such as Apache NetBeans.

The internet bandwidth capacity, stability, and coverage is the key risk indicator that poses a concrete restriction on the amount of multimedia and text data that can be transferred between a web server and its users across the region. This limitation underpinned the decision to reduce the use of images and multimedia to the lowest acceptable level and utilise JavaScript and Cascading Style Sheets to style the web application components, generate charts, and provide a pleasing interface for the system users.

The system development used a mixture of the waterfall and iterative development approaches, by starting with the system foundation development using a systems engineering approach, and switching to an iterative approach for the rapid development and user acceptance testing of the various back-end and front-end components of the web application. Regular meetings with IKMAA and the GICHD allowed the stakeholders to provide concrete and relevant input to the design of the web application, both at the onset of the system design and during the implementation process. The base system was deployed at IKMAA's Erbil head offices to allow for regular interaction and testing of the system, thereby allowing IKMAA to gain in-depth exposure to the new system and take ownership at an early stage. This positively impacted on the change management that is required by IKMAA to embrace the new system. The local implementing partners will also form part of the user acceptance testing to ensure that all stakeholders can contribute to the development of a robust system that works for both the national authority and other stakeholders.

The intermittent internet connectivity necessitates the adoption of a multi-location deployment of the new system, with a stand-alone node to be installed at a regional mine action centre. Based on IKMAA and iMMAP's extensive experience with the synchronisation of IMSMAng databases, the choice was made to normalise the database to the third normal form to simplify the data synchronisation between the two deployments.

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