Information-flow Quality Determinacy

By

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ABSTRACT

Background: Information-flow is derived from the theory of information and is about understanding how a piece of information travels from one place to another. The quality of information-flow can impact both information-flow improvement associated with improved performance, and information-flow failure associated with errors of information-flow and decreased performance. Information-flow quality metrics are important to measure information-flow and are useful for identifying the characteristics of information-flow that are desirable or undesirable.

Problem: Using healthcare as an exemplar, the consequences of healthcare information-flow failure impact patient safety and incur financial costs to the healthcare system. For example, failure in healthcare information-flow can result in human error by omissions and commission, which can result in clinical and other management errors. As such, there is a need to measure and understand information-flow to identify desirable and undesirable information-flow characteristics so that information-flow failure can be negated, and outcomes improved. This research investigated whether a healthcare information-flow framework could be developed to measure information-flow and whether information-flow quality metrics could be developed to characterise information-flow as desirable or undesirable.

Method: A Design Science Research Methodology was used to investigate the problem and develop a solution in the form of a framework. The research design consisted of multiple research methods in two stages, Stage 1 used a three-phased framework development approach, and Stage 2 used a three-phased framework refinement approach. The framework development approach included a scoping review, case study analysis, and the development of a capability maturity matrix. Subsequently, in the framework refinement Stage, the information-flow maturity framework was validated through an initial desk study, semi-structured interviews, and validation was confirmed through the final desk study.

Findings: The information-flow framework was devised using medication management and pathology as the area for investigation and as an exemplar. The outputs of this research are a healthcare information-flow maturity framework, which includes defined desirable and undesirable information-flow characteristics, a calculator tool as well as an updated definition of information-flow extended from the literature.

Impact: This research contributes to the existing literature and knowledge on information systems theory and information-flow research. No evidence could be found to indicate to suggest the development of an information-flow maturity framework with desirable and undesirable information-flow characteristics has been done before. The information-flow maturity framework has the

potential to be used by process administrators and quality improvement officers to measure their organisations' current information-flow maturity to inform improvement activities. Further, the significance of the framework to address common issues in healthcare caused by information-flow failures and the subsequent effect of those on patient safety using a maturity model to assess and improve healthcare information-flows, is likely to have a significant impact on patient outcomes, morbidity, and mortality.

DECLARATION

I certify that this thesis:

1. does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university

2. and the research within will not be submitted for any other future degree or diploma without the permission of Flinders University; and

3. to the best of my knowledge and belief, does not contain any material previously published or written by another person except where due reference is made in the text.

Signed: Rebecca Hermon

Date: 11/05/2023

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I dedicate this thesis to my dad Gordon who passed away in 2017. He was a caring and loving father who always supported my academic research and was always keen to read my essays and articles. Finally, I would like to thank the Lord for giving me the opportunities and blessing me with a caring and loving support network to help me through this journey.

LIST OF PUBLICATIONS

Career Publications:

1. Hermon, R & Williams, P.A.H. (2014). Big Data in Healthcare: What is it used for?. 3rd Australian eHealth Informatics and Security Conference, held on the 1-3 December, 2014 at Edith Cowan University, Perth, Western Australia SRI Security Research Institute, Edith Cowan University, Perth
2. Hermon, R & Kempt, N. (2020). The Potential of Digital Transformation to Enable Flattening of Army's Organisational Structure and Enhance Overall Performance. Unclassified (DST-Group-TN-1987). Edinburgh: Department of Defence Science and Technology
3. Hermon, R, Williams, P.A.H & McCauley, V. (2021). Software as a Medical Devices (SaMD): Useful or Useless Term?. Proceedings of the 54th Hawaii International Conference on System Sciences (pp.3722-3731). Hawaii: HICSS
4. Hermon, R & Williams, P.A. H. (2013). A Study on Information Induced Medication Errors. 2nd Australian eHealth Informatics and Security Conference, held on the 2nd-4th December, 2013 at Edith Cowan University, Perth, Western Australia SRI Security Research Institute, Edith Cowan University, Perth. DOI: 10.4225/75/57981e4131b42
5. Hermon, R (2019). Information-flow Points of Failure: A Systematic Review of Medication Use Cases. Poster Presented at the 2019 HIC Conference: Melbourne: HIC
6. Hermon, R & Williams, P.A. H. (2020). Points of Failure: A systematic review of information-flow using medication use cases. Proceedings of the 53rd Hawaii International Conference on System Sciences (pp.3862- 3870). Hawaii: HICSS. DOI: 10.24251/HICSS.2020.472

GLOSSARY

Exploratory Case Study Analysis Method: To "illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result" (Yin, 2018, p. 17).

Exploratory Case Study Analysis Method includes (Yin, 2012):

1. Identify texts to be used for case study
2. Review each text and record key notes
3. Analyse documents
    a. Purpose of metrics discussed
    b. Definition of metrics
    c. Industry/ area applied to/ in
    d. How this gives you metric boundaries or how you can use this for the boundaries
    e. Why it should be considered for information-flow metrics.
4. Compare and contrast texts.

Capability Maturity Model: "a structured collection of elements that described characteristics of effective processes" (Kasse, 2004, p. 31).

Desk Study: A desk study also known as desk research or secondary research uses pre-existing data such as published materials, published reports, statistics, online sources, government or agency reports, online journal articles, databases, libraries, conferences and even lectures and expert talks (Morris & Largan, 2019).

Healthcare Administration: The process of administration work that includes data entry and record keeping for the purpose of recording medication history, patient history, clinical records, documentation, and result.

Healthcare Information-flow Maturity Framework: An assessment tool used to measure information-flow characteristics of the Clinical Process.

Health IT System: "combination of interacting health IT (3.3.6) elements that is configured and implemented to support and enable an individual or organization's (3.1.8) specific health objectives" (ISO/FDIS 81001-1:2020, p. 6).

Health Information Technology: "documented and intended application of information technology for the collection, storage, processing, retrieval, and communication of information relevant to health, patient care, and well-being" (ISO/FDIS 81001-1:2020, p. 4).

Hermon Model: An Information-flow Framework developed during the Honours Research (Hermon & Williams, 2020). which incorporates several clinical process stages, in which information-flow failures can be mapped. Includes where the failure started, how it started, why and the outcomes of the failure.

Information-flow: The following definition of information-flow is an aggregation of the literature review. Information-flow is how information is communicated from one place to another. This could be from system to system, system to person, or person to person. Information-flow requires an understanding of information-flow dimensions and social, technology, security, governance, IT business alignment and operational context, and understanding of information-flow metric characteristics (coverage, relevancy, usability, availability, reliability, security, and quality assurance).

Information-flow Maturity Framework Development Method: A two staged Design Science methodological approach to developing, refining, and validating an information-flow maturity framework. Stage 1 includes Phase 1 – Scoping Review, Phase 2 – Exploratory case study analysis, Phase 3 – Capability Maturity Modelling. Stage 2 includes Phase 1 – Desk Study method, Phase 2 – Semi-structured interviews and Phase 3 – Desk Study method.

Information Systems: "Information system (IS) The entire set of software, hardware, data, people, procedures, and networks necessary to use information as a resource in the organisation" (Whitman, 2012, p. 588). This definition includes computers, electronic systems, and people.

Medication Administration: The process of prescribing and administrating medication to patients.

Metrics: A metric is a standard of measurement. It is dependent on the context, and the goal of the measurement.

Medication Error: An act by a health care professional/ patient that has resulted in a preventable mistake regarding medications that can occur throughout the various stages of the clinical process.

Scoping Review Method: A method which involves searching the literature based on search terms, categorising themes, and analysis (Peters, 2015).

Sociotechnical ecosystem: The impact of a connected and complex healthcare ecosystem is not limited to the health software and health IT systems. It is important to consider the larger sociotechnical environment (Figure 3) and the potential impact to safety, effectiveness, and security that can arise in each part of the ecosystem and through the interaction of these parts. This ecosystem includes:

a) The health IT infrastructure (for example, hardware, software, networks, interfaces to other systems, medical devices, and data), and the organizations involved in developing, implementing, and operating the many health IT components and services,

b) The healthcare delivery context (for example, the clinicians, patients, and other people involved, clinical workflow, and the specific organization setting where the health IT system is being deployed), and

c) The broader healthcare system (for example, regulations, funding, and policy implications) within which the HDO (and its supporting health IT systems/infrastructure) must comply and operate. (ISO/FDIS 81001-1:2020, p. 12).

CHAPTER ONE: INTRODUCTION

1.1 Background

Previous research by Hermon and Williams (2020) examined failure of medication information-flow, which prompted this investigation into common failures in healthcare information-flow with specific exemplars from medication management and pathology. Information-flow is derived from the theory of information and is about understanding how a piece of information travels from one path to another. Further, information-flow failure may contribute to poorer patient outcomes while improvement may lead to better patient outcomes. An example of the consequences of information-flow failure was established by Hermon and Williams (2020), which found that information-flow failure resulted in preventable medication errors that caused patient harm, such as hospitalisation and death. Likewise, the potential benefits of improving information-flow in healthcare are improved patient care and outcomes along with reduced costs associated with errors. A key to further understanding the impact of information-flow failure is through information-flow measurement. Information-flow measurement is important in identifying desirable and undesirable information-flow characteristics. Once information-flow and its applicable characteristics have been measured, implementations or strategies can be introduced to improve the characteristics that result in more efficient information-flow and potential associated benefits.

Timeline of Research

Honour research: A systematic review of information-flow using medication use cases. This research investigated information-flow in General Practice by developing an information-flow model for medication case management. This provided foundational and background research into information-flow.

PhD Research: This research focuses on measuring information-flow through the development of an information-flow capability maturity model.

1.2 Research Problem

The concept that an information-flow framework which can be evaluated using defined metrics, has yet to be investigated. Once developed, such a framework can be used to identify and measure healthcare information-flow failure. Without such tools, no clear understanding of how informational-flow failure impacts patient outcomes can be assessed. Therefore, this research has focused on understanding and measuring information flow within a defined framework and how using this to improve information-flow characteristics can improve patient outcomes.

1.3 Purpose of the Study

The purpose of this study was to further understand information-flow and identify a method to measure information-flow maturity. This study was designed to explore the characteristics of information-flow in order to assess a validate method of maturity in order to assist in preventing information-flow errors.

1.4 Importance of the Topic

Using healthcare medication and pathology errors as an exemplar, the consequences of information-flow failure and impact on patient safety were identified along with the financial costs to the healthcare system. For example, information-flow failure may be caused by human error omissions/ commission, which can result in medication errors. Measuring and understanding information-flow allowed identification of desirable and undesirable information-flow characteristics so that information-flow failure could be negated. The information-flow maturity framework has the potential to be used by process administrators and improvement officers to measure their organisations' current information-flow maturity to inform improvement activities.

The initial literature review identified essential gaps in the literature, especially regarding the lack of information-flow and lack of information-flow metrics research in healthcare. This also identified that no information-flow maturity framework had been found in the literature. While no standard definition for information-flow currently exists, a definition was selected for this thesis. The literature review identified that there is little research using the term information-flow. However, information-flow is contextual, and related concepts exist in the literature such as communication flow. While workflow was also identified as a proxy for information-flow on the basis that the similarities between workflows and information-flow may be used for developing an information-flow framework that may be used in different environments to measure information-flow failure. The literature review then explored measuring information-flow and the importance of information-flow standards and metrics. However, it also identified a lack of a standard definition for information-flow metrics. An information-flow metric definition was selected that was fit for information-flow research. In addition, the literature review identified that no previous study had developed metrics to measure healthcare information-flow failure, and there is a gap in the development of metrics to validate information-flow models and evaluate the quality of information within information systems. Following, the initial literature review, an exploration of why information-flow is important was undertaken through a discussion of the known issues caused by information-flow failure with specific healthcare examples. A key finding was that research investigating the impact of information-flow on patient misidentification is missing; subsequently, little is known regarding how information-flow can reduce patient misidentification. The literature review identified many technologies are either semantically confused or overlapping and consequently explored how information-flow could be improved through information-flow mapping, information-flow models and capability maturity models. However, it was discovered that there is a lack of information-flow mapping instructions and standards in the literature. Further, exploration of relevant model mapping revealed methods such as data flow and process mapping, which can be used to map information-flow, and further illustrated the lack of standard information-flow terminology in the literature. The importance of information-flow terminology also extended to the terms model and framework, as in the literature, the terms model and framework are often used interchangeably. Many frameworks and research did not specifically mention information-flow, however, and the published research revealed that information-flow improvement was involved as the models were used to improve information-flow within their context. The inability to differentiate between information-flow models and frameworks as well as the limited research and models that use the term information-flow, highlight the importance of information-flow terminology for information-flow understanding and research. In addition, the capability maturity models all have the aim of improving processes which impact information-flow. Although, many do not mention the term information-flow, these models improve processes which subsequently result in improved flow of information within those processes. No previous study was identified that had developed metrics to measure information-flow failure, nor had a framework or model been explicitly developed for information-flow metrics and characteristic in healthcare. Without information-flow healthcare metrics, it is difficult to evaluate benefit or harm of information-flow change. Further, this review has identified a gap in the development of metrics for the purpose of validating information-flow models and evaluating the quality of information within information systems. These knowledge gaps are the subject of the research described in this thesis. As such, this thesis aimed to address the lack of information-flow maturity framework in the literature by solving the following research questions in order to fulfill the literature gap.

1.5 Research Questions

Research Question: Can a healthcare information-flow framework be developed that can identify information-flow failure and demonstrate the framework's effectiveness in healthcare?

Sub Question: How can healthcare information-flow metrics be identified and measured?

This research involved analysis of information-flow and the development of information-flow metrics to identify and understand what measurable information-flow characteristics are desirable and undesirable. As such, an information-flow maturity framework was devised that includes instructions for using the information-flow maturity framework, an information-flow capability maturity matrix, supporting information-flow characteristics, a calculator tool to measure the information-flow characteristics and a suggested improvement table.

1.6 Objectives of Project

The objective of this research was to develop a healthcare information-flow framework that could improve information-flow by measuring the maturity of the process. The framework's purpose was to measure information-flow in healthcare where failure leads to suboptimal outcomes using medication management and pathology as exemplar domains. As such, this information-flow maturity framework has the ability to measure information-flow characteristics and fulfils the gaps in literature related to information-flow measurement.

1.7 Significance

This research built upon previous research by Hermon and Williams (2020) which developed an information-flow framework (Hermon Model) that could map information-flow failure in a General Practice setting. The significance of the Hermon model was that it contributed to ongoing research into the safety of health software by identifying information-flow failure in desktop medication management processes. While this research specifically investigated information-flow within a General Practice setting, it was a foundational step for understanding information-flow in healthcare and developing the concepts for the current research. In developing an information-flow maturity framework for use in healthcare, this research adds to the current literature on understanding information-flow and information-flow maturity. The benefits from this research include the development of evidence-based information-flow characteristics using a non-prescriptive information-flow framework that can measure information-flow maturity and provide guidance on improving information-flow. Using healthcare medication and pathology errors as an exemplar, the consequences of information-flow failure and impact on patient safety were identified along with the financial costs to the healthcare system. For example, information-flow failure may be caused by human error omissions/ commission, which can result in medication errors. Measuring and understanding information-flow allowed identification of desirable and undesirable information-flow characteristics so that information-flow failure could be negated. The information-flow maturity framework has the potential to be used by process administrators and improvement officers to measure their organisations' current information-flow maturity to inform improvement activities. Additionally, the information-flow maturity framework can be applied to different organisations and domains. While opportunities relating to the medication error exemplar include use during reporting and post-incident investigation of medication errors to further understand the undesirable information-flow characteristics that result in errors. This framework has application and relevance to address common issues in healthcare caused by information-flow failures, and the subsequent effect of those on patient safety using a maturity model to assess and improve healthcare information-flows and is likely to have a significant impact on patient outcomes, morbidity, and mortality.

The structure of the thesis is as follows:

- Chapter Two: Literature Review - This chapter is the initial literature review to understand the current research into information-flow and understand the gaps of literature review.
- Chapter Three: Methodology – This chapter outlines the methodology and methods used for this research.
- Chapter Four: Stage 1 - Framework Development – this chapter has focus on developing the information-flow framework to answer the research questions through a scoping review of the literature.
- Stage 2: Framework Refinement and Validation
    - Chapter Five: Phase 1 – Initial Desk Study – This chapter has focus on initially validating and testing the framework through using a desk study method.
    - Chapter Six: Phase 2 – Semi-Structured Interviews – This chapter discusses the interviews that took place to validate and refine the framework.
    - Chapter Seven: Phase 3 – Final Desk Study – This chapter outlines the final validation and refinement of the framework through a desk study method.
- Chapter Eight: Discussion – This chapter outlines the findings and final framework developed.
- Chapter Nine: Conclusion – Incorporates a summary of the research taken, significance and learning and reflections.

CHAPTER TWO: LITERATURE REVIEW

This research aimed to understand how information-flow failure could be measured to improve healthcare information-flow. A critical literature review was undertaken to understand previous work on information-flow within a healthcare context. Shown in *Figure* 1 are the literature review topics critically analysed in this chapter. The chapter begins with an introduction on what information-flow is, specifically drawing attention to identifying current definitions to provide a standard for this research. The literature review then describes how information-flow is measured and why information-flow is important to healthcare and information systems. This is followed by a detailed discussion on how information-flow can be improved. Finally, the review concludes with a discussion on the gap in this discourse that led to the research questions addressed in this thesis.

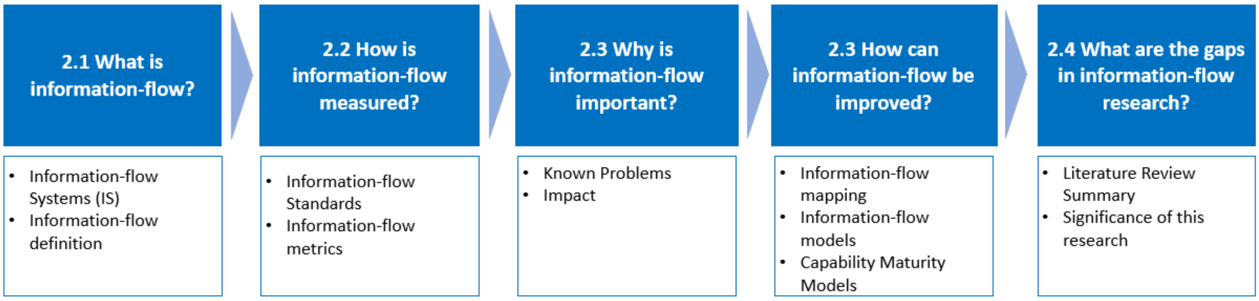
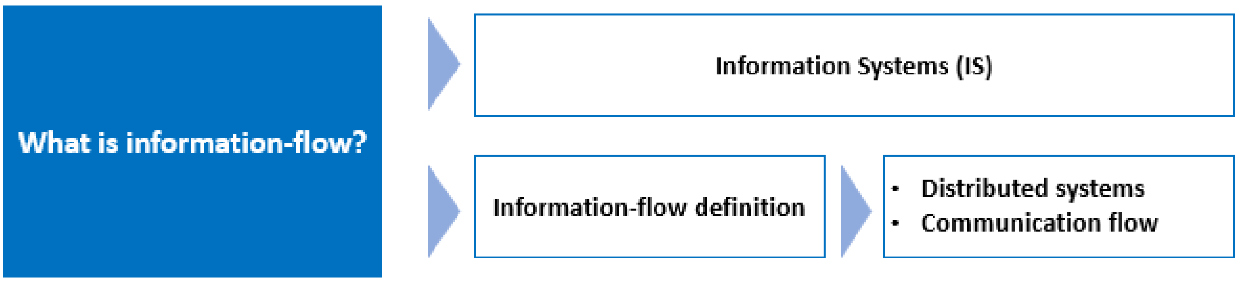


***Figure 1*. Information-flow Literature Review Topics.**

2.1 What is information-flow?



The following section includes a description of information systems, a definition of information-flow and a discussion on how distributed systems and communication flow relate to information-flow.

2.1.1 Information Systems (IS)

To understand the importance of information-flow, it is necessary to understand the context in which information-flow exists, which includes an understanding of information systems (IS). According to Desautels (2011) information systems refer to ‘’integrations of information technologies" and, as such, are used to achieve a specific result (Desautels, 2011, p. 186). Essentially, Desautels' (2011) definition means that information systems are created from devices, services, software applications, networks and information and have the purpose of assisting decision-making (Desautels, 2011). As Huryk and Park et al (2015) suggested, information systems are not exclusive to one domain, meaning they are applicable across multiple environments or industries. Further, information systems use refers to the "extent that a user utilizes the IS to carry out tasks and activities on the job for which the information system is designed to support" (Sun & Teng, 2012, p. 1565). Notably, the definitions by Desautels (2011) and Sun & Teng (2010) show that information systems consist of various technologies that communicate within a domain, to assist a user with a particular activity. However, as Park et al (2015) indicate, it is essential for these systems to have the correct information; otherwise, they become ineffective. As such, a quality assurance function called information assurance exists. **Information assurance** is defined as "the certainty that within an organization, information assets are reliable, secure, private, accurate and available" (Park et al., 2015, p. 321). The importance of information assurance in information systems can be demonstrated in the healthcare domain.

In the context of in-hospital healthcare, hospital clinical information systems are used to assist clinicians to improve clinical decision-making and can be defined as "a set of components and procedures organized with the objective of generating information which will improve healthcare management decisions at all levels of the health system" (Park et al., 2015, p. 326). In addition ISO/FDIS 81001-1:2020 defines a Health IT System as a "combination of interacting health IT (3.3.6) elements that is configured and implemented to support and enable an individual or organization's (3.1.8) specific health objectives" (ISO/FDIS 81001-1:2020, p. 6) and has further defined the sociotechnical ecosystem to include the health IT infrastructure (the IT involved), healthcare delivery context (the people involved), and the broader healthcare system (governance, policies and regulations) (ISO/FDIS 81001-1:2020) which is shown in *Figure 2*.

This image has been removed due to copyright restriction. Available online from ISO/FDIS 81001-1:2020, p. 14.

Figure 2. **ISO/ FDIS definition of System of Systems (ISO/FDIS 81001-1:2020, p. 14).**

Huryk (2012) suggested that the information systems need to be designed so that the primary focus is to record data and reproduce information to be functional and integrated into clinical workflow. Huryk (2012) further suggested that the constant flow of reliable information in healthcare benefited nursing abilities and enhanced decision-making processes. An example of information system benefit are those from an Electronic Medical Record (EMR), highlighted by Huryk (2012) to benefit researchers, professionals, providers, third party payers, government agencies and families by enabling nurses to collect organised and reliable information that is constantly available.

2.1.2 Information-flow definition

Information-flow is the concept in which users receive information within an information system. Table 1 illustrates several definitions identified in the literature.

Table 1. Information-flow Definitions.

Reference	***Information-flow Definition***
(Alvim et al, 2020, p.vii).	Information Flow is the transfer of information from a source (who knows the information) to a target (who does not know it yet).
(Kolinski et al, 2020, p. 163)	information flow uses data and documents to describe the communication between production and controlling processes.
(Bremer, 2004, p.10)	The theory of information flow is concerned with deriving some piece of information from another.
(Hainaut et al, 2013)	In a workflow (and particularly in a care path), an information flow is a particular view that focuses on the path followed by information entities. For instance, this view specifies of which processes a document is an input and an output.
(Van der Meyden & Zhang, 2013, p. 68)	"Information flow security is concerned with the ability of agents in a system to make deductions about the activity of others, or to cause information to flow to other agent".
(Ahlswede et al., 2000, p. 1204)	Network information flow is "a point-to-point communication network on which a number of information sources are to be multicast to certain sets of destinations".

Alvim et al's (2020) definition relates to information-flow security. It states, "Information Flow is the transfer of information from a source (who knows the information) to a target (who does not know it yet)" (Alvim et al, 2020, p.vii). While Kolinski et al's (2020) definition relate to supply chain management and states, "information flow uses data and documents to describe the communication between production and controlling processes" (Kolinski et al, 2020, p. 163). The example definitions by Kolinski et al's (2020) and Alvim (2020) show that there are different definitions of information-flow depending on the context. As this thesis looks at understanding and improving information-flow it was essential to adopt a definition of information-flow to act as a standard for this research. As such, there were many shortcomings of the definitions listed in Table 1, such as a simple and broad definition to ensure all aspects of information-flow were included, and which could be applied to healthcare. The information-flow definition chosen for this research was an aggregation of the literature review and was chosen for this research on the basis it included not just an understanding of how a piece of information travels but the theory of information. This was an important component for understanding information-flow and the concepts surrounding information-flow.

Information-flow Definition: Information-flow is about the theory of information and the semantic context of how information is communicated from one place to another. This includes how information travels from its original location to its intended recipient (*Figure 3*).

Figure 3. **Information-flow definition adapted from literature.**

In addition, the flow of information requires the "logic of distributed systems" (Bremer, 2004, p. 177), which contain separate parts for the information to flow from A to B. According to Saini & Yadav (2015) distributed systems refer to new applications, hardware, network components and workload change. They are about the communication of information through computer and web networks (Saini & Yadav, 2015). An example of distributed systems is Brown et al's (2010) investigation into distributed networks regarding electronic health records and health information. The study by Brown et al (2010) implemented a pilot distributed system, which resulted in evaluating medication use and diagnosis trends at five different sites. The research conducted by Brown et al (2010) demonstrated how distributed systems could collect and use electronic healthcare data for patient delivery, showing the real-life application and significance of distributed systems. Further, a closer look at Bremer's (2004) distributed system definition reveals that these distributed systems are also information systems, meaning that information-flow is contained within distributed systems. This also revealed that the literature on information-flow did not adequately consider semantic content; much of the literature specifically related to communication flow, which is a key component of information-flow as evident in the definition of information-flow by Kolinski et al (2020). Therefore, to further understand information-flow the following section discusses communication flow concepts which show only semantic differences to information-flow.

2.1.3 Communication Flow Models

Having defined information-flow, it is now necessary to examine communication flow and its relationship to information-flow. Communication is defined as the "transmission of information" (Ma, 2015, p. 21) and is an important component of information-flow as it facilitates the flow of information. According to Ma (2015, p. 15) there are three methods of information communication. They include:

- Nature-Nature communication (communication information exchanges between objects);

- ➢ Human-nature (communication information exchanges between an object and a person); and
- ➢ Human-human (communication information exchanges between a person and a person).

The terms communication flow and information-flow are semantically different; however, in the literature, they are often used interchangeably as they refer to similar concepts. Therefore, for this thesis, it is essential to highlight that the focus is on information-flow; however, concepts for communication flow have been used as they align with the information-flow and information system definitions. The following discusses Ma's (2015) four communication flow models that map the flow of communication. These communication flow models are important for identifying the communication process in graphical form and show the different ways communication can be shown.

Figure 4 shows the first communication model - the Shannon-Weaver Model (Shannon,1948) of Communication. According to Ma (2015) it was designed for signal transmission between machines and shows the information source flowing from the encoder to the decoder and then to the information sink. However, while this model is useful for illustrating signal transmission between machines it fails to depict other aspects of information-flow such as the human component and semantic content.

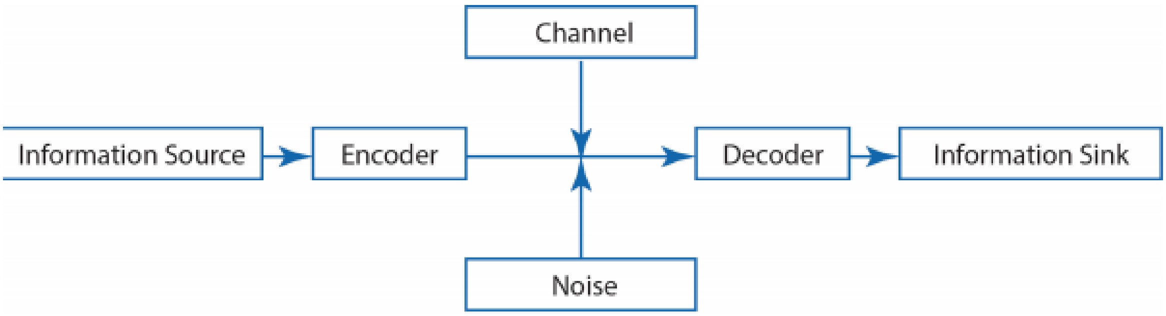


***Figure 4.* The Shannon-Weaver Model of Communication adapted by Ma (2015, p. 24) and originating in Shannon (1948).**

Figure 5 shows a second communication model - the Lasswell 5W's model (Lasswell, 1948). This model focuses on reviewing communication between humans and does not include other factors in information systems, such as noise. This model includes the sender, the information, the type of information, and the impact of the communication.

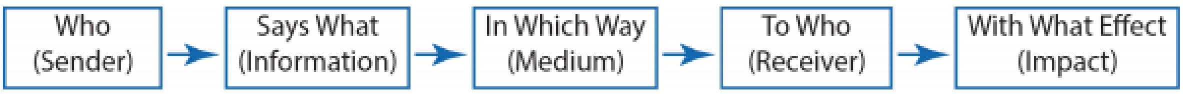


***Figure 5*. Lasswell's 5W model adapted by Ma (2015, p. 24) and originating in Lasswell (1948).**

Figure 6 shows a third model - the Schramms model. The Schramms model (Schramm, 1955) includes communication between two entities and highlights the process of communication. The Schramms model better articulates the flow of information compared to the Shannon-Weaver Model and Lasswell 5W model (Lasswell, 1948) on the basis, that it illustrates several factors relating to the flow of information. In particular, the Schramms model shows the information source, media (how it was transferred), audience and feedback to the information source.

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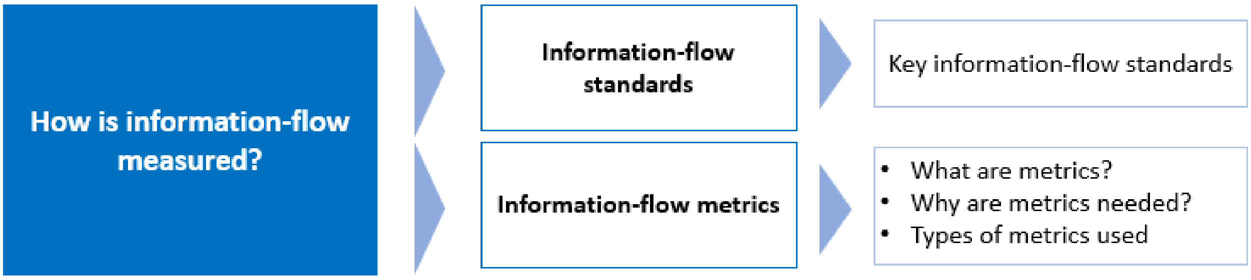
***Figure 6.* Schramms model adapted by Ma (2015, p. 35) and originating in Schramm (1955).**

Lastly, shown in *Figure 7* is the Vickery's S-C-R communication model, which highlights communication as a process that starts with a source and ends with a recipient. This is the most simplistic communication flow model and does not illustrate important detailed factors that the Schramms model includes. It should be noted that the Schramms model does not mention noise which is an important aspect of healthcare information-flow and is included in the Shannon-Weaver model. Noise refers to "all interferences on the correct transmission of information that are unintended by the parties, which may originate from malfunctions in machinery, or external factors" (Ma, 2015, p. 23). Noise is very influential in information-flow in healthcare and causes information distortions or interruptions in healthcare that may cause information-flow failure.

***Figure 7.* Vickery's S-C-R communication model adapted by Ma (2015, p. 26).**

Figure 4 to *Figure 7* show four communication flow models depicted by Ma (2015). Each model illustrates the communication flow at different levels of detail from a sender or source point to a recipient point. These four communication flow models are important as they show the semantic context of information-flow. This semantic difference illustrates a lack of standard and common terminology for information-flow in the literature and highlights the limited research on information-flow specifically. Having explained and defined information-flow, the following section will discuss how information-flow is measured and why measurement of information-flow is important.

2.2 How is information-flow measured?



The following section explores information-flow standards in the literature and how they play a role in information-flow measurement.

2.2.1 Information-flow Standards

Information-flow Standards play an important role in information systems describing a standard method for information-flow behaviour in information systems. Identifying the current information-flow standards is an important step in measuring information-flow as the information-flow measurement will be compared to an ideal or standard behaviour. Additionally, many standards aim to encapsulate best practice and when correctly implemented may lead to improvement. Table 2 summarises such Standards.

Table 2. Summary of key Standards for information-flow.

Standard	***Description***
Health Informatics — Terminology resource map quality measures (MapQual) ISO 21564 Standard (ISO, 2019)	The International Organization for Standardization (ISO) is an international developer for standards. As developers they have produced standards for healthcare and in particular health informatics. The ISO/TS 21564:2019 aims to be a health informatics terminology resource map quality measure (MapQual) that lists terminology standards for health informatics and use in health information-flows.
ASQHC Information Model (ACSQHC, 2022)	The Australian Commission on Safety and Quality in Healthcare (ASQHC) is an Australian Government agency that aims to assist healthcare through coordinated national improvements in safety and quality. They have developed a conceptual model for comprehensive care.
HL7 Reference Information Model (RIM) (HL7, 2022)	HL7 have developed an American National Standards Institute (ANSI) standard and Information Model for representing clinical data domains as an object model (HL7, 2017). This model is known as the Reference Information Model (RIM) v 2.47.
Clinical Information Modelling Initiative (HL7, 2022)	The purpose of the HL7 Clinical Information Modelling Initiative (CIMI) is to “improve the interoperability of healthcare systems through shared implementable clinical information models” (Riehl, 2015).
Object Management Group (OMG, 2022)	The Object Management Group (OMG) is an international association that develops standards for different domains and technologies. It uses end-users and vendors to manage the development of these standards. One standard which has been developed is the Interaction Flow Modelling Language (IFML). This is a language for

	developing models and is used for developers to map the flow of interaction between data objects and events (OMG, 2016).

The following expands on the Reference Information Model (RIM), Clinical Information Modelling Initiative (CIMI) and Object Management Group (OMG) models mentioned in Table 1. MapQual is a health information-flow Standard and is important in providing terminology Standards for health informatics. Health Level 7 (HL7) is an international Standards Development Organisation (SDO) with a focus on healthcare interoperability specialising in Health IT and the creation and reviewing of e-health system Standards. HL7 has developed global Standards for healthcare applications that are used to measure and share healthcare data with other systems and applications. Interoperability within healthcare systems is important because it allows patient information to be shared amongst clinicians in different environments. According to Priyatna et al. (2017) this model is useful in presenting a solution for semantic interoperability based on the RIM. The HL7 RIM is an object model that represents the various clinical data domains and has the purpose of improving the interoperability of healthcare systems (Riehl, 2015). The object model represents the overall domains and models each domain individually (HL7, 2017). While this model is detailed, a limitation is that it is a complex and very abstract model that requires the viewer to understand the HL7 definitions and terms. Lastly, the Object Management Group is another SDO that aims to develop technological standards. IFML was developed by OMG (2016) to create usability models and represent contributing factors in a graphical user interface for applications, which can be used in desktops, laptops, smartphones, tablets, and PDAs. Further, IFML has a Meta Model, which is comprised of three different packages (Core, Extension, and Data types). This Meta Model utilises data types from Universal Modelling Language (UML) (Nielsen et al, 2000) meta models and includes events, expressions, content binding, view elements and other structures. In addition, IFML was designed to display an interaction model, domain model and viewpoints (OMG, 2016). The interaction model displays the application from a user perspective, while the domain model displays the business perspective including relationships, methods, and behaviours.

Standards have been discussed as their application may improve information-flow to ensure the information adheres to safe, consistent, and reliable requirements. Additionally, these Standards allow the development of information-flow models and frameworks which can map information-flow. Further, information-flow models are used to understand and identify information-flow and ultimately promote information-flow assurance. The following section discusses information-flow metrics and methods to measure information-flow.

2.2.2 Information-flow metrics

The following section discusses information-flow metrics - what they are, why they are needed, the type of metrics available and how to analyse metrics. The critical objective of information-flow is to understand how a piece of information flows and travels. This information must reach the intended recipient and be reliable, secure, private, accurate and available (Park et al., 2015). Information-flow metrics are required to identify whether information-flow assurance has been achieved and potentially improve information-flow. Metrics are important to discuss regarding information-flow as they provide a standard method to measure information-flow, which becomes essential when determining information-flow maturity (*Figure 8*) and information-flow improvement.

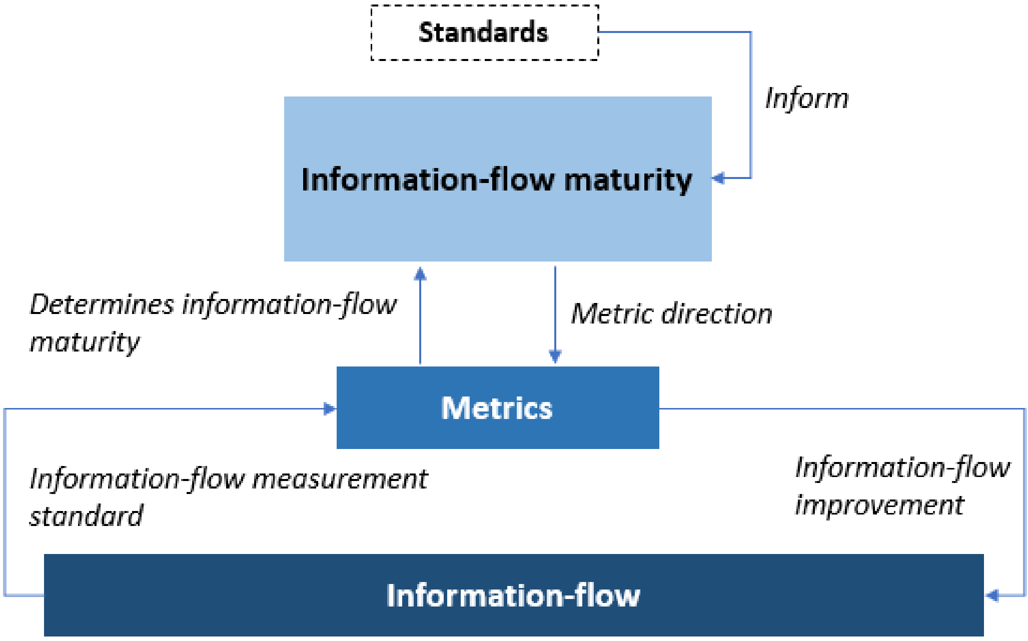


Figure 8. **Relationship between information-flow metrics and information-flow maturity.**

What are Metrics?

Table 3. Metrics Definitions.

Reference	***Metric Definition***
Hauser & Katz (1998)	"used by firms for a variety of commendable purposes" and are "used explicitly to influence behavior to evaluate future strategies, or simply to take stock, will affect actions and decisions" (Hauser & Katz, 1998).
Juneja (2015)	are numbers that tell you important information about a process under question. They tell you accurate measurements about how the process is functioning and provide base for you to suggest improvements" (Juneja, 2015).
Black et al (2009)	"tools to facilitate decision making and improve performance and accountability" (Black et a, 2009, p. 1).
Haydon (2010)	the act of judging or estimating the qualities of something, including both physical and nonphysical qualities, through comparison to something else" (Haydon, 2010, p. 27).

Shown in Table 3 are the several definitions of the term metric. Historically, Hauser & Katz (1998) suggested metrics are “used by firms for a variety of commendable purposes” and are “used explicitly to influence behaviour to evaluate future strategies, or simply to take stock, will affect actions and decisions” (Hauser & Katz, 1998). The benefit of the Hauser & Katz (1998) definition is that it refers to any metric and provides insights into how each firm choosing the right metric (context) is important and how it may impact decisions. In comparison, the definition by Juneja (2015) suggests metrics “are numbers that tell you important information about a process under question. They tell you accurate measurements about how the process is functioning and provide base for you to suggest improvements” (Juneja, 2015). Juneja’s (2015) definition is about Six Sigma, a framework used to improve the efficiency of organisations and suggests that metrics are accurate representations, while Hauser & Katz (1998) suggest that if the wrong metric is selected, the wrong measurements will be taken. While Black et al (2009) define metrics as the “tools to facilitate decision making and improve performance and accountability. Measures are quantifiable, observable, and objective data supporting metrics” (Black et al, 2009, p. 1). Black et al’s (2009) definition are about cyber security metrics to improve information technology. The benefit of this definition is that it incorporates aspects such as measures being quantifiable. While Haydon’s (2010) definition defines a metric as “some standard of measurement” (Haydon, 2010, p. 27). Although the simplest definition, this definition has been chosen as it is an easy-to-use definition that has been identified as applicable to information-flow. Haydon (2010) further explains this definition by depicting a metric as a result and measurement as an activity. Haydon (2010) additionally defines the term measurement as “the act of judging or estimating the qualities of something, including both physical and nonphysical qualities, through comparison to something else” (Haydon, 2010, p. 27) and does not limit measurement to quantitative data as does the Juneja (2015) definition. Although Haydon (2010) does not refer to healthcare specific, Haydon (2010) identifies a metric as an accepted standard of measurement and that the benefits of metrics are the development of predictions, frameworks, standardisation, fairness, refinement of descriptions, and a reduction in errors. (Haydon, 2010), which has relevance to the topic of developing a framework for information-flow.

Why are Metrics needed?

There are several reasons and purposes for a metric. According to Haydon (2010), Klubeck (2015) and Maurer (2013), these purposes are centred on the objective or goal of what the Metric will achieve. Examples of metrics purposes include to impact decisions, understanding relationship to profit, monitoring, safety, quality, stakeholder communication, the establishment of boundaries, measurement of performance, determining baselines, identifying trends, identify outcomes, assessment, prediction, improvement and many more (Hauser & Katz, 1998; Martin et al, 2015; Kerzner, 2017; Prentice et al, 2016; Chew et al, 2008; Savola, 2007; Tariq, 2012).

What are the types of Metrics used related to information-flow?

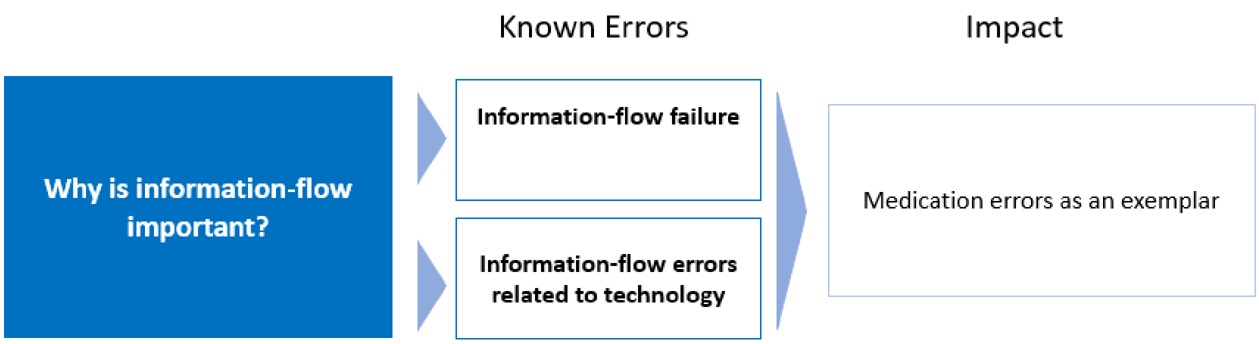
A review of the literature showed that there are both qualitative and quantitative metrics for security, information, and performance measurements. (Haydon, 2010; Hauser & Katz, 1998; Wang, 2005; Holman, 2009). The different metrics examples include Key Performance Indicators (KPIs), goals, actionable metrics, informational metrics, and vanity metrics. The term vanity metrics refers to metrics that can be measured but which do not matter as they are measured for appearances only (Spacey, 2017), and are important for awareness when measuring information-flow.

How to analyse metrics?

Metric analysis is dependent on the type of metric that is being measured. There are multiple analysis methods. Kluebeck (2015) suggests that marketing analysis, predictive analysis and statistical analytical tool methods can be used. Accordingly, it is important to document the analysis type and ensure the method is repeatable. (Klubeck, 2015). In comparison, Hayden (2010) suggests two types of metric analysis: applied and exploratory. Applied analysis aims to answer known questions, while exploratory analysis aims to find and answer new questions (Haydon, 2010).

While the literature contains substantial knowledge on metrics, it is important to highlight that in the literature no previous study has developed metrics to measure the benefit and failure of an information-flow framework for healthcare. Without information-flow in healthcare metrics, it is difficult to evaluate benefit or harm of information-flow. Further, this thesis addresses a gap in the development of metrics for the purpose of validating information-flow models and evaluating the quality of information within information systems. The next section will discuss the importance of information-flow.

2.3 Why is information-flow important?



The following section discusses why information-flow is important and outlines the known problems with information-flow and the impact of these known problems by using medication errors as an exemplar.

2.3.1 Known problems

Information-flow failure

The known problems of information-flow are related to information-flow failure. Information-flow failure is caused by information disruption. This can be problematic as information-flow has the purpose of transmitting information from one point to the other. However, if there is a disruption at any point of that information-flow, it can potentially result in information-flow failures. Causes of disruption include miscommunication between people (includes acts of omission or commission), disruption of flow between technological systems and people, and disruption in flow between technological systems. Other forms of information-flow failure include noise from work-flow interruptions, introduced misinformation, information corruption and media disruption, which has been defined as a "change of medium during the transmission of information within the transmission chain" (Tomanek, 2017, p. 83). Tomanek (2017) further suggests that mistakes during the information transmission can result in errors and redundancy. As shown in *Figure 9,* Tomanek (2017) has developed a value add heatmap for information-flow which in essence shows the value information-flow plays when there are no disruptions, where value is achieved through effective communication between processes. This heatmap is useful as it indicates that errors on the first level (Value Added Level 0) do not result in a loss of value. *Figure 9* also shows that limited value is added to written information exchange. This is in line with historical examples of illegible writing prior to the integration of computer systems causing errors and miscommunication (Magrabi, 2013). It is also interesting to note that higher value is associated with more digital exchanges of information.

This image has been removed due to copyright restriction. Available online from Tomanek and Schroder (2017, p. 86).

Figure 9. **Value added heatmap for information-flow taken from Tomanek and Schroder (2017, p. 86).**

Shown in *Figure 10* is the evolution of information-flow in relation to the industrial revolution. Kolinski et al (2020) has described the information-flow characteristics in alignment with the industry. It is interesting to note that a higher level of information-flow complexity characterises more advanced information-flow. However, it should be noted that technologically advanced information-flow contexts do not necessarily result in reduced information-flow failure. The next section will discuss information-flow failures that are related to technology.

This image has been removed due to copyright restriction. Available online from Kolinski et al (2020, p. 161).

Figure 10. **The evolution of information-flow according to digital industrial revolutions taken from Kolinski et al (2020, p. 161).**

Information-flow failures related to technology

There are many causes of information-flow failure related to ICT technology and healthcare system errors. For example, shown in *Figure 11* are the ICT technology issues that result in information-flow failure and ultimately impact patient safety (Kim et al, 2017).

This image has been removed due to copyright restriction. Available online from Kim et al (2017, p. 247).

***Figure 11*. Information value chain that shows IT problems and the results taken from Kim et al (2017, p. 247).**

According to Coiera (2013) and Sittig et al (2018) there is a correlation between ICT-related harm and ICT use and is due to a focus on technology rather than investigating the root causes of the errors (Coiera, 2013; Kim et al, 2017).

This image has been removed due to copyright restriction. Available online from Magrabi (2013).

Figure 12. **Health ICT errors are likely to increase with Health ICT usage. Different systems will determine the likelihood of opportunity for harm - Magrabi (2013).**

Sittig et al (2018), Ash, Berg & Coiera (2004) as well as Magrabi (2013) suggest the main causes of ICT technology and healthcare systems failures that cause harm are related to poor design and implementation, poor user interfaces, and software and hardware issues (*Figure 12*). Other causes of ICT technology failures are outdated, non-intuitive or non-user-friendly system interfaces which result in time lag and user error (Ash, Berg & Coiera, 2004). A common error in healthcare systems is juxtaposition errors which refer to the use of multiple screens open, resulting in clinical errors interpreting data in the wrong patient context (Ash et al., 2004). Other issues include multiple, repeated, and complex data entry requirements, multiple screens and applications being open, resulting in misinterpretation of information context or data entry into the wrong context as well as user information overload. According to Coiera (2013) it is common for patient safety to be impacted by ICT technology errors as healthcare systems are often complex. A historical example of errors was in the study by Koppel et al. (2005), who investigated medication errors facilitated by entry systems and found approximately 22 entry error risks were present. Another example showing the ability of an information technology incident to impact patient safety was the incident in which a patient admin system automatically cancelled pathology orders for patients already discharged from the emergency department. As a result, a total of 36,080 orders that related to 4,665 patients were accidently cancelled (Magrabi, 2013). This incident showed the importance of clinical databases and how database and system design and specification failures impact patient safety. Magrabi (2013) also demonstrated that technical problems are fifteen times more likely to result in errors than human errors. However, a limitation of the Magrabi (2013) study is that prior to the commencement of ICT integration, these errors were not often studied.

In addition, Lyell, Magrabi & Coiera (2018) were the first to study the relationship between cognitive load and automation bias in electronic prescribing software. Automation bias refers to 'the tendency to use automated cues as a heuristic replacement for vigilant information seeking and processing" (Lyell et al., 2018, p. 1). A randomised controlled experiment involving 120 medical students was conducted to identify if electronic clinical decision support systems had a higher risk of automation bias (Lyell et al., 2018). Lyell, Magrabi & Coiera (2018) in essence, showed that users of electronic clinical decision support systems would rely on electronic information within the system, even if that information is incorrect. According to Lyell, Magrabi & Coiera (2018) omission errors were associated with lower cognitive load and contradicted the initial assumption that automation bias resulted from increased task complexity and cognitive load. Instead, the Lyell, Magrabi & Coiera (2018) paper shows that errors result from insufficient allocation of cognitive resources and suggests that clinical decision support designers need to be aware of automation bias as there are risks such as increasing task complexity. In addition, there are several errors relating to information-flow failure, with some errors relating to technology. Many of the examples provided were from a healthcare context. The next section will further discuss the impact of information-flow failure with medication errors as an exemplar to illustrate the importance of information-flow further.

2.3.2 Impact

Medication Management Errors

ICT technology and healthcare systems errors have been shown to contribute to information-flow failure that results in medication variances that can impact clinical safety and user acceptance of healthcare technology. Medication variance in the literature has been defined as a “discrepancy between a medication order and what was actually administered to the patient” (Taylor, Loan, Kamara, Blackburn, & Whitney, 2008). In comparison, the term medication error has been defined as an “act by a health care professional/ patient that has resulted in a preventable mistake regarding medications that can occur throughout the various stages of the clinical process” (Hermon & Williams, 2020, p. 3862). In the literature, the terms medication error and variance are often used interchangeably. However, medication variances do not always impact patient safety.

The term medication variance is not new and previous studies have investigated medication variances in hospitals. For example, the study by Sherman (1989) investigated medication variances within hospitals and, as a result, classified medication variance information into error rate and average daily census. Further, Sherman (1989) discussed the idea that comparing hospital medication variances could result in identifying medication administration errors. In addition, previous research by Hermon and Williams (2013) found that medication errors occur at all levels of the clinical process including: administration, diagnosis, treatment, and discharge. This is supported by Roughead et al (2013), who investigated medication errors during hospital admission studies in the emergency department, medical wards, and other areas (*Figure 13*). As shown in *Figure 13*, findings of former studies calculate medication-related hospital admissions in Australia and suggest that medication errors resulting in hospital admissions occur at a rate of 275,000 annually (Roughead, 2013; Lim et al, 2022).

This image has been removed due to copyright restriction. Available online from Lim et al (2022, p. 251).

***Figure 13*. Medication related hospital admission studies taken from Lim et al (2022, p. 251).**

Roughead, Semple and Rosenfeld (2016) have suggested that medication errors commonly occur within inpatient wards. Additionally, Roughead, Semple & Rosenfeld (2013) conducted a literature review of medication safety in Australia and identified that around 2-3% of inpatient hospital admissions are a consequence of medication errors and suggests a large proportion of these admissions are medication error-related, and up to 50% of the errors may be preventable (Roughead, Semple & Rosenfeld, 2013).

Shown in Table 4 Roughead et al. (2016, p. 117) are the types of patients and the median number of medication errors per patient as well as the percentage of patients affected that occurred during hospital admission. It should be noted that Tompson et al (2012), Vasileff et al (2009) and Chan et al (2010) did not assess the extent of harm as shown in Table 4 This shows that more research is needed to identify the outcomes of medication errors in medication error hospital admission studies.

Table 4. Medication error hospital admission studies taken from Roughead et al. (2016, p. 117).

Study and Characteristics	***Patients accessed***	***Patients with at least 1 error***	***Median errors per patient***	***Extent of harm***
Tompson et al 2012 (n=487, multi-centre)	Patients aged over 50 years, with at least two chronic conditions, and who took at least three medications regularly.	66%	1	Not assessed
Vasileff et al., 2009 (n=45, single centre)	Limited to patients admitted via the emergency department, aged over 60 years, who took four or more regular medications, and had three or more conditions or had been admitted within the previous 3 months.	76%	2.5	Not assessed
Chan et al., 2010 (n=100, single centred)	Patients over 18 years brought to the emergency department by ambulance, taking at least four regular medications. Patients were not from institutional care, subsequently admitted to hospital.	Not reported	1.5	Not assessed
Yong et al., 2012 (n=200, single centre)	Patients admitted through the acute assessment unit prior to admission to a medical ward.	Not reported	Not reported	24% of errors serious enough to cause temporary harm or require intervention (37% if on 10 or more medicines).

Duguid (2012) has documented that healthcare delivery challenges, such as medication errors, can pose a threat to patient safety and result in adverse outcomes requiring hospitalisation or patient death (Pham et al., 2011; Roughead & Semple, 2009). In addition, to the adverse outcomes on patient safety, medication errors are a burden to the overall healthcare system. It is estimated that in Australia AU$1.2 billion dollars is spent annually on medication-related admissions (Roughead, Semple, & Rosenfeld, 2013). Rattanarojsakul and Thawesaengskulthai (2013) have suggested that medication errors cost approximately, AU$350 million dollars annually. The Medical Technology Association of Australia (2010) estimates that for every adverse event prevented, approximately AU$1125 would be saved. This demonstrates the costs medication errors impose on the healthcare system and highlight the necessity to reduce and prevent medication errors.

Types of medication errors and causes

Incorrect dosage, the incorrect type of medication, allergies to medication and missed medication dosage are just some of the many ways medication errors can occur (MIGA, 2011,)Hermon and Williams 2013). Errors in administration, diagnosis, treatment, and discharge can occur (Hermon and Williams, 2013), resulting from human error (Williams, 2007a), ranging from medication omissions to medication commissions by staff or even patients. Omission is attributed to a lack of knowledge, failure to adhere to process, failure in an action (a slip) or failure to recall (a lapse in memory) (Roughead et al., 2013). According to the Australian Department of Health (2012-2015), from 2008 to 2010 approximately 34% of medications errors were due to medication omissions and 18% of the medication errors observed were due to medication overdoses. Medical equipment and computer systems can also fail when they do not maintain updated patient information regarding medication allergies, resulting in patients receiving inappropriate medications. Furthermore, errors within the prescription and dispensing processes, as well as patient misunderstanding of medication, can result in a medication error. (Joanna Briggs Institute, 2005). Medication errors can be further caused by a lack of knowledge, failure to follow a rule or failure in an action, such as a failure to recall (Duguid, 2009). According to the Australian Department of Health (2012-2015), approximately 33% of medication errors reported were due to failure to follow policy and procedure or misinterpretation of prescribing information. According to Rogers (2011) many computer systems may not maintain updated and correct patient medication allergies, resulting in incorrect or potentially harmful prescription medications. Moreover, simple human mistakes, especially with tired or emotional staff, may result in medication errors that may have potentially devastating consequences (Rogers, 2011). Clinical staff ranging from nurses to doctors, can misinterpret a diagnosis or a written prescription due to illegible handwriting (Rogers, 2011). Often similar sounding or looking medication can cause confusion and result in the wrong medication being prescribed. While time pressure on physicians to make a diagnosis or discharge quickly can increase the likelihood of a medication error occurring (Weingart et al., 2000). Failure to communicate information concerning patient welfare can occur between nurses and doctors, while incorrect staff training and patient ignorance can also increase the risk of a medication error. Failure to communicate effectively and efficiently may also increase the probability of medication-related errors (Commission, 2005). Failure in information-flow has been identified to be at the root of many medication errors.

Clinical Safety

Failure of information-flow can lead to incorrect identification of a patient and result in a medication error. Research conducted by Schulmeister (2008), Spruill et al (2010), Dunn & Moga (2010) and Gray (2006) all indicate that patient misidentification resulted in medication variances. A search of the literature revealed that patient misidentification was a concern for patient safety. Although this error is well researched it remains a worldwide issue for patient safety (Latham et al., 2012). Schulmeister (2008) has identified patient misidentification as the result of miscommunication, mispronouncing patient names and a failure to check patient information during the prescribing or patient administration phase. Schulmeister (2008) further suggests that the wrong patient or wrong identifier (ID) can be used during patient administration. Additionally, patient misidentification results in unnecessary testing, procedures, and transfusion errors for a patient (Schulmeister, 2008). Gray (2006) investigated patient misidentification in Neonatal Intensive Care Unit (NICU) patients with the objective of investigating similar patient names and hospital records. The research obtained one year's worth of electronic patient information and categorised patients at risk of being misidentified. They categorised at risk patients as those with similar surnames, same surnames, and similar hospital IDs (Gray et al., 2006). The study by Gray (2006) investigated 121186 days of patient care with 1260 patients. This study showed that the number of at-risk patients per day fluctuated daily between 20.6% and 72.9%, which resulted in 44% of risks being attributed to similar hospital IDs, 34% of risks attributed to same surnames and 9.7% of risks being attributed to similar surnames; further, twins and triplets were identified as 1/3rd of the patients at risk.

In a 2004 cancer treatment study, the United States Pharmacopeia reported that 3871 errors involving chemotherapy occurred and that 14% of these errors were patient misidentification related (Spruill et al. 2010). Although the reporting of these errors occurred, both Schulmeister (2008) and Spruill et al (2010) suggest that patient misidentification is primarily underreported, with the real figure being unknown. The research conducted by Dunn & Moga (2010) and Schulmeister (2008) confirm that two unique identifiers are commonly used to prevent patient misidentification. However, according to Spruill et al (2010) this verification in 2008 did not include a bedside check during chemotherapy in the Bone Marrow Transplant Unit (BMT). Subsequently, bedside patient identification was implemented by the nursing staff. A follow-up study by Spruill et al (2010) on data collected from 2008 to 2009 showed no medication variances relating to patient misidentification demonstrating the effectiveness of improved clinician/patient information flow. Although this study did not include the rate of patient misidentification prior to the bedside check, it shows that small process changes that enhance information flow can result in greatly increased patient safety.

Dunn & Moga (2010) conducted research that focused on the misidentification of laboratory specimens. Their research aimed to identify vulnerabilities in the laboratory process, which includes specimen collection, processing, analysis, and reporting stages. They conducted a qualitative analysis of 227 reports from the USA Veterans Health Administration, revealing that patient misidentification resulted in 182 of the 253 adverse events analysed. Incorrect patient labelling during admission and incorrect laboratory tests ordered from the electronic patient system resulted in 132 adverse events. They concluded that patient misidentification is due to a set of causal factors such as using printed labels from the previous patient or two patients with the same name but different middle initial. Meyer et al (2009) also researched patient misidentification within the laboratory. The research was conducted with the objective of reducing slide labelling errors through a systems-based approach. In 2006 all mislabelled slides were documented, and a root cause analysis was undertaken; following this, the process was modified so that the slides were labelled on opposite ends, which resulted in a decrease in error rate to between 0.59% to 0% (Meyer et al., 2009). Shown in *Figure 14* is the process of pathology laboratory specimen workflow. Although this mapping was used to represent the laboratory process, it can also be used to understand the information-flow process of laboratory specimens and identify the areas where patient misidentification occurs as well as further areas at risk of variances. For example, shown in Table 5 are the different points of failure that can be found in the laboratory specimen information-flow process. As shown in Table 5, specimen labelling and handwritten labelling can result in incorrect patient or specimen information and can later impact laboratory processes. Research conducted by Meyer et al (2009), Dunn & Moga (2010), Schulmeister (2008) and Gray (2006) highlight the significance of patient misidentification and its impact on both the patient and the healthcare system. Additionally, this work recognised that patient misidentification could result in pathology result errors and have similar consequences to medication errors. Currently, research investigating the impact of information-flow on patient misidentification is missing, and little is known regarding how improved information-flow can reduce patient misidentification.

Table 5. Potential points of failure from Figure 14: Laboratory Process adapted from Meyer et al., 2009, p. (1298).

Potential Points of Failure	***Error that leads to adverse outcomes***
Specimen labelling by doctor’s office/staff	Incorrect patient/ specimen labelling
Label printing	Incorrect patient information printed
Handwrite glass slides with patient information including name and accession number	Incorrect patient information, hard to read writing. Incorrect accession number
Load specimen with corresponding glass slide on machine, which dispenses material onto the slide and stains the slides with Papanicolaou stain	Wrong glass slide loaded
Match handwritten slides with printed label and stick printed label on each slide (48 at one time)	Printed label stuck on wrong slide

Potential Points of Failure	***Error that leads to adverse outcomes***
Print TriPath's Focal Point slide Profiler report	Incorrect information printed from report
Slides to file	Wrong slides added to file

This image has been removed due to copyright restriction. Available online from Meyer et al., (2009, p.1298).

Figure 14. **Laboratory Process taken from Meyer et al., (2009, p. 1298).**

In the Australian context, pathology laboratory errors are often caused by pre- and post-analytical errors (Gay & Badrick, 2020) as such laboratories have implemented quality assurance programs such as tracking errors through incident monitoring and management systems (Gay & Badrick, 2020). In addition, Gay and Bardrick (2020) identified that since the implementation of the Key Incident Monitoring and Management System program (KIMMS) in Australian medical laboratories, there had been a 6.5% reduction in incidents from 2015 to 2018. In addition, The Royal College of Pathologist of Australia (RCPA) has further developed quality assurance programs such as peer-reviewed assessments and education activities. These programs aim to ensure pathology disciplines across Australian laboratories adhere to best practices to reduce pathology laboratory errors (The Royal College of Pathologists of Australasia, 2021).

According to Levin et al (2012), electronic medication management systems can lead to medication variances and adverse drug events, which was also shown in an Australian General Practice medication management system by Westbrook (2015). Levin et al (2012) suggested that the patient misidentification demonstrated by research conducted by Dunn & Moga (2010) was largely due to computerised ordering systems. Levin et al (2012) also indicated in a Computerised Physician Order Entry (CPOE) system study on the American Veterans Affairs National Centre for Patient Safety database which identified 253 adverse events, that 22% were patient misidentification errors attributed to CPOE. As such Levin et al (2012) showed that one out of eighteen patient misidentification errors had resulted in an adverse event. Levin et al (2012) used two email surveys and an automated detection trigger within the computerised ordering systems at a paediatric hospital to identify the risk factors for patient misidentification within these computerised systems. The findings showed that “patient age, last name spelling, bed proximity, medical service, time/date of order and ordering intensity” (Levin et al., 2012, p. 1294) were factors for computerized patient misidentification. Levin et al (2012) stated that the incidence of patient misidentification was 0.064% per medication order, and further agreed with the ideas presented by both Schulmeister (2008) and Spruill et al (2010) regarding the underreporting of these errors. The next section will discuss health data systems’ roles in information-flow failure and medication errors.

As highlighted by Westbrook (2015), the implementation of clinical information systems is complex and is impacted by socioeconomic and technical factors. Since Westbrook's foundational study (2015), the Australian Commission on Safety and Quality in Health Care (ACSQHC) has introduced a national standardised medication management tool called the National Inpatient Medication Chart (NIMC). This chart has been standardised across health service organisations to reduce medication variances through standard processes for recording of prescribing, dispensing, administering, and reconciling medications.

Atik (2013) investigated the effects of the NIMC on prescription variances and whether these charts had been correctly filled out. Atik (2013) This study discovered that none of the 1877 prescription charts studied had been correctly completed and concluded that although the NIMC had benefited patients, further research and interventions were required.

Westbrook (2015) has conducted notable research on electronic prescribing systems and their effectiveness on prescribing errors. Westbrook (2015) categorises medication errors into procedural and clinical errors. Likewise, Morimoto (2004) categorises errors based on severity, preventability, disability, ameliorable actionability, stage of the process and cause. However, the studies have not investigated electronic medication management from the perspective of information-flow. Subsequently, Hermon & Williams (2013) investigated medication errors from the perspective of information-flow categorising medication errors based on the clinical processes of Administration, Diagnosis, Treatment and Post Treatment.

A study by Peddie et al (2018) investigated a dataset for clinicians to communicate adverse drug events. Peddie et al (2018) used a mixed methods study which comprised of a systematic review of the data fields, qualitative observations, workshops, and a pilot trial to identify 108 adverse drug event reporting systems worldwide (Peddie et al., 2018). In the 108 reporting systems, were 1782 data fields for adverse drug event reporting. According to this study, patients are often treated at multiple health and provider locations, however, the patient records across the multiple electronic systems are not standardised, leading to increased risk of inaccurate medication histories and unintentional patient errors and harm (Peddie et al., 2018). It was noted that information sharing about adverse drug events remains low and that this could be improved through electronic systems. As a result of this study, a standardised set of data fields was developed by Peddie et al (2018) to improve the reporting of adverse drug events.

The above section explored information-flow failure using medication management and pathology in healthcare as exemplars. The next section discusses further impact from the perspective of user acceptance on information-flow failures in healthcare.

User Acceptance of Technology in Healthcare

User acceptance or user adoption is important in preventing medication errors due to information-flow failure. As stated previously by Roughead et al (2016) and Ash et al (2004), medication errors occurred because of either lack of patient medication administration training/ knowledge or because the technology needed to be more intuitive. These problems occurred within the information-flow process and indicate the significance of user acceptance in preventing medication errors related to technology. A description of different user acceptance theories are described in Table 6. This is particularly important as an understanding of these theories can result in successful user acceptance and prevention of medication errors related to healthcare technologies.

Table 6. Comparison of different user acceptance theories in literature.

Reference	***Theory***
Alomary & Woollard (2022)	Suggests the Technology Acceptance Model is a robust model which is applicable across a broad range of end-user computing technologies.
Mamra et al. (2017)	Wellness and youth are factors for user acceptance. Physicians consider privacy, security, cost, and legal issues. User Acceptance: individual factors, technical factors, and organizational factors. Models supported are: Technology Acceptance Model (TAM), Theory of Reason Action (TRA), Unified Theory of Accepts and Use of Technology (UTAUT).
Bush, Kuelbs, Ryu, Jiang, & Chiang (2017)	Medical training, clinical practice workflows, and specialty practice are factors in acceptance. Performance expectation and facility conditions and behavioural intent can predict acceptance.
Ahlan & Ahmad (2014)	User acceptance results in quality care, reduced costs, and patient safety. System adoption is from timeliness of system, interoperability, and lack of staff resistance. Technology Acceptance Model (TAM) is supported. TAM2 is supported.
Zhang et al., (2017)	Self-efficacy and response-efficacy are linked to perceived ease of use. Perceived usefulness and perceived ease of use are factors in user acceptance.
Eysenbach, Kazemi, Archer, & Cocosila (2011)	Behavioural point of view, general doubts are linked to acceptance. Perceived overall risk and perception of ease of use are factors for acceptance.
Kim, Han, Yoo, & Yun (2012)	User perceived ability is linked to acceptance. User's perceived ability is linked to knowledge and internet efficacy.

Health information technologies such as electronic health and medical records, computerised ordering systems and clinical decision support systems have been shown to improve patient safety and reduce health costs (Ahlan & Ahmad, 2014). However, these systems are not always used effectively; for example, user resistance can result in reduced clinical adoption and use (Ahlan & Ahmad, 2014); therefore, it is vital that successful adoption of these systems occurs to effectively use these technologies. According to Mamra et al (2017), little research into user acceptance of these systems has been conducted. They showed that user acceptance had different contributing factors depending on the study's focus. For example, privacy, security, trust, cost, and ease of use were shown to be the factors affecting user acceptance of Personal Health Record systems. Patient administration systems were not accepted because of the extra time needed for entering data, reviewing the decision provided by the system, interoperability and user and staff resistance. Similarly, Bush et al (2017) suggested that the barriers to Healthcare Information Technology (HIT) acceptance were technical support concerns, insufficient time, and workflow challenges. Mamra et al (2017) have further classified user resistance into three categories: individual, technical and organisation factors. According to Ahlan & Ahmad (2014), Mamra et al (2017) and Zhang et al (2017) several theories can be used to describe user behaviour with regard to technology acceptance. These include the Theory of Reasons Action (TRA), Diffusion of Innovation (DIO), and unified technology acceptance and use of technology (UTAUT) (Ahlan & Ahmad, 2014; Mamra et al., 2017; Zhang et al., 2017). However, much of the literature to date agree that the Theory Acceptance Model (TAM) is the most widely accepted (Ahlan & Ahmad, 2014; Kim et al., 2012; Zhang et al., 2017). The TAM model (*Figure 15*) was originally designed to represent the behavioural factors that influence user acceptance of Information Systems.

This image has been removed due to copyright restriction. Available online from Ahlan & Ahmad (2014, p. 1290).

Figure 15. **Theory Acceptance Model taken from Ahlan & Ahmad (2014, p. 1290).**

While the TAM model has been used for understanding user behaviour, Ahlan & Ahmad (2014) has further developed a model based on TAM (Rahmns), which includes HIT in order to foster further acceptance of HIT in developing countries (*Figure 16*). The TAM model can be used to identify user behaviour in relation to information-flow medication management systems. Additionally, once the behaviour drivers of the users have been identified, interventions to increase user acceptance towards medication management systems and omissions errors through lack of knowledge and disruption of information flow can be undertaken.

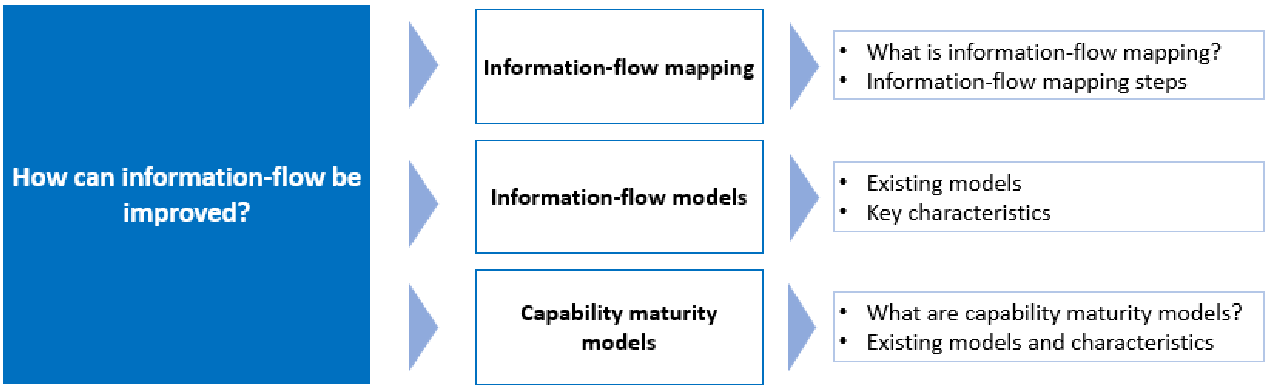
This image has been removed due to copyright restriction. Available online from Ahlan & Ahmad (2014, p. 1294).

Figure 16. **Rahmns HIT user acceptance Model taken from Ahlan & Ahmad (2014, p. 1294).**

As shown in *Figure 16,* the model includes cost-effectiveness and output quality as primary factors that influence user perceptions of usefulness regarding Health Information Technologies (Ahlan & Ahmad, 2014). Zhang et al (2017) emphasised that there are two perceived efficiencies; self-efficiency and response efficiency. According to Zhang et al. (2017), response efficiency is the degree to which users believe these technologies can avoid a health threat, while self-efficiency refers to the ability to complete a task unaided. Therefore, health technology implementations should incorporate both self and response efficiency. Kim et al. (2012) suggested that technology implementation should include ease of use, perceived usefulness, and perceived credibility. This idea is further supported by Eysenbach et al (2011) and Bush et al (2017), who recognised the need for users, particularly clinicians, to be involved in the design and implementation of health information technologies. Additionally, developers should consider the emphasis on user and clinician training to address their concerns and needs (Bush et al., 2017). Hence, from the literature, it is evident that for health information technologies to be successfully utilised, user acceptance and training are critical factors; otherwise, they are at risk of being inefficient technologies or not used at all. Additionally, inefficient technologies can result in clinical errors, including patient misidentification. Studies such as Eysenbach et al (2011) and Bush et al (2017) indicate the significance of user acceptance within healthcare. This is particularly important in preventing medication errors and understanding how these errors relate to failures in information-flow. Successful implementation of the areas identified in the TAM model is important to successfully adopting information systems and impacting how users accept information technologies. By identifying factors that influence a user to accept new technology, decision-makers, managers, and developers can introduce training or interventions to assist users with the acceptance of emerging technologies. As identified by Ahlan & Ahmad (2014), user resistance to technology can result in ineffective use. The resultant failures in information-flow are a root cause of information system errors.

This section has shown that successful user acceptance and adoption of patient administration or clinical information systems can reduce medication and other errors related to lack of training or knowledge and associated failures of information-flow. The next section will discuss how information-flow can be improved.

2.4 How can information-flow be improved?



The following section explores how information-flow mapping, frameworks, models as well as capability maturity models play a role in information-flow improvement.

2.4.1 Information-flow mapping

Information-flow mapping is important to identify how information is transferred from one point to another within an organisation (Hibberd & Evatt, 2004). This is particularly important in identifying information-flow failure and areas which can be improved. According to Hibberd and Evatt (2004), mapping information-flow can identify how information is used and whom it is used by and identify information services to which could be used to improve an organisation. In essence, information-flow mapping is a visual illustration of how information-flow is connected and has similarities to data flow and process mapping. Shown in Table 7 are methods to map information-flow, which show how data and process mapping can be used to map information-flow. Shown in Table 7 are steps by Hibberd & Evatt (2004) that were originally designed to increase value for organisational goals and objectives. Information Services Division (2013) has suggested information-flow mapping from the objective of mapping out dementia post-diagnostic support. Information Services Division Scotland (2013) have developed an information-flow mapping guide that highlights the importance of information-flow as documenting the current state of information and can be used to develop new information-flow states that improve information-flow. While IT Governance (2022) has focussed on mapping data to comply with the European Union Data Protection Regulation (EU GDPR). Although the EU GDPR focuses on data protection, the data mapping process describes an information-flow mapping process and has such there is no difference between information-flow mapping and data mapping.

Table 7. Methods of mapping information-flow.

Reference/ purpose	Information-flow mapping steps	Information required
Hibberd & Evatt (2004)/ organisational value	1. Describe current situation 2. Describe potential clients 3. Map potential clients 4. Rank solutions by priority 5. Create an information map	➢ What are the departments? ➢ What are the external influencing factors? ➢ What is the client's budget, operational and production information? ➢ What are the organisational goals? ➢ What are the tasks and objectives? ➢ What information is necessary? ➢ What is the current solution?
Information Services Division (2013)/ Dementia post diagnosis	1. Map and describe the current processes from the questions 2. Review current data being collected 3. Create an ideal information-flow state 4. Compare the current processes with the ideal state 5. Implement changes to the current processes	➢ Where the data originates? ➢ What data is missing? ➢ Where does the data go? ➢ Who is involved in the data capture? ➢ What data is duplicated? ➢ Are there errors in the process?
IT Governance/ GDPR Data Mapping	1. Understand the information-flow 2. Describe the information-flow 3. Identify its key elements	➢ Data items ➢ Formats ➢ Transfer method ➢ Location ➢ Accountability ➢ Access ➢ Lawful bias

The information-flow mapping steps by Hibberd and Evatt (2004) and Information Services Division (2013) can be used to map information-flow. However, the steps shown in Table 5 have some limitations as they are missing critical steps in reviewing the current and ideal state for information-flow with both Hibberd & Evatt (2004) and Information Services Division (2013) missing steps that explain how to map the information-flow in detail. While IT Governance (2022) includes data elements for mapping information-flow its focus is on adhering to the European Union (EU) General Data Resource Protection (GDRP) requirements rather than information-flow improvement. In addition, it should be noted that research to date has yet to develop an information-flow healthcare heat map, which identifies where and how the information travels from its origination to destination. However, information-flow models and frameworks have been used to depict and map information-flow. The next section discusses information-flow models and frameworks for information-flow improvement.

2.4.2 Information-flow models

This section discusses information-flow models and frameworks as a method to understand and improve information-flow. here are three concepts to note. Firstly, the terms models and frameworks have been used interchangeably in the literature; therefore, both models and frameworks have been included in Table 8. Secondly, many of the frameworks and research do not specifically mention information-flow. However, reviewing these frameworks, models, and research reveals that information-flow improvement is involved as it shows the models were used to improve information-flow within their context. Lastly, the inability to differentiate between information-flow models and frameworks, as well as the limited research and models that use the term information-flow, highlight the importance of information-flow terminology for information-flow understanding and research.

Shown in Table 8 are key information-flow models and frameworks identified from the literature, categorised according to six domains - risk management models, security models, information technology models, healthcare models and political and energy sector models. While there are several models identified in Table 8, the next section provides further discussion on the relevant model characteristics for this thesis, which includes the models purpose, limitations, and relevance to improving information-flow.

Table 8. A comparison of Information-flow models.

Domain	***Information-flow Model/ Reference***	***Purpose of Model***	***Model Characteristics***
Risk Management	Swiss Cheese Model/ Reason (2000)	Accident causation model	Refers to human systems as multiple slices of Swiss cheeses stacked against each other. Threats are mitigated by the next layer and failures/ errors go through the holes of the cheese. Has a Cross domain use for risk management, aviation, safety, cybersecurity, patient safety and engineering.
	Bow Tie Model/ Kerckhoffs et al (2013)	Visualise risk	Involves the use of hazards, events, threats, barriers to visually understand risks. Not domain specific.
Security	FM security Model/ McLean (1990)	Security model based on information-flow	FM shows the treatment of security relevant causal factors.
	Decentralized model for information-flow control/ Myers & Liskov (1997)	Model for controlling information-flow in systems with mutual distrust and decentralized authority	Model allows users to share information with distrusted code yet still controls how it is shared.
Information technology	Sutherlands No deducibility Model/ Sutherland/ (1986)	Computer system Model	Information-flows in a system from high level objects to low level objects.
	The Bell Model/ Bell & La Padul (1976)	A state machine model used for access control	Represents elements of computer systems and security of information in a computer system.
	Network information flow model/ Ahlswede, Ning, Li, & Yeung (2000)	Looks at computer network application communication	Point to point communication network. Information sources which are mutually independent.
Healthcare	Health Care Utilization Sequence/ Herrmann et al (2017)	Describes the structure of health care utilization	Model includes consultations as events in sequences, the dimension of time, the providers, and the different flows of information between the providers.
	Hermon Model/ Hermon & Williams (2013)	Describes the flow of clinical information in a local GP setting	Suggests clinical information is a process that can be affected by a variety of factors which result in medication errors. The outcome, event and original error is depicted. Admin, Diagnosis, treatment, and post treatment sections are also included.
	Chronic disease care information-flow mode/ Unertl et al (2009)	Workflow and information-flow models to support disease care	Three models for different diseases (Multiple Sclerosis, Cystic Fibrosis, Diabetes Mellitus).
	Critical care information-flow model/ Stitzlein & Sanderson (2010a)	Electronic Health Record in ICU Australia	Model looks at separate pathways for the flow of medical information. Convergence points of information.
	Closed Loop medication process workflow and HIT framework/ Drozda et al (2017)	Tracking of medical device safety with implementation of UDI in Electronic Health information	Focus is on UDI linkage and systems, data flows, actors, and data model.

Domain	***Information-flow Model/ Reference***	***Purpose of Model***	***Model Characteristics***
	Medicine and dentistry information flow model/ Hummel & Gandara (2011)	Looks at the information workflow of medicine and density with diabetes patients	Focus is on the events of the clinical workflow and electronic record communication between different providers.
	DIB/ Galliers, Wilson, & Fone, (2007)	DIB determining information-flow breakdown for analysing adverse	DIB analyses adverse events by locating breakdowns in information-flow. Detailed modelling and questioning of the clinical environment. The key components are the situation of interest and analysing with a checklist.
	Sequence diagram for health monitoring/ Triantafyllidis, Koutkias, Chouvarda, & Maglaveras (2013)	Chronic patient health monitoring information-flow	Looks at the events, patient activities and what information will be sent.
	Medication Communication Framework/ Kitson et al (2013)	Maps medication communication for patients	This framework shows the patients at the centre and the provider roles linked.
	Mathflow model/ Butler et al (2014)	A modelling and analysis tool suite for healthcare	A method that uses modelling and analysis tools to make measurable improvements to clinical workflow for health information technology systems.
	Outpatient medication setting information flow path/ Benedict & Caldwell (2012)	An Information Flow framework that maps paths between patients, providers, and pharmacists in the Outpatient Medication Setting	Depicts the flow of information from the patient, provider, and pharmacist. Includes methods of information transfer such as face to face, script, email and fax.
	Medication communication framework/ Kiston (2013)	Uses the circle of care model to depict medication communication	The circle of care modelling approach was used to develop a medication communication model where the patient is at the centre of the communication activities. Providers and relationships are mapped to the patient.
	Clinical coordination across levels of care/ Aller et al (2015)	Indicators to measure coordination of clinical information and management across levels of care	Includes indicator category that depicts the type, dimension and attribute. Such as the Clinical information coordination, transfer of information and information flow across levels.
Political Sector	Legislative Decision Making/ Sabatier & Whiteman, (1985)	Two stage and three stage models of legislative decision making	Shows the link between legislative staff and their information sources that leads to decision making.
Energy Sector	Petri net modelling/ Wang, Sechilariu, & Locment, 2013)	Power flow Petri Net modelling	Energy management modelling of a multi-source power system.

The following section provides a further discussion on the frameworks and models from Table 8, starting with risk management models.

Risk Management Models

The models categorised under risk management models include the bow tie and the Swiss cheese model. These models were categorised under risk management because they were originally intended for risk management and identification.

Bow Tie Model

The bow tie model shown in *Figure 17* was initially intended as a risk assessment tool in which the threat, critical event, escalation, and consequence are captured (Kerckhoffs et al, 2013). However, as shown in *Figure 18,* the bow tie model has been used in a hospital setting to identify the causes and consequences of medication adverse events. Kerckhoffs et al (2013) further suggest that the bow tie model can be used to perform a risk assessment, risk management and communication to address medication adverse events thus enable users to identify routes leading to medication adverse events and help identify barriers or interventions to prevent or reduce adverse events.

This image has been removed due to copyright restriction. Available online from Kerckhoffs et al. (2013).

Figure 17. **The bow tie model taken from Kerckhoffs et al. (2013).**

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As shown in *Figure 18,* the bow tie model has been applied to a healthcare setting and illustrates the importance of communication Smorenburg et al (2009) and the ability of the bow tie model to be used in different domains with different purpose. While the bow tie model does not specifically address information-flow maturity or information-flow, the bow tie model could be used to capture information-flow failure. For example, underlying causes, initial errors, events, prevention measures and consequences can be used to map information-flow failure. In addition, the bow tie model could be used to identify information-flow risks and consequences. However, there are certain limitations with the bow tie model, as it only identifies a specifically defined event, resulting in missed threats, and only one threat can be the root cause of an event. In addition, where adverse events are multi-factorial as is commonly the case in healthcare, the bow-tie model may miss many contributing issues.

This image has been removed due to copyright restriction. Available online from Smorenburg et a al. (2009).

Figure 18. **Application of the bow tie model in a hospital setting taken from Smorenburg et al. (2009).**

Swiss Cheese Model

Reason (2000) discusses human error from the perspective of the person and system and likens error prevention to Swiss cheese. Shown in *Figure 19* is the Swiss cheese model, which is comprised of procedures, policies, and administrative controls at the defensive layer against errors. However, a combination of active failures and latent conditions occurring together or in close temporal proximity contribute to the holes in the defensive barriers aligning, resulting in adverse events, comparable to Swiss cheese (Reason, 2000). Both active failures and latent conditions are related to human errors, with active failures referring to mistakes, slips and lapses. While latent conditions arise from the system and stem from management yet, “we cannot change the human condition, but we can change the conditions under which humans work” (Reason, 2000, p. 769). According to Reason (2000), appropriate procedures and training can also eliminate much of the opportunity for human error that contribute to the holes in the defensive layers. While this research did not look at information-flow specifically, it should be noted that both active failures and latent conditions result in information-flow failure. As such, the practical significance of this research indicates that a framework could be developed to change the system where latent conditions arise, ultimately preventing information-flow failure. This framework can address risk management by identifying threats, hazards and events that impact information-flow. The next section discusses the healthcare models shown in Table 8.

This image has been removed due to copyright restriction. Available online from Reason (2000).

***Figure 19.* Swiss Cheese model taken from Reason (2000).**

Healthcare Models

Table 8 identifies 14 healthcare information-flow models. For example, the Critical Care Information-Flow Model developed by Stitzlein and Sanderson (2010b) specialises in representing the pathways of medical information and the convergence point of information, with a focus on electronic health records in an Australian ICU environment. The Health Care Utilization Sequence Model (Herrmann, Haarmann, & Baerheim, 2017) describes the structure of healthcare utilisation looking explicitly at consultations as events in sequences and highlights the importance of the providers and different flows of information between providers.

According to Berry et al (2016), there is a relationship between workflow models and information-flow as integral parts of healthcare information systems. Workflow identifies the sequence of processes for a task or action, while the Math flow model integrates information modelling (Butler. 2014). Shown in *Figure 20* is the Math flow Model developed by Berry et al (2016), which emphasises the importance of the information-flow relationship with workflow and suggests that quality information is the result of the relationship. The relevance of this workflow model is the emphasis on health information technology as a factor to improve the care process and health information technology systems. However, it should be noted that this model does not include the ability to measure information-flow.

This image has been removed due to copyright restriction. Available online from Berry et al (2016, p .18).

Figure 20. **Math flow Model taken from Berry et al (2016, p. 18).**

Other healthcare models shown in Table 8 include the Chronic Disease Care Information-Flow Model by Unertl et al (2009), which maps out the workflow and information-flow for three different disease conditions - Multiple Sclerosis (MS), Cystic Fibrosis (CF) and Diabetes Mellitus (DM). This model enables clinicians to understand the information process for the treatment of disease care pathway through the actions described in a workflow.

Medication information-flow research is important in understanding, identifying, and preventing medication errors due to information-flow disruption One particular study by Unertl et al (2009) investigated information-flow and workflow from the perspective of chronic disease care in three chronic diseases - MS, CF and DM in long-term care facilities. This included 150 hours of observations with 157 patient-provider interactions leading to an analysis of people, processes, and technology interactions. This study used open coding to develop models of workflow, information-flow, and guidelines for each facility. Open coding refers to the analytic process of observing and recording data. *Figures 21, 22* and *23* show how Unertl et al (2009) developed workflow models that represent sequences and patterns of tasks and information thus highlighting several common factors within each clinic workflow. For example, the interaction between providers and the use of electronic health record systems during handoff from nurse to provider and the paging systems were evident within all clinics. It should be noted that in *Figure 21* MD is the abbreviation for a USA provider and that paging systems are missing from *Figures 21 to 23*.

This image has been removed due to copyright restriction. Available online from Unertl et al. (2009, p. 830).

Figure 21. **Workflow Models developed for Chronic Disease facilities taken from Unertl et al. (2009, p. 830).**

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***Figure* 22. Workflow Models developed for Chronic Disease facilities taken from Unertl et al. (2009, p. 830).**

This image has been removed due to copyright restriction. Available online from Unertl et al. (2009, p. 830).

***Figure 23.* Workflow Models developed for Chronic Disease facilities taken from Unertl et al. (2009, p. 830).**

Unertl et al (2009) proceeded to develop graphical models of information-flow for each clinic and from this a consolidated information flow for chronic disease care. *Figure 24* shows how the patient plays a central role in providing and receiving information in this model.

This image has been removed due to copyright restriction. Available online from Unertl et al. (2009, p. 832).

Figure 24. **Excerpt of Information-flow in Chronic Disease Care taken from Unertl et al. (2009, p. 832).**

The complexity of Figure 24 reflects the complexity of the underlying system and shows how the events of both clinical workflow and clinical information-flow can be combined to represent information flows from provider to receiver. Benedict & Caldwell (2010) investigated a system-of-systems perspective to study the outpatient medication information-flow process and developed a conceptual framework to display information-flow paths between key actors in the outpatient process (*Figure 25*). This represents the multiple information-flow paths between providers, pharmacists, and patients and how such information-flow paths can then be understood within the outpatient medication process. It should be noted that in Australian General Practice settings, fax communication is now very uncommon and has been replaced by multiple specialised secure communication channels.

This image has been removed due to copyright restriction. Available online from Benedict & Caldwell (2010, p. 4).

Figure 25**. Conceptual outpatient process framework taken from Benedict & Caldwell (2010, p. 4).**

Information-flow has been studied by Aller et al (2015) using a systematic review of the literature to develop indicators to evaluate clinical coordination across levels of care and identified 52 indicators that addressed 11 attributes of clinical coordination. This review defined clinical information transfer based on information-flow and the quality of information resulting in a set of indicators to identify areas that could be used to improve the coordination of clinical information and management. 21 were output indicators which included indicators for: clinical information transfer, adequacy of the data, diagnostic testing, medication evaluation, completion of diagnostic/ follow-up processes and access to appropriate level of care. Shown in *Figure 26* is a model of nursing workflow and associated information-flow described by Unertl et al (2009). This highlights the complexity of information-flow in healthcare information systems.

This image has been removed due to copyright restriction. Available online from Unertl, Johnson & Lorenzi (2012, p. 398).

Figure 26. **Nurse-based workflow model taken from Unertl, Johnson, & Lorenzi (2012, p. 398).**

The above studies did not specifically mention the terms information-flow metrics. However as previously noted, it was evident that information-flow is present in the literature in many different guises using different terminology, such as distributed systems, workflow, or communication flow.

Shown in *Figure 27* is a study by Kitson et al (2013), who investigated medication communication flow by modelling medication activities to the Circle of Care Model (CCM). Like Unertl et al (2009), this model uses the approach of positioning the patient at the centre of the system and linking medication communication relationships to the patient. 39 patients or providers were interviewed or observed to develop the medication communication flow framework. Patient/provider activities were mapped against the medication communication model resulting in a further understanding of the communication pathways. Kitson et al (2013) concluded that a patient has multiple communication activities which are distributed across provider roles and suggested that using the CCM enabled identification of the communication processes. These findings showed the significance of communication flow within healthcare and how communication flow can be investigated to understand information-flow.

This image has been removed due to copyright restriction. Available online from Kitson et al (2013, p. 5).

Figure 27. **Medication Communication Framework taken from Kitson et al. (2013, p. 5).**

Clinical Information-flow Framework (Hermon Model)

Previous research by Hermon and Williams (2013) investigated information-flow failure that results in medication errors. That research used a systematic literature review to develop a reflective model (the Hermon model) that mapped clinical information-flow as a process. The clinical information-flow model is categorised under the healthcare domain model category in Table 8 as its specific context is healthcare industry-related. This research highlighted that factors such as miscommunication could result in medication errors, ultimately impacting patient safety. This clinical information-flow framework was developed to represent information-flow failure during the clinical information-flow process. Shown in *Figure 28,* the Clinical Information-flow framework maps key events during a medication error, such as the outcome, the event itself and the root cause that resulted in the medication error incident. It should be noted that this previous research did not include other errors in the clinical process that may have occurred and only focused on medication errors.

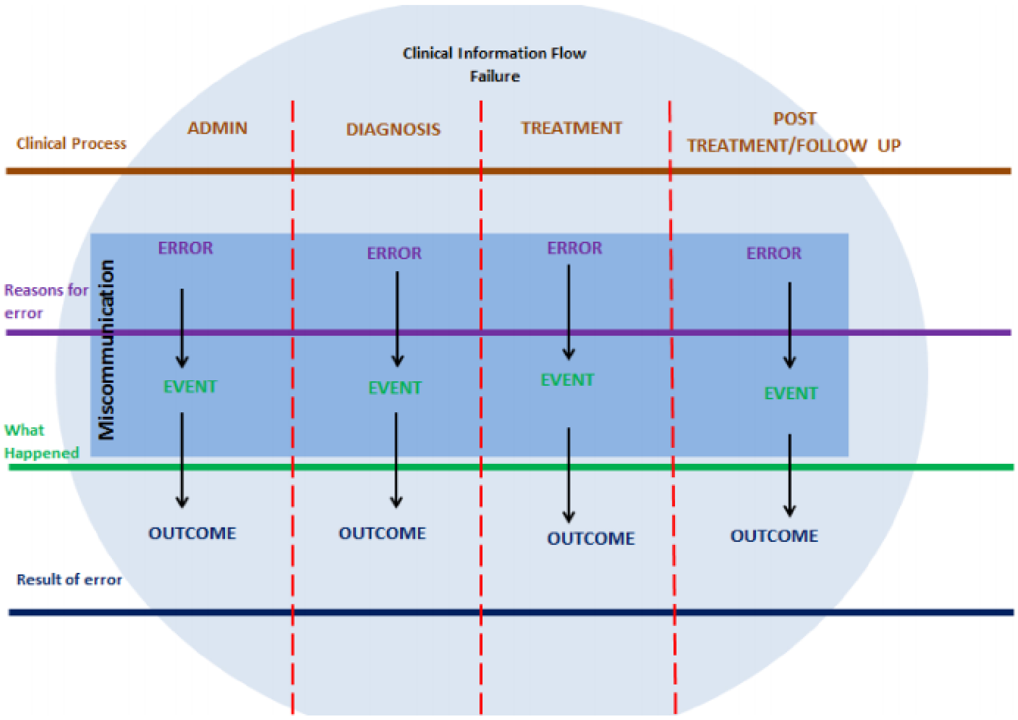

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Figure 28. **Clinical Information-flow framework taken from Hermon & Williams (2013, p.7).**

Hermon and Williams (2020) investigated the prevention of medication errors due to information-flow in Australian General Practice which modelled the Threat to Patient Safety (TAPS) Study (Makeham et al, 2006) in order to determine whether the previously developed Hermon Model could be used to identify General Practice medication errors due to information-flow failure, identify information-flow failure in GP desktop systems, and recommend possible solutions and future research that would apply the clinical information-flow model.

Hermon and Williams (2020) used an information systems methodology, comprised of case study and interview methods. The case study aimed to build on the existing Hermon model through the mapping of cases which was initially completed by the primary researcher and then confirmed by independent expert researchers in the group. The Threat to Patient Safety (TAPS) study by

Meredith Makeham (Makeham et al, 2006) was chosen to validate the Hermon Model on the basis that it used anonymous reporting of errors by GPs via a secure web-based questionnaire to determine the rate of errors reported by GPs in New South Wales, which included patient safety events such as medication errors. The TAPS study thus enabled case study mapping to identify information-flow failure(s) associated with medication errors. The Hermon and Williams (2020) case studies assessed 418 available TAPS reports of patient safety incidents. 164 reports matched the search criteria for the case study mapping as they related to medication management reports. These reports were then categorised and mapped using the following taxonomy:

- Electronic prescription writing or medication charting errors
- Other prescription or medication charting errors
- Medication dispensing and delivery errors
- Patient self-administration of medication errors
- Medication errors not otherwise specified

An example of a mapped case is shown in *Figure 29.*

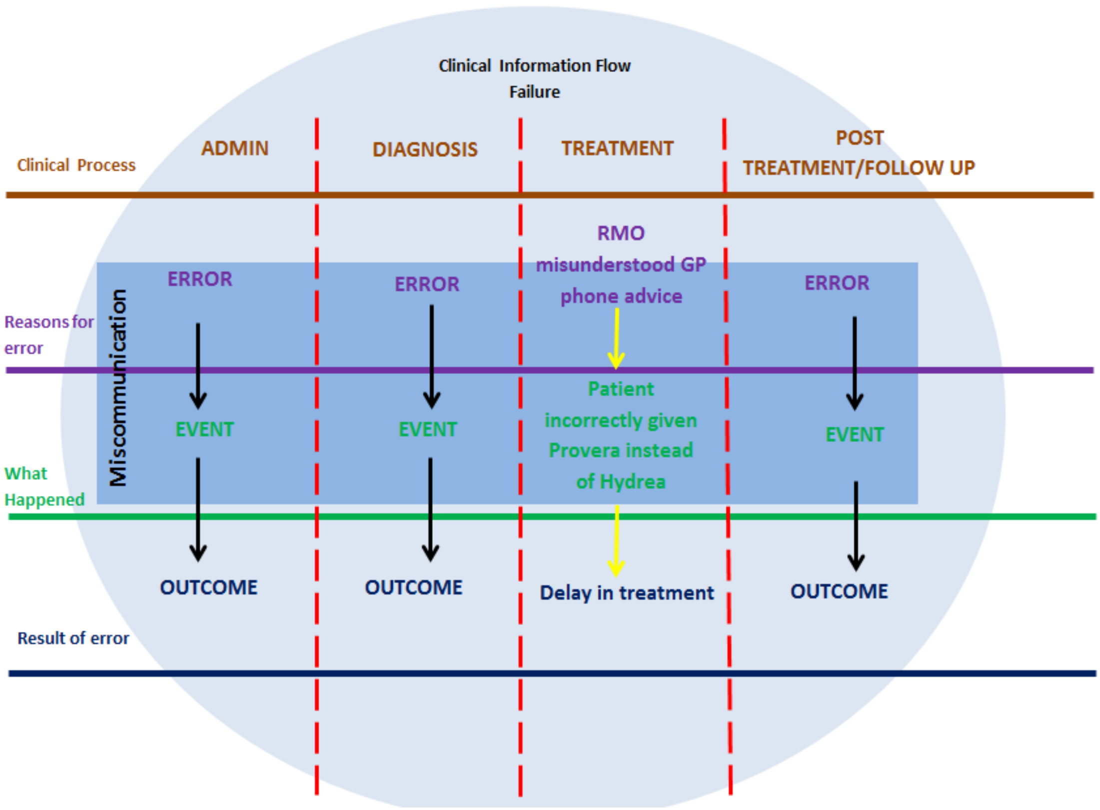

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Figure 29. **Example of Case Study #7 mapped to the Hermon Model.**

Case Study # 7 Report no. 93: Patient given incorrect medication during 9-day hospital admission of Provera instead of Hydrea (Rx of essential thromboxythemia), due to RMO misunderstanding GP phone advice on regular medications. (Hermon and Williams (2020)

Mapping the 164 case studies against the Hermon model validated the Hermon model as applicable to the GP environment as the model was successful in identify the medication error relationship to the information-flow. The mapped case data showed that medication errors occurred across each clinical process point of the Hermon Model. However, most errors occurred in the Treatment phase Treatment errors such as wrong prescription, wrong dosage and wrong medications were just some of the many medication errors that were the most common. The Hermon model was subsequently refined to include a section on what type of treatment error had occurred and whether it involved medication management. The case study mapping also revealed that not all errors are medication management related and many were related to other information-flow failures. Miscommunication, uniformed/misinformed GPs, and clinical desktop systems errors were found disrupt information-flow. A category regarding Software needed to be incorporated within the model, as 22% of errors was associated with GP desktop software systems. Human errors were often due to a lapse in memory or an accidental slip. Further, from the case studies, many reported that lack of computer alerts was a factor in the occurrence of the medication error. Additionally, communication between GPs and patients, and other entities such as pharmacies and hospitals, is of great significance. Communication failure between individuals was a cause of medication errors, whilst appropriate communication and double-checking of medications resulted in interventions. Subsequently, the TAPS case study mapping highlighted the importance of reporting medication errors. Analysis of case study mapping results indicated that GPs, clinicians, and pharmacists were the main cause of errors. Therefore, the model was revised to better fit the General Practice environment (Figure 30).

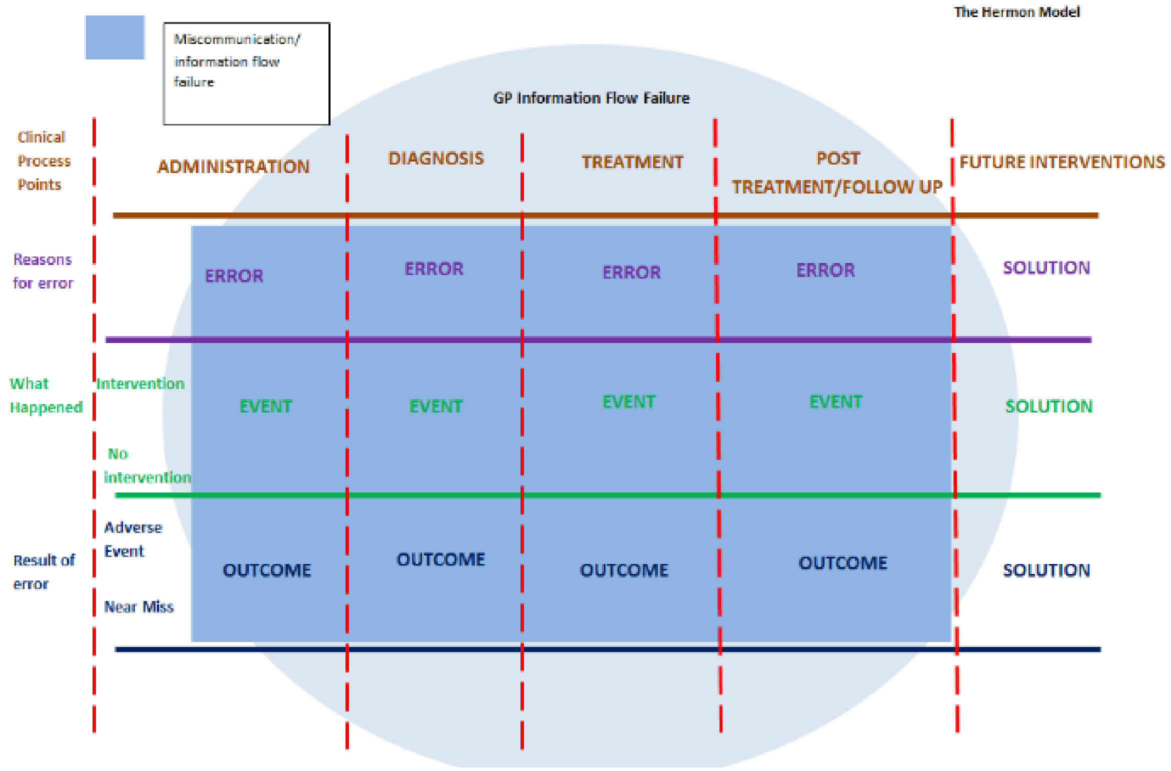

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Figure 30. **Hermon Model revised for General Practice from TAPS mapping and Interviews.**

An outcome of this study was that the Hermon model could map out medication errors which would result in the identification and understanding of these errors. The research used existing General Practice medication error report cases from the Threat to Patient Safety (TAPS) Study to map against the Hermon model and validated this mapping through consultations with General Practitioners. Importantly, this framework was identified to have the capacity to map medication errors within General Practice, which can ultimately allow an improved understanding of medication errors. Whilst this is one clinical example, using a General Practice setting, the model could potentially be used in medication error and incident reporting analysis in other healthcare environments. The main outcome of this research was demonstrating the medication mapping to the Hermon model. This demonstrated its ability to assist in understanding and identifying information-flow failure, which can result in medication errors. This is important to understand and potentially prevent medication errors associated with the use of GP desktop systems.

This section has discussed information-flow models and frameworks. Each model has been shown to have a different purposes and characteristics within each domain. For example, the general category includes the Swiss Cheese and Bow Tie models, which can be applied to multiple situations, while the security domain emphasises the FM Security and the decentralised model for information-flow. The domain Information Technology identifies the Bell, Sutherlands, and Network models as information-flow. Additionally, domains in politics and energy feature information-flow models relevant to their domains. It is important to highlight the Chronic Disease Care information-flow model and the Health Care Utilization Sequence model, as they describe the information-flow processes within healthcare, which are particularly relevant for the current research. A number of these models have been used cross-domain. However, research on the effectiveness of these domain-specific models across multiple domains has yet to be evidenced in the literature. Interestingly, these models require the use of information-flow metrics as a baseline to evaluate effectiveness and accuracy. Without a set of metrics, verification of the validity of these information-flow models is not possible. The next section will discuss capability maturity models as a way to measure information-flow.

2.4.3 Capability Maturity Models

This section begins with a discussion on capability maturity models are and is followed by key capability maturity models in the literature.

What are capability maturity models?

Kasse (2004) defined a model as “a structured collection of elements that described characteristics of effective processes” (Kasse, 2004, p. 31). According to Rouse (2007), IT Governance (2022b) and Lutkevich (2020), the Capability Maturity Model (CMM) provides organisations with a methodology to develop and refine the software development process. Originally the CMM was designed to create an objective evaluation of software subcontractors for the US air force (Lutkevich, 2020) and was formulated by Watts Humphrey and Phil Crosby of the Software Engineering Institute (SEI) in the 1980s (IT Governance, 2022b; Rouse, 2007). The CMM is now a well-known methodology used to assist organisations to improve process and management systems (Governance, 2020; White, 2018). Rouse (2007) describes the CMM with five levels that use a continuous process improvement framework. IT Governance (2022b) proposed an associated maturity level scale for measuring the maturity of organisational processes with each level defined by an associated goal that needs to be reached. By contrast, Australian Public Service Commission (2018) defines maturity as “the degree of formality and optimisation of process – from ad hoc through formally defined steps and metrics, to achieve optimisation of process”. The five maturity levels as defined by Henshall (2019) and Kasse (2004) are:

1. Initial level: processes are disorganised and individualistic
2. Repeatable level: basic project management techniques
3. Defined level: organisational standards for software processes
4. Managed level: organisation monitoring and control – data collection and analysis

5. Optimising level: continuous process improvement from feedback

These are shown in *Figure 31* and *Figure 32*.

This image has been removed due to copyright restriction. Available online from Godfrey (2008).

***Figure 31.* Five maturity levels taken from Godfrey (2008).**

This image has been removed due to copyright restriction. Available online from Kasse (2004, p. 219).

***Figure 32*. Maturity levels taken from Kasse (2004, p. 219).**

Martin (2020) highlights that there are many limitations of CMM as it does not state how to implement these maturity levels. Additionally, according to Martin (2020), there is no focus on software process improvement and does not indicate how an organisation should/ undertake implementation. Gajšek, Sternad, and Lerher (2018) also discuss the limitations of CMM as an oversimplification of complex issues through step-by-step increments and that there are multiple identical models in existence, and that new models are made frequently (Gajšek et al., 2018). Nonetheless, Martin (2020) suggests many benefits of using the CMM, such as improved software quality, a repeatable standard, reduced learning time, clear organisational expectations, cohesion, and improved processes. Since the initial development of the CMM, it has evolved into the Capability Maturity Model Integrated (CMMI). This successor combines several maturity models into an integrated model (Governance, 2020). The CMMI includes product and service development, service establishment, management and delivery, and product and service acquisition (Governance, 2020). The original CMM model had no focus on software-intensive systems, and there was a growing need for the model to be applicable across disciplines (Kasse, 2004; White, 2018). Consequently, the capability maturity model, the electronic industries alliance interim standard and the integrated product development CMM were combined to develop CMMI (White, 2018). White (2018) suggests that the benefits of CCMI include increased customer satisfaction, increased new clients, better productivity and efficiency, better profits, and decreased risk. Additionally, the CCMI could be used to improve performance through measurable goals and by creating structures that promote productivity, resulting in organisational cultural behaviour changes (Kasse, 2004; White, 2018). Further, CMMI has an increased focus on lessons learned and on the customers' organisations' goals and vision (Kasse, 2004; White, 2018). White (2018) suggests that the future of CMMI has a focus on performance, value, ease of use and integration with agile, scrum, safety, and security (White, 2018). In addition, Kasse (2004) suggests using the Goal Question Metric (GQM) to develop metrics to measure the Maturity Levels. Kasse (2004) highlights some of the characteristics of CMMI: efficiency, reliability, security, usability and scalability, modularity, clarity, maintainability, expandability, and portability. The next section discusses the key capability maturity models relevant to this thesis.

Key Capability Maturity Models

A review of the literature surrounding CMM reveals a liberal number of Capability Maturity Models currently available. Additionally, there are many literature reviews comparing different models within the literature. These have provided insight into how to design a Capability Maturity Model for information-flow failure.

Shown in Table 9 are the influential capability maturity models identified in the literature. These models have been categorised to identify their purpose, limitations, strengths, the information that they look at and how the model is used. However, many of the models do not explicitly state their limitations. Where limitations are not available from the literature, the limitations category has been determined by identifying what is relevant to this research. For example, shown in Table 9, the Baskarada et al., 2006 model has a limitation in that it is a model that has yet to be tested and verified, whilst other models, such as Williams (2008), have been tested and verified. In comparison, the Health Information Network model limitation is that it does not show the outcome of the CMM process or proof of process improvement. The models listed in Table 9 aim to improve processes and specifically target different areas such as Canada’s health information network, hospital information systems, medical security, information quality systems, logistics 4.0 and industry 4.0, interoperability in healthcare, digital hospital transformation and coordination of care. Strengths outlined include Baskarada et al’s (2006), four information categories and dimensions which can relate to information-flow metric characteristics as well as Baskarada et al’s (2006) Total Data Quality Management (TDQM) cycle within the maturity model, which provides a structure for process improvement through defining, measuring, analysing, and improving. Further, Baskarada et al (2006) and Williams (2008) have defined their models as frameworks. This has been categorised as a strength because frameworks enable the organisation to have a guide rather than a prescriptive instruction and are likely to be useful to describe information-flow metrics as there is also no single prescribed solution.

Table 9. Influential Capability Maturity Models found in the literature.

Reference	***Name***	***Purpose***	***Limitation***	***Strength***	***Have they looked at information***	***Model applicability***
(Baskarada et al., 2006)	Information Quality Management Maturity Model	Information Quality Management	• Total Data Quality Management (TDQM) focus is on the manufacturing industry • Places Information Quality Management (IQM) and Information Management (IM) separately • No detailed measurements or metrics. • Model has yet to be "tested, verified and enhanced"	• The model has four information quality categories and information quality dimensions defined • The model tries to prevent Information Quality Problems • Includes TDQM cycle in the maturity model • Model is a framework	Yes	Improve information quality management for effective decision making.
(Gajšek et al., 2018)	Maturity Levels for Logistics 4.0 based on NRW's Industry 4.0 Maturity Model	Logistics 4.0 and Industry 4.0	• Focus is on industry production with customers and suppliers • Basic model shown. Not detailed. • Has yet to be tested	• Focus was on Industry 4.0 model which includes IT systems and human-machine communication • Shows maturity levels in simple terms for information flow	Yes, but the focus is not information Information-flow is mentioned	To improve Logistics 4.0 maturity model. The model is used to assist companies in developing characteristics for connectivity with Industry 4.0 companies.
(Williams, 2008)	Operational CMM	Medical Security		• Proof of concept and model implementation is listed • Model has standards and had testing	Information governance security	Using the model for capability assessment for Tactical Information

Reference	***Name***	***Purpose***	***Limitation***	***Strength***	***Have they looked at information***	***Model applicability***
				• Applicable to real life		Governance Security (TIGS) model for medical practice.
(Carvalho et al., 2017)	HISMM – Hospital Information System Maturity Model	Hospital Information Systems (HIS)	• No Scoring	• Includes HIS growth and maturity progression in 6 stages • Based on literature review and surveys. Then validated by interviews. • Uses Design science research • Defines a set of activities and factors. Factors show the characteristics of each maturity stage. The factors represent criteria required for a maturity stage • Benefits according to paper suggests hospitals can define current maturity stages, determine the next stage and identify the characteristics required to meet that new stage	Yes – within hospital information systems	As a tool for HIS management to then be used for an automatic HIS maturity assessment tool.
(Infoway, 2015, p. 5)	Health Information Network (HIN) Maturity Model	Canada's Health information Network	• Doesn't show the outcome of the actual CMM	• Several different domains • Applied to a real-life scenario • 10 capability domains and a summary level	Information is involved. Clinical information exchanges	Tool for HIN planners and operators for leading practice for Canada Health.

Reference	***Name***	***Purpose***	***Limitation***	***Strength***	***Have they looked at information***	***Model applicability***
				• States the min HIN maturity levels for clinical uses		
Australian Digital Health Agency (2022)	National Electronic Health Transition Authority (NEHTA) Interoperability Maturity Model	Interoperability in Healthcare	• 2007 -	• Follows CMMI • 5 maturity levels with interoperability goals • Assessment framework measures maturity levels • Maturity levels for different domains such as local, enterprise and e-health community. • Assessment framework provides sequential steps for applying model	Yes	e-health interoperability maturity model to define paths towards e-health interoperability.
Williams 2019	Outcomes-Based Infrastructure Maturity Assessment for Digital Hospital Transformation	Digital Hospital Transformation		• Information use characteristics define eight information systems maturity levels and technology infrastructure capabilities • The levels are mapped to users' experiences and links between infrastructure and experience outcomes	Yes, including information flows Defines information and maturity Multiple dimensions to enable and support health care process	Allows digital hospitals to assess the maturity of their infrastructure in terms of digital transformation and information-flows, aligning to business outcomes.

Reference	***Name***	***Purpose***	***Limitation***	***Strength***	***Have they looked at information***	***Model applicability***
Health Level Seven (2021)	HL7 Service Functional Model (SFM)	HL7 coordination of administrative and clinical care software services		• Methodological approach that defines responsibilities and processes	Yes – efficient health information exchange	"specifies discrete functions or capabilities required for the development of electronic systems which support coordination of care by a collaborating care team." (Hl7 Service Functional Model Coordination of Care Services (CCS), STU Release 1, 2017 p. 28).

The section summarises the key Capability Maturity Models included in Table 9.

Information Quality Management by Baskarada, Koronios, & Gao (2006)

Research by Baskarada et al. (2006) focused on improving information quality for effective decision-making. A TDQM based CMM model for information quality management was developed. According to Baskarada et al. (2006), CMM can assist organisations to assess and enhance information quality through the assessment of processes into staged levels and highlighted that organisations have too much information and cannot process this information meaningfully, a key information quality challenge of increased information. The model Baskarada et al. (2006) developed is based on CMMI and has the standard five levels.

This image has been removed due to copyright restriction. Available online from Baskarada et al (2006, p. 6).

***Figure 33*. Information quality management capability maturity model taken from Baskarada et al. (2006, p. 6).**

As shown in *Figure 33,* each level in the model represents an information quality capability. By separating Information quality goals into levels, objectives for information quality can be achieved incrementally. Additionally, this maturity model adapts Total Data Quality Management (TDQM) methodology for Information Quality improvement and integrates TDQM cycles with the maturity levels of CMM. Baskarada et al. (2006) have identified information quality dimension categories such as intrinsic, representational, contextual and accessibility. These dimensions have been applied to the Baskarada et al. (2006) Capability Maturity Model and have included process areas that impact Information Quality. Level 1 represents no attempts to manage Information Quality, while levels 2 to 5 represent the TDQM cycles. The main difference between the Baskrada et al capability maturity model is that it includes the level 1 reactive level. Shown in Table 10 is an extract of Baskarada's et al. (2006) information quality dimensions. This model is useful for this thesis as it contains information quality metrics that can be applied to information-flow measurement.

Table 10. Information Quality Dimensions.

IQ Category	***IQ Dimension***
Intrinsic	Accuracy, objectivity, believability, reputation
Representational	Interpretability, ease of understanding, concise representation, consistent representation
Contextual	Relevancy, value-added, timeliness, completeness, amount of information
Accessibility	Accessibility, access security

Logistics based on Industry 4.0 CMM (Gajšek et al., 2018)

The research by Gajšek et al. (2018) et al, focused on the improvement of the logistics sector and industry 4.0. Industry 4.0 has been described by Gajšek et al. (2018) as the current trend of automation and data exchange for manufacturing technologies. Gajšek et al. (2018) further explained that Industry 4.0 includes IoT, cyber-physical systems and cloud computing systems. and suggested that CMM is appropriate for use in Logistics 4.0 as CMM's purpose is to describe maturity paths which can be applied to Industry 4.0 and is capable of depicting current models and describe progressive levels of maturity. This work explores industry 4.0 maturity model, which has the purpose of self-evaluation by an organisation. The industry 4.0 maturity model integrates multiple areas such as business models, IT systems, quality management, process management, production planning, control of production, logistics, distribution and management of public procurement, and human-machine communication. The authors developed a CMM that can be used in logistics (*Figure 34),* illustrating the maturity levels for external logistics. This starts at the basic level, which is data transmitted in paper form, with the second level using feedback on paper. However, data is now converted to a digital format and documented. The third maturity level represents internal logistic information transmitted through Enterprise Resource Planning (ERP) systems. The fourth level represents the use of internal logistic information in real-time, emphasising real-time analysis that results in the delegation of resources and detection of errors. Lastly, the fifth level has all data digitised and focuses on automatic real-time feedback and data usage to prevent interruptions in internal logistics information flow.

This image has been removed due to copyright restriction. Available online from Gajsek et al. (2018).

***Figure 34*. Gajsek et al. (2018) Logistics 4.0 Capability Maturity Model taken from Gajsek et al. (2018, p. 704).**

Williams (2008) Capability Maturity Model

Williams (2008) studied the introduction of information and electronic storage and communication capabilities into the medical environment and the resulting challenges to information security. This research aimed to develop a CMM for medical information security practice in order to assess the current capability of medical practice and identify how improvements in information security can be made. The study reviewed several CMM models such as the software engineering CMM, systems engineering CMM, CMMI, systems security engineering CMM, integrated product development CMM, software acquisition capability maturity model, requirements CMM, people CMM and HIPAA CMM. Common relevant CMM characteristics were identified such as maturity levels, key process areas and goals, common features and key practices and used CMM as a template to define activities rather than processes along with achievement level as a guide for effective practice. This research also examined the issues that arise with the application of CMM within a medical environment and found that only repeatable activities are improved and does not address activities that are not repeatable. Another notable finding was that implementation of change in healthcare takes five to ten years rather than the initial 12 months suggested by CMM. CMM within the medical environment needs to be designed to include measurement in combination with simplicity in order to complete security assessments. As shown in *Figure 35,* Williams (2008) has proposed a CMM as an operational framework that incorporates the planning and tracking of activities and described common characteristics to focus on providing a practical solution to medical practice security. These characteristics are relevant to information-flow characteristics in healthcare.

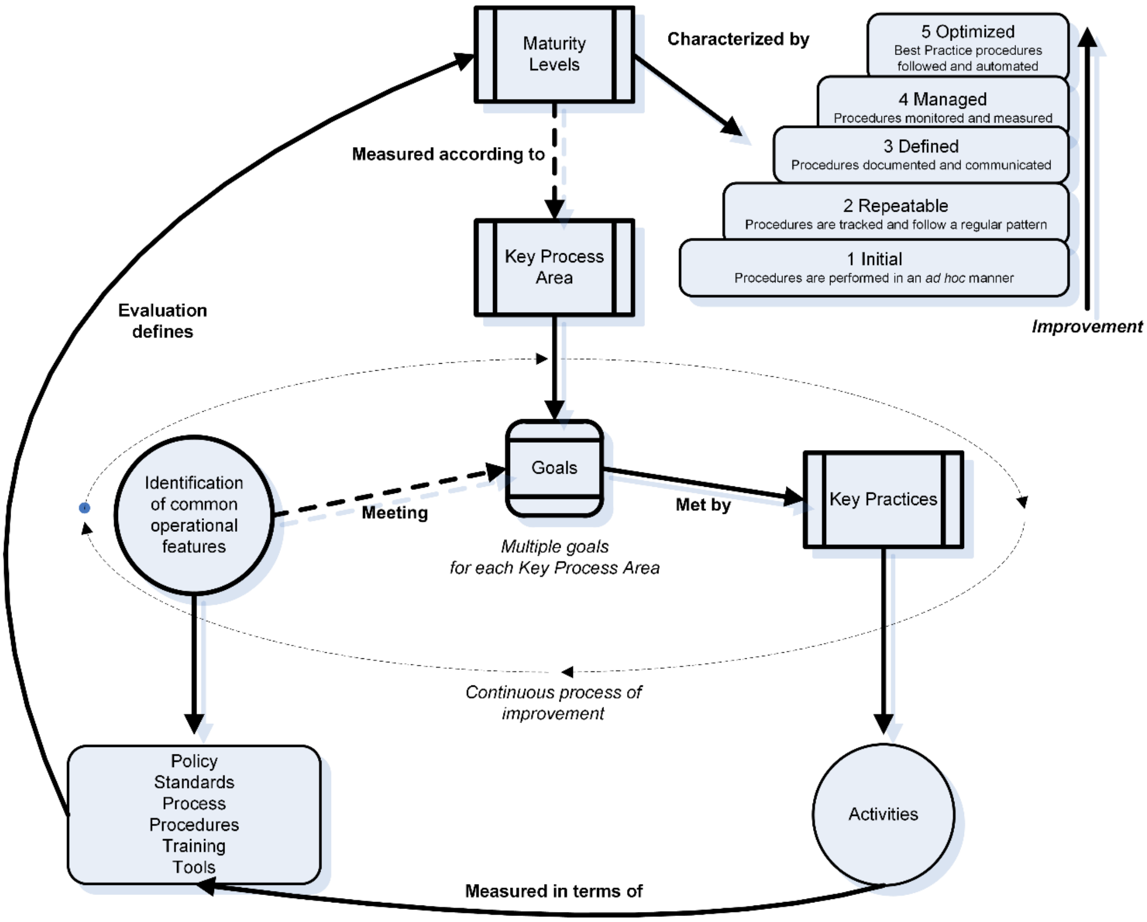

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***Figure 35*. CMM as an Operational Framework in Healthcare - Williams (2008, p.64).**

Hospital information systems CMM (Carvalho, Rocha, & Abreu, 2017)

Research by Carvalho et al. (2017) developed a maturity model for information system management in healthcare. This model is referred to as the Hospital Information System Maturity Model (HISMM) and can identify the maturity of information systems and implementation activities and actions to achieve goals for information system management. The HISMM was revised from Nolans 4 stage maturity model, and Gallier's and Sutherland's (1991) revised model. The HISMM was designed with maturity stages rather than levels and described the influence factors for healthcare information systems. Each maturity stage is defined by specific characteristics and contains health information system measurable outcomes. Therefore, the HISMM can be utilised by hospitals to define maturity stages and identify and define outcomes for health information systems. Shown in Table 11 is the HISMM as a matrix, showing the first two stages and factors such as people, strategy, and data analysis.

Table 11. HISMM Capability Maturity Model

Factor	***Stage 1 - adhocracy***	***Stage 2 – starting the foundations***
Data Analysis	• Isolated and fragmented data analysis solutions • Data integrity issues	• Centralised data repositories • Automated production of internal reports
Strategy	• There is no global strategy • There is no formal strategy	• Plans are shared between silos • Lack of understanding of how to achieve success
People	• Inconsistency when performing existing practices • Lack of responsibility and capacity of existing managers/ staff	• Adoption of communication and coordination procedures • Introduction of performance management

Canada Health Information Network Capability Maturity Model (Infoway, 2015)

The Canadian Health Information Network Maturity Model is used by "planners and operators to objectively assess themselves, and to develop plans for enhancing their operational capabilities" within the Canadian Healthcare system (Infoway, 2015, p. 14). This CMM can be used to determine the current maturity level of a health information network, develop maturity level goals, and provide guidance on how the health information network can move to the next maturity level. The Canadian Health Information Network Capability Maturity Model has ten capability domains and five maturity levels per domain. Shown in *Figure 36* is an extract that contains definitions of the three levels and a summary of the capability domains.

This image has been removed due to copyright restriction. Available online from Infoway (2015).

Figure 36. **Canada Health Information Network Capability Maturity Model maturity levels taken from Infoway (2015, p.5).**

Table 9 summarises the key Capability Maturity Models that were reviewed and their associated maturity level definitions and metrics. They all follow the CMM/CMMI levels, with optimised being the highest and none or initial being the lowest level with three or four intermediate levels. Reviewing the actual levels themselves, most follow the maturity levels of the CMM/CMMI format. The HIN model was applied to several domains, including Vision and Stakeholder Engagement, Governance and Technology Infrastructure and Applications (Infoway, 2015). Additionally, the HL7 Service Functional Model does not have any maturity levels but is relevant when developing an information-flow maturity model as it is a model that addresses efficient health information exchange, which mediates healthcare information-flow. As shown in Table 12, the capability maturity models aim to improve processes that impact information-flow. Although many do not mention the term information-flow, these models improve processes and information quality that results in improved information-flow within those processes. This results in better information-flow and effective decision-making and underlines the importance of terminology. The major characteristics of the key capability maturity models are shown in Table 12.

Table 12. Characteristics of Capability Maturity Model Levels.

Capability Maturity Model / Reference	***Maturity Levels Characteristics***
Information Quality Management Maturity Model/ (Baskarada et al., 2006)	• Reactive: No awareness of any IQ issues. Only reacting to IQ • Quantified: IQ metrics have been developed and IQ is being assessed • Optimizing: Processes causing IQ problems are continually improved • Managed: Root causes of IQ problems have been identified and impact of poor IQ has been calculated • Aware: All information products and their quality specifications have been defined
Maturity Levels for Logistics 4.0 NRW's Industry 4.0/ (Gajšek et al., 2018)	• Paper transfer of data • Transfer of paper data in digital form • ERP system • Digital data completeness • Automatic transfer of data
Operational CMM/ (Williams, 2008)	• Initial: procedures are performed in an ad hoc manner • Repeatable: Procedures are tracked and follow a regular pattern • Defined: Procedures are documented and communicated • Managed: Procedures are monitored and measured • Optimised: Best Practice procedures followed and automated
HISMM – Hospital Information System Maturity Model / (Carvalho et al., 2017)	• "ad hocracy" • Starting the foundations • Centraslied dictatorship • Democratic cooperation • Entrepreneurial opportunity • Integrated relationships
Health Information Network (HIN) Maturity Model/ (Infoway, 2015, p. 5)	• Initial • Anticipate • Interoperate • Collaborate • Optimise
NEHTA Interoperability Maturity Model/ (Australian Government, 2022)	• None: No awareness of e-health interoperability issue nor processes to support it. Isolated system design, development, and procurement • Initial: Awareness of e-health interoperability requirement. Initial e-health interoperability solutions typically within clinical/ administrative • Managed: Begin adoption of e-health standards. Shared understanding of data/services/internal processes. Early governance • Defined: Defined guidelines for healthcare standards, services, policies, processes and legal compliance. Established governance • Measured: Processes for appraising e-health interoperability e.gh. conformance/ compliance or run-time monitoring • Optimised: Driven by feedback from monitored processes, interoperability capability continuously improves overall e-health capability
Outcomes-Based Infrastructure Maturity	• Initial: procedures are performed in an ad hoc manner • Repeatable: Procedures are tracked and follow a regular pattern

Capability Maturity Model / Reference	*Maturity Levels Characteristics*
Assessment for Digital Hospital Transformation/ (Williams et al, 2019)	• Defined: Procedures are documented and communicated • Managed: Procedures are monitored and measured • Optimised: Best Practice procedures followed and automated

This section discussed how information-flow could be improved through information-flow mapping, information-flow modelling, and capability maturity models. The next section will discuss the gaps in information-flow research and the overall literature review summary and the significance of the current research.

2.5 What are the gaps in information-flow research?

2.5.1 Literature Review Summary

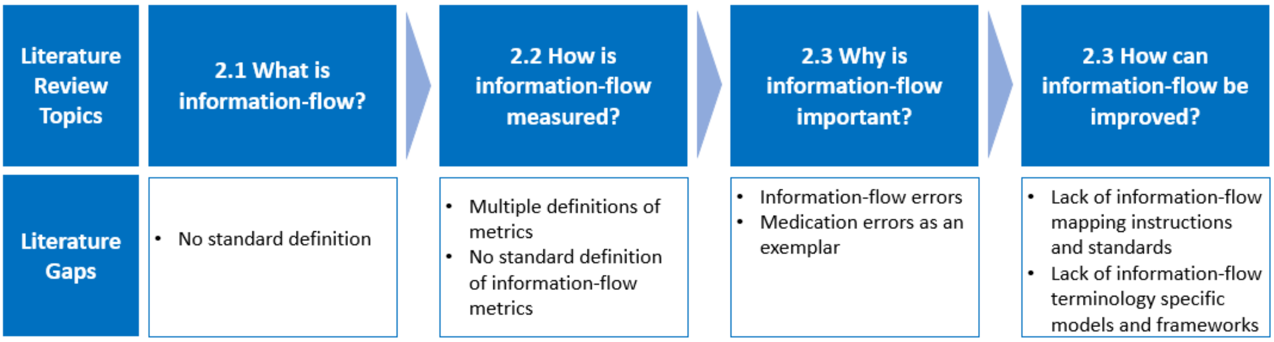


Figure 37. **Information-flow literature review topics and gaps.**

Table 13. Summary of Information- flow research.

Theme	**Research**
What is information-flow?	The initial literature review identified essential gaps in the literature, especially regarding the lack of information-flow and associated metrics research in healthcare. While no standard definition for information-flow currently exists, a definition was selected for this thesis. Information-flow is about the theory of information and the semantic context of how information is communicated from one place to another. This includes how information travels from its original location to its intended recipient.
How is information-flow measured?	The literature review then explored measuring information-flow and the importance of information-flow standards and metrics. However, it also identified a lack of a standard definition for information-flow metrics. An

	information-flow metric definition was selected that was fit for information-flow research. In addition, the literature review identified that no previous study had developed metrics to measure healthcare information-flow failure, and there is a gap in the development of metrics to validate information-flow models and evaluate the quality of information within information systems.
Why is information-flow important?	The known problems of information-flow are related to information-flow failure. Information-flow failure is caused by information disruption. This can be problematic as information-flow has the purpose of transmitting information from one point to the other. However, if there is a disruption at any point of that information-flow, it can potentially result in information-flow failures. Causes of disruption include miscommunication between people (includes acts of omission or commission), disruption of flow between technological systems and people, and disruption in flow between technological systems
How can information-flow be improved?	Information-flow mapping is important to identify how information is transferred from one point to another within an organisation (Hibberd & Evatt, 2004). This is particularly important in identifying information-flow failure and areas which can be improved. According to Hibberd and Evatt (2004), mapping information-flow can identify how information is used and whom it is used by and identify information services to which could be used to improve an organisation. In essence, information-flow mapping is a visual illustration of how information-flow is connected and has similarities to data flow and process mapping. Information-flow models and capability maturity models developed for information-flow were also identified as tools to identify and measure information-flow in order to identify improvement areas.

The literature topics reviewed (*Figure* 37) explored the definition of information-flow and how it is used to understand and identify how information travels within information systems. The initial literature review identified essential gaps in the literature, especially regarding the lack of information-flow and associated metrics research in healthcare. While no standard definition for information-flow currently exists, a definition was selected for this thesis. The literature review identified that there is little research using the term information-flow. However, information-flow is contextual, and related concepts exist in the literature such as communication flow. While workflow was also identified as a proxy for information-flow on the basis that the similarities between workflows and information-flow may be used for developing an information-flow framework that may be used in different environments to measure information-flow failure. The literature review then explored measuring information-flow and the importance of information-flow standards and metrics. However, it also identified a lack of a standard definition for information-flow metrics. An information-flow metric definition was selected that was fit for information-flow research. In addition, the literature review identified that no previous study had developed metrics to measure healthcare information-flow failure, and there is a gap in the development of metrics to validate information-flow models and evaluate the quality of information within information systems. Following, the initial literature review, an exploration of why information-flow is important was undertaken through a discussion of the known issues caused by information-flow failure with specific healthcare examples. A key finding was that research investigating the impact of information-flow on patient misidentification is missing; subsequently, little is known regarding how information-flow can reduce patient misidentification. The literature review identified many technologies are either semantically confused or overlapping and consequently explored how information-flow could be improved through information-flow mapping, information-flow models and capability maturity models. However, it was discovered that there is a lack of information-flow mapping instructions and standards in the literature. Further, exploration of relevant model mapping revealed methods such as data flow and process mapping, which can be used to map information-flow, and further illustrated the lack of standard information-flow terminology in the literature. The importance of information-flow terminology also extended to the terms model and framework, as in the literature, the terms model and framework are often used interchangeably. Many frameworks and research did not specifically mention information-flow, however, and the published research revealed that information-flow improvement was involved as the models were used to improve information-flow within their context. The inability to differentiate between information-flow models and frameworks as well as the limited research and models that use the term information-flow, highlight the importance of information-flow terminology for information-flow understanding and research. In addition, the capability maturity models all have the aim of improving processes which impact information-flow. Although, many do not mention the term information-flow, these models improve processes which subsequently result in improved flow of information within those processes. No previous study was identified that had developed metrics to measure information-flow failure, nor had a framework or model been explicitly developed for information-flow metrics and characteristic in healthcare. Without information-flow healthcare metrics, it is difficult to evaluate benefit or harm of information-flow change. Further, this review has identified a gap in the development of metrics for the purpose of validating information-flow models and evaluating the quality of information within information systems. These knowledge gaps are the subject of the research described in this thesis.

2.5.2 Significance of this research

A review of the literature has identified gaps in knowledge of data and information-flow in healthcare. These gaps highlight information-flow and its measurement as an important factor in clinical outcomes. There is currently no research into the effects of information-flow on medication variances as an exemplar. In addition, the literature review has identified that healthcare information-flow metrics designed to measure the desirable and undesirable characteristics affecting clinical outcomes, have yet to be developed. The concept that an information-flow framework which can be evaluated using defined metrics, has yet to be investigated. Once developed, such a framework can be used to identify and measure healthcare information-flow failure. Without such tools, no clear understanding of how informational-flow failure impacts patient outcomes can be assessed. Therefore, this research has focused on understanding and measuring information flow within a defined framework and how using this to improve information-flow characteristics can improve patient outcomes. The next chapter will discuss the methodology used for this research.

CHAPTER THREE: METHODOLOGY

The aim of this research was to understand if an information-flow framework for use in healthcare could be developed that can measure information-flow failure; through identifying information-flow characteristics that are desirable and undesirable. To ensure the research outcomes were valid, applying of a rigorous and sound methodology was essential. Therefore, this chapter begins with an overview of the theoretical basis for this research, specifically drawing attention to the research paradigm that this research falls under. Additionally, this chapter discusses a range of appropriate methodologies and provides the justification for the chosen methodology - Design Science. There follows the research framework and design. Finally, the chapter concludes with a discussion on the ethical considerations and limitations of conducting this research.

3.1 Research Paradigm

A research paradigm can be defined as an "overarching philosophical or ideological stance, a system of beliefs about the nature of the world" (Broom, 2007, p. 17). In relation to methodology, the paradigm plays a role in how knowledge is gained. The following discusses three types of paradigms: Creswell's (2013) positive and interpretive paradigms and Weber's (2010) socio-technologist paradigm.

3.1.1 Positivist Paradigm

According to Creswell (2013), positivist paradigms create objective knowledge through the methodology, and that reality is fixed with a scientific approach to research. Additionally, Creswell (2013) suggests that the theoretical lens is social science and that the positivist paradigms are well known for logical steps into research and multiple perspectives rather than a single perspective. Positive paradigms are known for their rigorous research methods of data collection and analysis as well as the use of computer programs to assist the analysis of research (Creswell, 2013). Examples of the methods that utilise a positivist paradigm include epidemiological design strategies, which include controlled trials, survey research, secondary document analysis, structured interviewing, systems reviews, and meta-analysis. A key feature of the positivist paradigm is determinism, in which the phenomenon to be studied may be predicted from knowledge and objectivity where bracketing of the inquirers' experience will take place (Creswell, 2013). While quantification, reliability, and generalisability are aspects of a positivist paradigm research that need to be addressed to reduce limitations.

3.1.2 Interpretative Paradigm

According to Creswell (2013), the interpretive paradigm, also known as social constructivism, seeks an understanding of the world and is displayed as a subjective meaning of experiences. Further, knowledge is constructed from society and is subjective in nature, while methods that are commonly used include interviews, observations, focus groups and secondary discourse analysis (Creswell, 2013). While features displayed often include interpretivist paradigms, which seek understanding of subject meanings. Another feature of this paradigm is the naturalistic feature which suggests that data is to be collected in the setting of everyday life. Subjectivity, complexity, as well as political features, are also associated with this paradigm.

3.1.3 Socio-technologist Paradigm

In contrast to the positivist and interpretive paradigms, Weber (2010) suggests socio-technologist or developmentalist as a third paradigm for information systems research. Weber (2010) indicates that the paradigm of socio-technologist fits within the positivist and interpretive paradigms, and reality is the practical application, development and evaluation of software and technology. Additionally, Gregg, Kulkarni, and Vinzé (2001) indicate that the socio-technologist paradigm contains multiple created realities that are interdependent with software and technology. *Figure 38* illustrates three types of paradigms mentioned by Weber (2010) and demonstrates how the interpretive and positivist paradigms provide knowledge from reality and methodology that flows into the socio-technologist paradigm. As a result, software and technology are created, and the knowledge gained is delivered back into the positivist and interpretive paradigms (Gregg et al., 2001).

This image has been removed due to copyright restriction. Available online from Weber (2010).

Figure 38. **Three types of paradigms taken from Weber (2010, p. 4).**

While Liu (2003) illustrates a different philosophical view from Creswell (2013) and Weber (2010) and explores information systems from the perception of objectivist and subjectivist paradigms (refer to *Figure 39*).

This image has been removed due to copyright restriction. Available online from Liu (2003).

Figure 39. **Objectivism and Subjectivism Paradigms taken from Liu (2003, p. 23).**

Table 13 shows the differences between objectivist and subjectivist paradigms taken from Liu (2003).

Table 14. Objectivist and Subjectivists Paradigm.

Objectivist Paradigm	Subjectivist Paradigm
• Subject-independent world • Single reality • Some objective reality • The world is made from entities (facts and objects) • The human mind is a 'blank sheet' until knowledge is 'written' by the external world. • Supports models and methods from natural sciences.	• Individuals are the starting point for a shared reality • Emphasis on abilities of individuals and choices • Understand human life through studying subjective experiences • Language is constructive • A social world can be created, altered, and twisted by language • The world constantly changes

3.1.4 The Paradigm chosen for this Research

Having discussed the types of paradigms that exist for information systems, it is important to discuss the information systems paradigm chosen for this research. Displayed in Table 14 are the differences between the objectivist and subjectivist views on information systems concepts and the chosen paradigm for this research. As shown in Table 14, an objectivist view was chosen for most of the information system concepts on the basis that this research is about information-flow failure within healthcare and requires factual data that has been recorded and evidence from research. However, except for the concepts of information system and role of the analyst, both an objectivist and subjectivist view were taken as the Researcher has their own bias and perceptions when mapping and analysing information-flow.

Table 15. Information Systems Paradigm.

Concept	***Objectivist View***	***Subjectivist View***	***This Research Paradigm View***
Reality	Objectively given and the same for everyone	Created subjectively, subtle differences between groups of knowing the agents	Objectivist View
Data	A means of representing the truth about reality	A means of indicating intentions and coordinating actions	Objectivist View
Truth	The correct correspondence between real entities	A consensus reached (temporarily) as a basis for coordinated action	Objectivist View
Meaning	A relationship between a sign and some real entity	A relationship between a sign and some pattern of action established as a norm within a group	Objectivist View

Concept	Objectivist View	Subjectivist View	This Research Paradigm View
Information System	A kind of "plumbing system" through which data flows	A semi logical system, mainly informal but supplemented by formalised messages	Objectivist and Subjectivist View
Role of the Analyst	To specify the truth, data structure and functions of the system needed by the users	To assist the users to articulate their problems, discover their information requirements and evolve a systemic solution	Objectivist and Subjectivist View

This section has examined positivist and interpretive paradigms, drawing attention to the objectivist and subjectivist views on information system realities, particularly the type of view this research assumes. The next section will discuss the theoretical framework of Information Systems Theory.

3.1.5 Theoretical Frameworks (Information Systems Theory)

The theoretical basis has a significant role in the research process and explains concepts, definitions, and theories. A significant artefact in the research question is information-flow (IF), which has the theoretical basis in Information Systems Theory (IST). Different information systems theories were reviewed to determine the epistemological approach for this research. Lerner 's (2004) IST ideology, which is founded on connecting the world with information and information technologies, suggests IST's focus should be the transmission of information and to recognise regularities. Further, Lerner (2004) defined information systems as "an interconnected set of interactions that exchange information, and which are capable of integrating themselves into a common information unit (Subsystem, system)" (Lerner, 2004, p. 406). Similarly, Gregor (2002) refers to IST as the "design, delivery, use and impact of information technology in organizations and society" (Gregor, 2002, p. 2). Additionally, Gregor (2002) highlights the idea that theory cannot be discovered but rather invented and suggests that there are five theories for Information Systems. The five theories by Gregor (2002) are:

- Theory for analysing and describing
- Theory for understanding
- Theory for predicting
- Theory for explaining and predicting
- Theory for design and action

Interestingly, Gregor (2002) created a structured taxonomy to classify the theories taken from other disciplines and are fundamental to Information System Research (Shanks, Bekmamedova, & Johnston., 2012). Similarly, Shanks (2012) expresses that Information System Theory improves research and understanding and has defined theory as "a particular kind of model that is intended to account for some subset of phenomena in the real world" (Shanks, Bekmamedova & Johnston, 2012, p. 2). Additionally, Shanks (2012) describes process theory into three approaches; causal associations, event chains and sequence of activities. Furthermore, Shanks (2012) outlines four types of process theory:

1. Life cycle process theory: Features a sequence of events followed by a predictable path;
2. Evolutionary process theory: Sequence of events shaped by survival of resources;
3. Teleological process theory: No Sequence of events, set goals for action; and
4. Dialectic process theory: Sequence of events that show conflict of operations (Shanks, Bekmamedova, & Johnston, 2012).

Building on the idea that there are several information systems theories, an associated concept of information systems theory is semiotics. As such, this next section illustrates the relevance of semiotics. Liu (2003) has discussed semiotics demonstrate information systems as a data, process, and behaviour-orientated method (Liu, 2003). This is important to information system theory and information-flow as it enables the information and nodes/ actors to be represented. Additionally, semiotics has been defined as a “whole cycle of a sign” (Liu, 2003, p. 13), which essentially describes semiotics as the study of meaning and communication. Liu (2003) further highlighted syntactic, semantics and pragmatics as the three fields within semiotics and suggests that semiosis is required to interpret the signs. Semiosis and the fields of semiotics can be applied within computing and are referred to as “nature of computer-based signs and how they function” (Liu, 2003, p. 18). Shown in *Figure 40*, ‘signs’ are shown as systems, artefacts, behaviour, and knowledge, which are all linked into semiotics and result in system development, design, and descriptions.

This image has been removed due to copyright restriction. Available online from Liu (2003).

Figure 40. **Information-flow semiotics taken from Liu (2003, p. 18).**

Highlighted by Liu (2003) and Lim et al (2009), are the number of different information system theories to support research. As shown in *Figure 41*, Shanks (1999) has also demonstrated information systems theory from the perspective of communication and understanding. The basis of information systems theory is to “represent the structure and behaviour of other systems” (Shanks, 1999). Information systems theory involves communication and coordination, while it is suggested by Shanks (1999) that the philosophical understanding of information systems theory lies in an ontological position. This suggests that artefacts have related attributes that include data and information (Shanks, 1999). Data refers to things that have not been interpreted and can range from various sources (Ilkka, 1999/2000). Information, on the other hand, is attributes of the data which are related (Shanks, 1999).

This image has been removed due to copyright restriction. Available online from Shanks (1999).

***Figure 41*. Information Systems Theory taken from Shanks (1999).**

Shanks (1999) suggests that meaning can be derived from data, while information is derived from perception, a combination of knowledge and experience (Shanks, 1999). Assumptions can be made due to information, in which information may be interpreted in a particular way, due to knowledge and experience (Shanks, 1999). An individual's perception and understanding of the world is subjective and is known as an epistemological position (Shanks, 1999). Subsequently, knowledge can give meaning to information (Ilkka, 1999/2000). Information systems arise as the world is interpreted with symbols due to knowledge. In comparison, the term ontology refers to the theory of how individuals perceive the world (Shanks, 1999). Shank's (1999) highlights the levels at which individuals can interpret data:

- The syntactic level is associated with the form of the data or symbols. The need for rules and correct interpretation of data is a key factor at the syntactic level;
- The semantic level requires experience and knowledge to take meaning from the symbols;
- The pragmatic level involves the use of the data and refers to the context of the data and how it can be properly used; and
- The social levels are associated with understanding the data because of culture and social bias (Shanks, 1999).

The levels mentioned by Shanks (1999) are significant to information system theory as they provide an explanation for the way in which individuals can interpret information and data. Interpretation of information and data is an important factor in information-flow and information-flow mapping, which is the subject of this research. Additionally, Rowlands (2017) highlights the idea that data is derived from facts, concepts or instructions that are in a formalised presentation. With information referring to data with context and knowledge as the act of information with wisdom.

This image has been removed due to copyright restriction. Available online from Rowlands (2017).

***Figure 42.* How data turns into action taken from Rowlands (2017).**

Shown in *Figure 42* is Roland's (2017) perception of how data turns into action. This is supported by Shanks (1999), who suggests that individuals who communicate with each other result in information-flow. However, this is where issues within information-flow arise, as individuals can either possess knowledge or lack knowledge (Shanks, 1999). In the context of this research, this may be seen directly as information-flow failure (Hermon, 2014) that impact patient safety within healthcare. While information-flow failure lies within the process of communication and information systems theory from which the concepts of data and information are derived. Key information system theories that explain the concepts and theories behind information-flow have been discussed, with Shanks (1999) information systems theory chosen for this research on the basis that it is most relevant to information technology and information-flow. Having reviewed the theoretical basis for the research, the next part of this chapter will compare a variety of research methodologies that were used to choose Design Science as the methodology.

3.2 Research Methodologies

As shown in Table 15, there are several qualitative methodologies that can be used for information systems theory research, which includes the strengths, weaknesses, application, and justification of this research.

Table 16. Methodologies applicable to this research adapted from Creswell (2013).

Research Methodologies	***Strength***	***Weakness***	***Application and justification to Research***
Experimental Research (Creswell, 2013)	To document one person's (organisation's) history and development.	Transferability, researcher selection of material, point of view.	Understand clinical information-flow failure though an individual's experience of medication errors.
Survey Research (Creswell, 2013)	To discover participants perceptions.	Does not confuse perceptions with statements about facts.	Understand clinical information-flow through interviews.
Ethnography Research (Creswell, 2013)	To develop new theoretical directions.	Difficulty personal bias.	Data collected to create interpretations about clinical information-flow.
Phenomenological Research (Creswell, 2013)	To find out about (sub) cultural transmission, norms and beliefs.	Time-consuming.	Gain better understating of (sub) culture values regarding clinical information-flow.

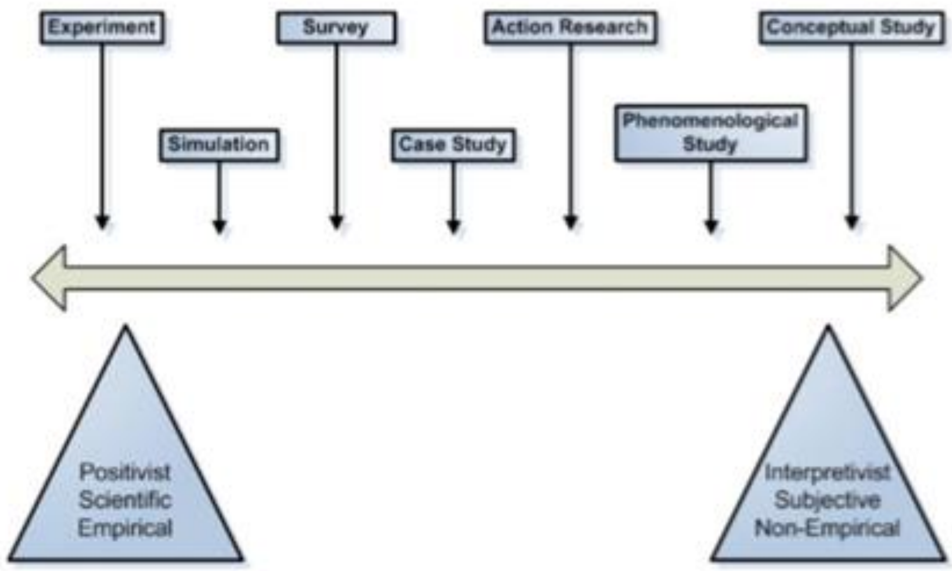
Research Methodologies	***Strength***	***Weakness***	***Application and justification to Research***
Grounded Theory (Creswell, 2013)	Examine a phenomenon holistically using multiple data sources.	May have a very limited transferability.	Explore a phenomenon holistically. Instrumental case study can be used to explore clinical information-flow failure.
Action Research (Creswell, 2013)	Action research incorporates systematic inquires to enhance the contextual working environment. Through observations and communication solutions to problems are generated.	Validity poses as a weakness.	Can be used to systematically inquire about medication errors. Cycles can be used to conduct investigation into phenomenon.
Discourse Analysis (Ritchie & Lewis, 2009)	Explores systems of social meaning; uses documents, interviews, and conversations.	Data is voluminous and requires to be reduced.	Both document and conversation analysis can be used to understand medication errors and points of information-flow failure.
Case Studies (Simons, 2009)	Experience and objectives are studied in an in-depth case. Explores the process of change and is flexible.	Data is voluminous, reports are long, and subjectivity and validation remain a limitation.	Useful for exploring the causal links of information-flow. Provides evidence of success/failure of information-flow models. Useful for evaluating objects for decision making influences in medication errors.
Design Science (Wieringa, 2014)	Design and investigation in artefacts in a context. Focus is on a solution to a real problem.	Reliability and bias of solution. Lack of knowledge from experts.	Design Research is founded in information systems theory. Problem is medication related information-flow failure. Focus is to design a model to provide a solution to the context.
Activity Theory (Bakhurst, 2009)	Useful for understanding human computer interactions in information-flow.	Can be ambiguous and time can be considered a limitation.	The information-flow model contains human computer interactions which can be understood through Activity Theory.
Distributed Cognition Theory (Rogers, 1997)	The focus is to understand and analyse the relationships between human computer interactions.	Relationships and models require a lot of time to understand the concepts and interpret the data. This methodology cannot be applied to design problems.	This methodology could be used to develop an information-flow model through analysing the relationships in information-flow.

Shown in Table 15 are the different methodologies that could have been applied to this research. However, further review of these methodologies revealed that Grounded Theory, Action Research, Case Studies, and Design Science were methodologies that were most relevant to this research as they all had the ability to understand information-flow systems. The following section is a description of each of these methodologies and their justification for application to this research. Additionally, this section elaborates and justifies the reasoning and selection of Design Science as the chosen methodology for this research.

3.2.1 Grounded Theory

Grounded theory was first developed in 1967 by sociologists Glaser and Strauss and was developed to focus on the data rather than theories and analytic constructs (Bryant & Charmaz, 2007). Grounded theory focuses on the process of identification and the product of that process. This methodology enables phenomenon to be understood through methods, such as comparative analysis, theoretical sampling, and theoretical decoding. Bryant and Charmaz (2007) suggest there are no steps for grounded theory research as the researcher is encouraged to constantly review the research process and, if required, change the research question or direction. As a result, the research question of grounded theory is open-ended and aims to identify a phenomenon. Data collection includes semi-structured interviews, participant observations, focus groups and diaries, while the data analysis includes coding of the data. This methodology is known for contextualising social processes and identifying how humans manage social situations and processes. The benefit of this approach to this research would enable information-flow and human social processes to be understood. Through data collection methods such as interviews and participant observations, an information-flow framework could be developed that identifies the human processes. However, the main disadvantage of grounded theory is that, as a sociological methodology, it does not help us understand information-flow from an information system perspective. Therefore, Grounded Theory as a methodology was not chosen for application to this research.

3.2.2 Action Research



Reproduced with permission

Figure 43. **Where action research is placed according to paradigms taken from Williams (2006, p. 5).**

Williams (2006) has explored Action Research and its paradigm. This has resulted in a *Figure 43* which identifies action research as a paradigm that sits in between both Positivist and Interpretivist. Nonetheless, as action research involves participants as researchers, it is identified that it slightly falls further into the Interpretivist paradigm. Therefore, Action Research was identified as appropriate to this research, as information-flow can be investigated through the cycles of planning, acting, observing, and reflecting. Accordingly, the qualitative methodology action research could have been chosen for this research project as it most appropriately reflects the research design of the research by providing the research processes to investigate information-flow and medication errors through the Action Research cycles.

This image has been removed due to copyright restriction. Available online from Koshy (2005).

Figure 44. **Explanation of action research cycle taken from Koshy (2005, p. 7).**

Action research has been defined by Costello (2011) as a methodology that is "usually described as cyclic, with action and critical reflection taking place in turn. The reflection is used to review the previous action and plan the next one" (Costello, 2011, p. 5). Therefore, action research can be understood as a process of problem-solving by individuals (Costello, 2011). According to Shoba (2015), the philosophical origins of action research are founded in different social groupings and cultures. In addition, Shoba (2015) suggests that pragmatic philosophy, humanistic philosophy, and complexity theory have contributed to the theoretical perspective of action research. Shoba (2015) has also suggested that learning is a key factor of action research, and because of learning, action will immediately follow. Action Research has taken on both an emancipatory and collaborative approach, as its purpose is to understand and ultimately improve the world (Shoba, 2015). Key perspectives include discovery, action and improving practice, while the cyclic nature of action research is suggested to hold a dialectical relationship between retrospective understanding and prospective action. Therefore, the questions asked by the researcher are comprehensive (Shoba, 2015). Currently, there are a variety of action research models that can be used; three of which have been identified by Master (1995), and include the scientific-technical view, practical-deliberation action research and critical–emancipatory action research. Further, as shown in *Figure 44,* Participatory Action Research (PAR) is an action research model that is often used within health research; therefore, justifying its use within this research project (Koshy, 2005). Further, action research is often applied to the health environments to solve problems (Koshy, 2005). The key stages of action research within a cycle include planning, acting, observing, and reflecting. Once the reflection stage of action research has been completed within a cycle, the next cycle will commence with the planning stage, which will result in cycles repeat and becoming a spiral. Costello (2011) has developed an eight-step action research framework that can be applied to the research process.

The steps include:

- Step 1: defining the enquiry
- Step 2: describing the educational situation
- Step 3: collecting and analysing evaluative data
- Step 4: reviewing the data and looking for contributions
- Step 5: tackling a contradiction by introducing change
- Step 6: monitoring the change
- Step 7: analysing evaluative data concerning the change
- Step 8: reviewing the change and deciding what to do next

The research question proposed in this research could have been answered with the use of Action Research cycles. Action Research cycles could have been used to analyse and develop metrics to characterise the information-flow failure and benefit. Following the development of the metrics, another cycle could be designed to evaluate the metrics. A third cycle would then be designed for the development and evaluation of an information-flow model. However, there are certain drawbacks associated with the use of Action Research. For example, results are often interpreted, which can result in a time-consuming analytical research stage. Additionally, the benefits and relevance of Design Science as a methodology outweighed the benefits of Action Research.

Therefore, Action Research, while practical and associated with several benefits, was not the chosen methodology for this research.

3.2.3 Case Studies

Simons (2009) has defined a case study as “a study of the singular, the particular and the unique” (Simons, 2009, p. 3). Although this methodology has foundations in several domains, such as sociology, anthropology, history, and psychology, the sole purpose is to explore a singular case. Case study methodology was particularly favoured in education research in the USA and UK in the 1960s because it provided evidence for the success or failure of a case. A case can be referred to a person, classroom, programme, or policy whilst referencing other cases. Qualitative case studies are subjective, and value multiple perspectives of the participants involved. According to Simons (2009), there are generally two perspectives of case study methodology; the first is the concentration of the education process, while the second is the follows the concept or the narrative of the case study. In addition, there are three types of case studies; they include intrinsic, instrumental, and collective. Intrinsic refers to a case studied for the case itself, instrumental refers to a case answering a research question, and a collective case study refers to researching a collective understanding of the research question. A variety of methods can be used during a case study methodology and can range from both qualitative and quantitative research methods, which include interviews, observations, and document analysis. Strengths of case study methodology include in-depth analysis of objectives and experiences, multiple perspectives of document analysis, exploration of the change process and evidence of outcomes. The research questions could have been answered with the use of case study methodology as the causal links associated with information-flow, and medication management could be analysed. Further, case studies can provide appropriate evidence metrics of information-flow that characterise failure and benefit. Additionally, case study methodology can be used for evaluating the information-flow process and the decision-making influences. Although case study methodology had several benefits, and applications to this research, it was not chosen as results are often difficult to replicate and case study methodology can be time-consuming. In addition, the number of cases may not be sufficient and may result in a generalisation. However, case study as a method was not dismissed as the Researcher identified the benefits of using case study as a method to examine the phenomenon. These benefits of case study as a method are discussed further on in the chapter (Chapter 3.5) in relation to this research methods used.

3.2.4 Activity Theory

Activity Theory was explored as a potential methodology for this research. According to Hashim & Jones (2014) and Crawford & Hasan (2006) Activity Theory was first developed by Vygostky and Leontec in the 1920s, as part of a cultural and historical studies in psychology. Much of Vygostky’s work in social psychological theory concerned individuals shaped by their subjective social and cultural experiences (Hashim & Jones, 2014; Crawford & Hasan, 2006). As defined by Hashim & Jones (2014), Activity Theory is a “theoretical framework for analysis and understanding of human interaction through their use of tools and artefacts” (Hashim & Jones, 2014, p. 1). Essentially, the subject is the person being studied, the objective is the intended activity, and the tool is the device that is being used (Hasim & Jones, 2014). Shown in *Figure 45* by Hashim & Jones (2014) is the relationship between tools, subjects, and objectives. Additionality, Hashim & Jones (2014) has included rules, community, and division of labour, which result in an outcome.

This image has been removed due to copyright restriction. Available online from Hasim & Jones (2014).

***Figure 45*. Relationship between tools, subject and objective taken from Hasim & Jones (2014).**

Traditionally, the Activity Theory methodology was used for social psychology theory. However, since the 1990s, an increasing amount of Human-Computer Interaction research has occurred. As identified by Hashim & Jones (2014) and Crawford & Hasan (2006), Activity Theory is currently a relevant methodology for information system research and development in healthcare. Hashim & Jones (2014) and Crawford & Hasan (2006) highlight that this methodology is useful for understanding human activity through understanding tools and can be used to understand how the interactions between individuals and technologies can influence activity. Further, both Hashim & Jones (20140) and Crawford & Hasan (2006) agree that tools or artefacts that represented the Activity Theory refer to computers. Similarly, this research is based on information systems theory and examines information-flow in healthcare; therefore, Activity Theory was considered a suitable candidate for this research. Additionality, the Activity Theory methodology applies to this research as it has relevance in information system research and practice (Crawford & Hasan, 2006). This research aims at developing an information-flow framework. Therefore, Activity Theory would be useful in understanding the relationships between technologies and human interactions in information-flow. However, Activity Theory was not chosen for this research as this research does not just look at the relationships between technologies and human interactions. This research also focused on developing an information-flow metric to determine if an information-flow model can result in benefit or harm in healthcare. Therefore, Activity Theory was not chosen as a methodology suitable needed to have the ability to develop an information-flow maturity framework.

3.2.5 Distributed Cognition Theory

This section explores Distributed Cognition Theory as a Human-Computer Interaction research methodology. Historically, Distributed Cognition Theory was applied to human activity research (Perry (2003). However, it was soon developed as an approach to understanding the interactions between individuals and technologies (Hollan, Hutchins & Kirsh, 2000). Hollan, Hutchins & Kirsh (2000) suggests that Distributed Cognition Theory explores cognition and information systems and enables understanding of these systems through models (Hutchins, 2017). For example, information-flow models, layouts, and artefacts of systems. Additionally, Rowland (2017) highlights information-flow models to illustrate information-flow and communication within these systems. This methodology demonstrates Human-Computer Interaction research and provides context for analysing and understanding of information-flow within models and information systems. (Rogers, 1997). Therefore, Distributed Cognition Theory could have been used to develop an information-flow model as the interactions between individuals and systems could be identified (Rogers, 1997). However, the focus of Distributed Cognition Theory is the Human-Computer Interaction research component. Although this methodology would have been useful for developing information-flow models, it could not have been applied to developing information-flow metrics. This is due to the focus of Distributed Cognition Theory on processing of work activities and relationships between Humans and Computers.

3.2.6 Design Science

Design science refers to the "design and investigation of artefacts in context" (Wieringa, 2014, p. 3). Artefacts refer to systems, organisations, services, processes, techniques, while context refers to software, hardware, services, goals, methods, and structures. Design Science aims to improve a problem within the context of the artefact. According to Wieringa (2014), there are two types of research problems in design science: design problems and knowledge questions. Design problems refer to a design that solves a real-world problem while knowledge questions refer to a proposition to a real-world problem as shown in *Figure 46.*

This image has been removed due to copyright restriction. Available online from Wieringa (2014).

***Figure 46*. Design Science perspective taken from Wieringa (2014, p. 5).**

Design Science is a solution-orientated methodology with its foundations in information system theory, architecture, engineering, education, psychology, and the arts (Hevner, 2010; Wieringa, 2014). According to Hevner (2010), design science directly addresses the role of IT in information system research and improves IT problems. It is important to highlight in *Figure 47* that the Design Science framework is designed with stakeholders as the social context and is designed with the use of knowledge context (Wieringa, 2014). Thiese (2014) suggests that knowledge context refers to theories, research, facts, and knowledge that can come from scientific literature, technical literature, professional literature, and oral communication. As shown in *Figure 47,* both design problems and knowledge questions provide feedback to and from the knowledge context, which results in continual solving of current problems/ questions and new problems and questions to answer, therefore, improving both design and knowledge.

This image has been removed due to copyright restriction. Available online from Wieringa (2014).

Figure 47. **Design Science framework taken from Wieringa (2014, p. 7).**

Design Science is founded upon information systems theory (Wieringa, 2014), which links with this research as epistemology is also information systems theory. According to Wieringa (2014), design science is relevant to information system research because of the role of the IT artefact in Information System research. Wieringa (2014) further highlights the idea that design science is a pragmatic research paradigm that results in the creation of artefacts to solve wicked problems. Conversely, Weber (2010) has developed a research framework that focuses on design research results as product and processes. As shown in *Figure 48,* Weber (2010) suggests kernel theories as impacting factors of these products and processes. Kernel theories have been described by Weber (2010) as factors impacting the requirement of IT, while the relationship of evaluation and instantiation to ensure the value of the product or process. Weber's (2010) framework was developed from existing approaches and represented the relationship between processes and products within research. This relationship is important in identifying the organisation's IT requirement and can be used to re-evaluate the process that was used to design the product.

This image has been removed due to copyright restriction. Available online from Weber (2010).

Figure 48. **Design Science Research Framework taken from Weber (2010, p. 2).**

As described, many methodologies were reviewed for their relevance and application to this research. Many methodologies, such as activity theory, distrusted cognition theory and action research could have been used. However, after reviewing those methodologies' theories, background and research applications, Design Science was ultimately chosen as the most appropriate methodology for this research. There were several reasons why Design Science was chosen; firstly, the key benefit to Design Science is that it has a focus on organisations, teams, and individuals, which includes information-flow systems and, to a larger extent the organisations surrounding information-flow such as healthcare. Secondly, Design Science can solve real-world problems using knowledge context, investigation, and design as an iterative approach. This is directly applicable to this research as the problem involves developing an information-flow framework that can identify desirable and undesirable characteristics; for the purpose of measuring information-flow in healthcare and ultimately improving information-flow. Thirdly, Design Science has the perception of improving processes and products, which was identified to enable understanding of information-flow characteristics and mapping and to capture the complexities of a solution to this current world problem. Lastly, the application of Design Science methodology to this research enabled several different methods to be built into the research. These methods would result in designing, investigating, and creating knowledge in the context of this discourse. The next section explores the Research Questions for this research.

3.3 Research Questions

3.3.1 Main Research Question:

Can a healthcare information-flow framework be developed that can measure information-flow failure and demonstrate the framework's effectiveness in identifying information-flow maturity in healthcare?

3.3.2 Sub Research Question:

How can healthcare information-flow metrics be identified and measured?

This research involved analysis of information-flow to develop an information-flow metrics framework that could identify and understand what information-flow characteristics are considered desirable and undesirable.

The research required analysis of current information-flow frameworks to identify whether an information-flow framework could measure information-flow, on the basis that an improved understanding of clinical information-flow changes could inform the development of ways to avoid failure and improve the effectiveness of communications. The next section describes the research road map and design steps used in this research.

3.4 Research Roadmap

Figure 49 indicates where the research design within Information Systems Theory. It shows how the methods, problems, frameworks, and theories relate to Information Technology through scholarship, practice, and research

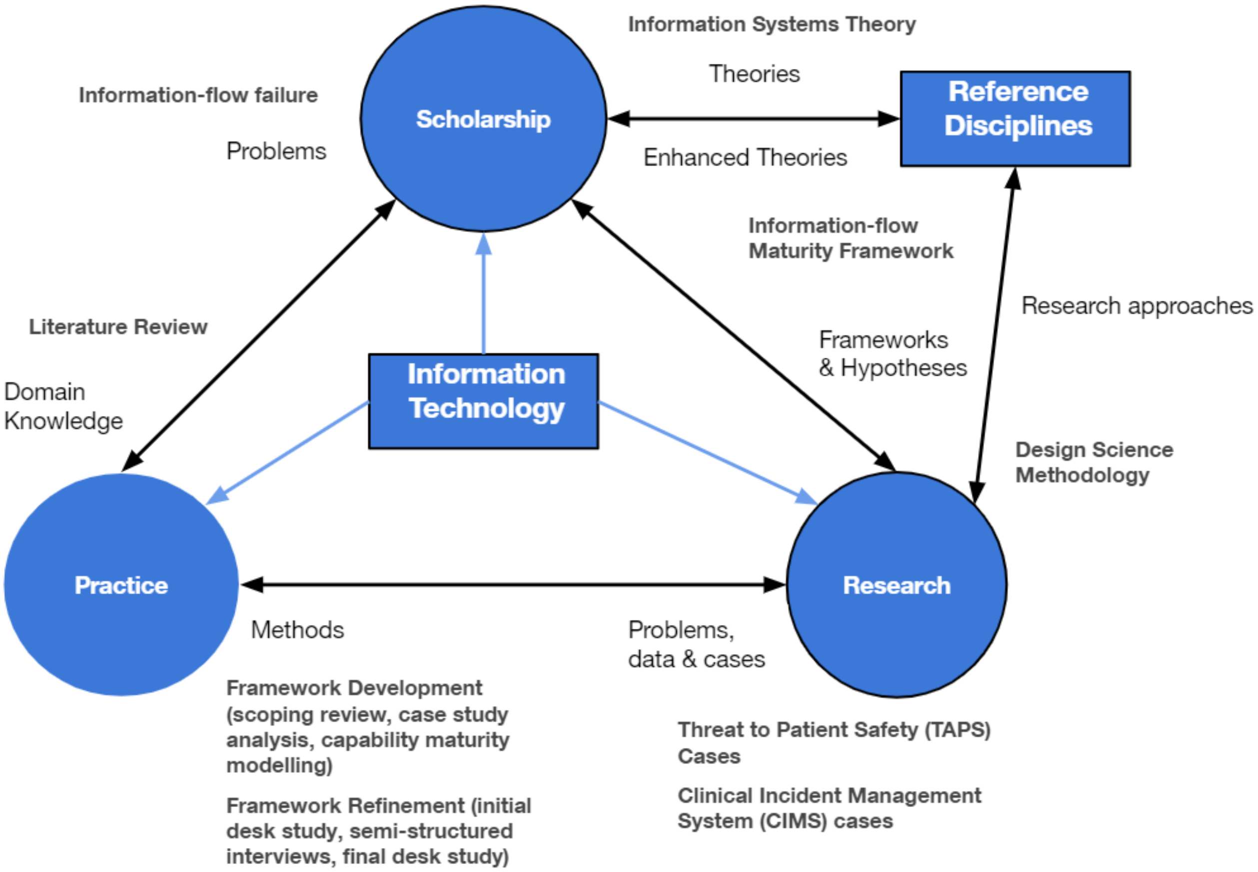


***Figure 49*. Where this research fits in Information Systems Theory adapted from Shanks (1999) information system theory.**

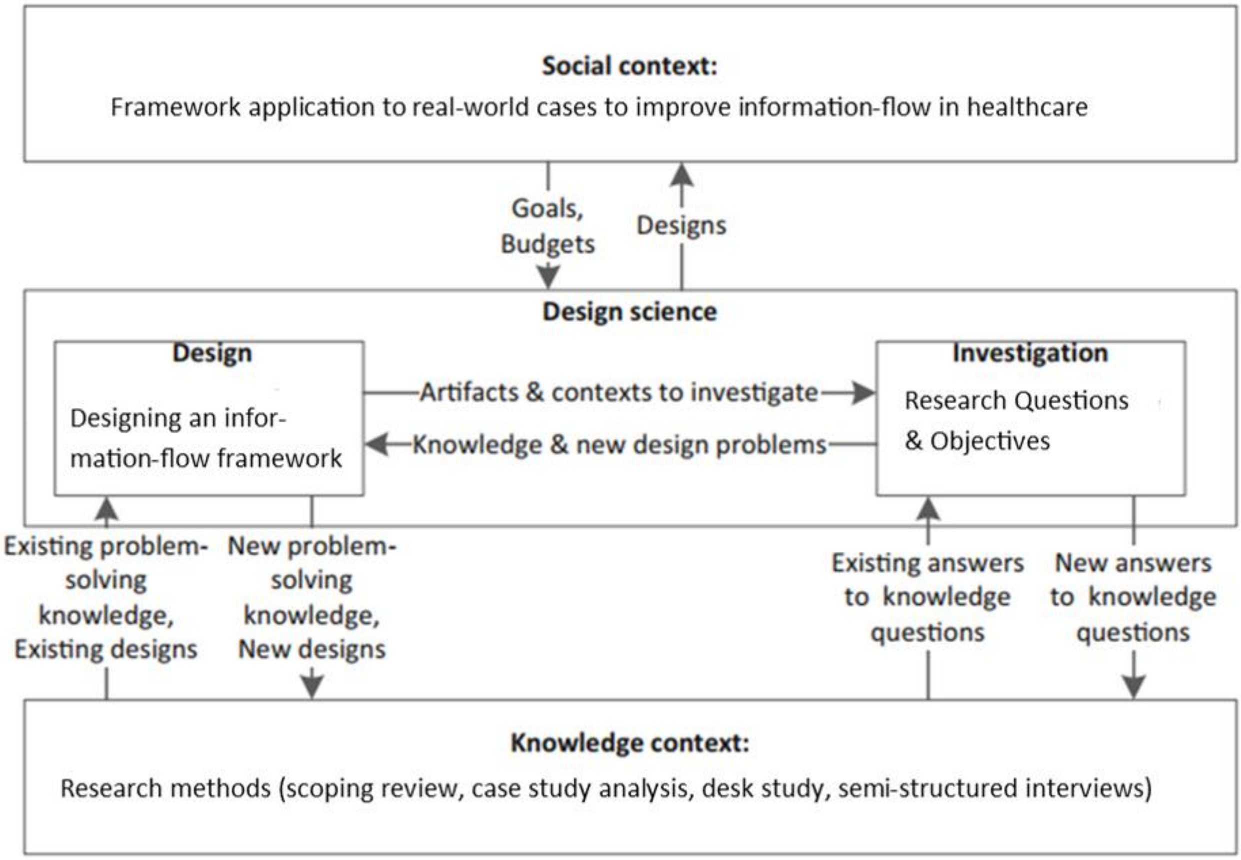


Figure 50. **Research Design. Wieringa (2014, p.7).**

Shown in *Figure 50* is the research road map for this research. This research roadmap adapts the Design Science research framework from Weber (2010) to this research. The Research Questions have replaced the social context and demonstrate the link to Design Science as the goals and budget flow into the Research Design methodology. While the Designs from Design Science feedback into the Research Questions. Additionally, *Figure 50*, shows designing an artefact to improve a problem context. This artefact is developing an information-flow framework and associated metrics, that can be used to improve information-flow within healthcare. The artefacts and contexts to be investigated inform the research questions. This investigation refers to the information-flow research used to develop the information-flow framework and metrics and is shown to feedback into the Design. The knowledge context refers to the key search terms and literature review findings that are were also used to support the investigation and develop the design of the information-flow framework. *Figure* 51 illustrates the Research Design steps that were informed by the Research Design in *Figure* 50.

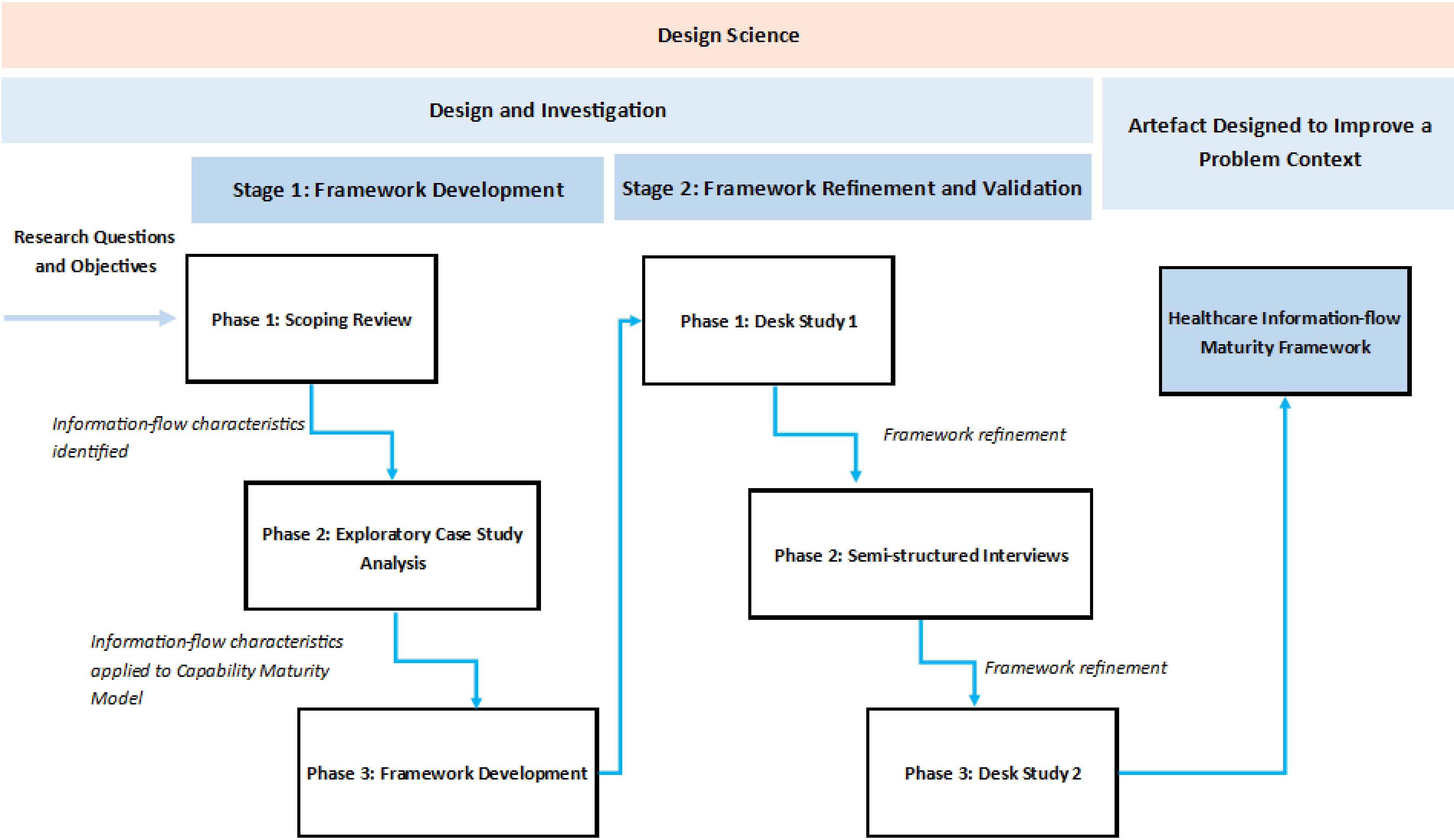


Figure 51. **Research Design Steps. Johannesson & Perjobs (2014)**

3.5 Research Design Steps

As shown in *Figure 51,* there are two parts to this research. The first is Stage 1: Framework Development, which consists of three phases and the second is Stage 2: Framework Refinement and Validation, which also consists of three phases. The following discusses the two stages and methods used in the phases.

3.5.1 Stage 1 - Framework Development

Stage 1 Framework Development consists of three phases which led to the initial development of the information-flow maturity framework. Stage 1 allowed for specific problem definition and for identifying a potential solution. The next section discusses the method used in Phase 1 of Stage 1, which was a scoping review of the literature.

3.5.2 Phase 1 of Stage 1: Scoping Review of the literature

Phase 1 of the framework development was a scoping review of the literature. The scoping review focused on searching the literature based on search terms, and the findings were categorised into themes and analysed by the Researcher. Following the scoping review, the key findings included information-flow characteristics; however, the scoping review findings also brought new questions for the research, such as how to develop information-flow metrics.

The following outlines the scoping review process adapted from Peters (2015) that was used as the method for Phase 1.

Step 1: Define a clear review topic, objective, and sub-questions

The aim of the scoping review was to further identify the problem. Therefore, the purpose of the scoping review was to understand metrics and information-flow characteristics within the literature.

Step 2: Develop a protocol and conduct systematic searches

Peters (2015) suggests a methodology needs to be developed prior to the search with definitions, objectives, preliminary searches, justification for the review, and eligibility criteria to be defined prior to the commencement of the scoping review. In reference to Phase 1, search criteria and search terms were defined, and both databases and grey literature were searched.

Step 3: Screen results that meet the search criteria

The results of the systematic searches were then screened for irrelevant materials, duplicates and for search items that did not meet eligibility criteria.

Step 4: Extract and chart relevant data

Results were then analysed and categorised according to themes. Relevant data was charted in tables and graphs.

Step 5: Write up evidence to answer your question

Following the analysis, a discussion was written as to what was found in the scoping review, such as information-flow characteristics.

3.5.3 Phase 2 of Stage 1: Exploratory Case Study Analysis

Reliability and Validity of Case Study Research

At the start of Chapter 3, several different methodologies were reviewed and compared, which included the exploration of case study analysis. Exploratory case study analysis was chosen as a method for Phase 2 of Stage 1, as it required an in-depth analysis of developing metrics for an information-flow maturity framework, and the purpose of case study research is to investigate a phenomenon in a real-life context; and define the boundaries between the context and phenomenon (Yin, 2012). In addition, case study research is relevant for knowledge utilisation and focuses on 'how' and 'why' research questions (Yin, 2012), which is another reason why case study analysis was used for Phase 2 of Stage 1. Yin (2018) defines case study as research method as the ability to "illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result" (Yin, 2018, p. 17). In addition, cases include individuals, organisations, processes, programs and even events (Yin, 2018). Streb (2010), Yin (2012) and Zainal (2007) all suggest that exploratory case study research investigates phenomena that has lack of detailed preliminary research. Additionally, Zainal (2007) defines case studies to "explore any phenomenon in the data which serves as a point interested" (Zainal, 2007, p. 3). It should be noted that case study research in particular has been emphasised by Streb (2010) as useful in situations where the research questions or data collection is not clearly defined. Further, Streb (2010) highlights the benefit of exploratory case study research as it provides flexibility and independence to the research design. While Zainal (2007) suggests this method of case study research allows exploration and understanding of complex issues through a robust, holistic and in-depth explorations. Additional advantages of the exploratory approach include using data within context of use, using qualitative and quantitative data and exploring real life scenarios (Zainal, 2007). Additionally, Yin (2012) further suggests that research design is the relationship between the research questions posed and the data collected. It is noted that research design is particularly important to case study research as it enables the study to be both reliable and valid in its design quality (Yin, 2009). While the disadvantages of this approach have been illustrated by both Yin (2012) and Zainal (2007) as case study research can be perceived as sloppy, with lack of rigour, too small subjects or too long. Further, Yin (2018) states that case studies can be difficult to complete due to their lack of rigour and systematic procedures. While problems with case studies are further exacerbated by non-existent case study research skills and the inability to screen if a researcher has case study research skills (Yin, 2018).

Shown in Table 16, Yin (2009) identifies four types of tests to facilitate quality case study research design.

Table 17. Adapted from Yin's (2009, p. 41) Case Study tactics for four design tests.

Tests	***Case Study Tactic***	***Phase of research in which tactic occurs***	***Application to research***
Construct validity	• Use multiple sources of evidence • Establish chain of evidence • Have key informants review draft case study report	Data collection/ composition	• Three documents for in-depth analysis. • Each document is from a different source.
Internal validity	• Do pattern matching • Do explanation building • Address rival explanations • Use logic models	Data analysis	• Comparing and contrasting the findings of each document. • Explanation building of each document.
External validity	• Use theory in single-case studies • Use replication logic in multiple-case studies	Research design	• Findings from documentation can utilise replication logic.
Reliability	• Use case study protocol • Develop case study database	Data collection	• Protocol to reduce bias and acceptance opposing findings to be implemented.

As shown in Table 16 the four design quality tests were implemented in Phase 2 case study design, data collection and analysis stages. This is due the data collection and result being unknown and requiring exploration. Further, design quality tests were utilised through understanding researcher bias and accepting opposing findings, using multiple cases from different sources, which data and findings can be replicated and through in-depth explanation summaries of the documentation. Importantly, Yin (2009) highlights that both the strengths and weakness of using documentation for case study research. In depth analysis of documentation strengths include stable and review sources of information, repeatable, unobtrusive, exact and a broad coverage. While the weaknesses of documentation are retrievability, bias, repeating bias, and access. Nonetheless, this case study analysis as a method was primarily chosen as it uses the researcher's intuition to explore the unknown (Yin, 2012). Following, three texts that were used in the Phase 1 scoping review, were chosen based on their context and detailed descriptions of developing metrics. Further, the design quality tests shown in Table 14 were incorporated into Phase 2 on the basis that an explanatory case study could explore and understand how to develop information-flow metrics. The following describes the steps used to conduct Phase 2.

1. Identify texts to be used for case study
2. Review each text and record key notes

3. Analyse documents
    a. Purpose of metrics discussed
    b. Definition of metrics
    c. Industry/ area applied to/ in
    d. How this gives you metric boundaries or how you can use this for the boundaries
    e. Why it should be considered for information-flow metrics.
4. Compare and contrast texts.

The findings from the texts were analysed and identified that there is no one method of developing a metric. Therefore, a capability maturity assessment was recognised as the method to develop the information-flow metrics for this research.

3.5.4 Phase 3 of Stage 1: Develop Framework

A capability maturity model assessment was chosen to create the information-flow metrics. Therefore, Phase 3 involved developing an initial healthcare information-flow maturity framework. Capability maturity models traditionally have six levels and the Researcher adapted a process for developing the information-flow maturity framework based on the key findings from the exploratory case study analysis and capability maturity model levels (*Figure 52*).

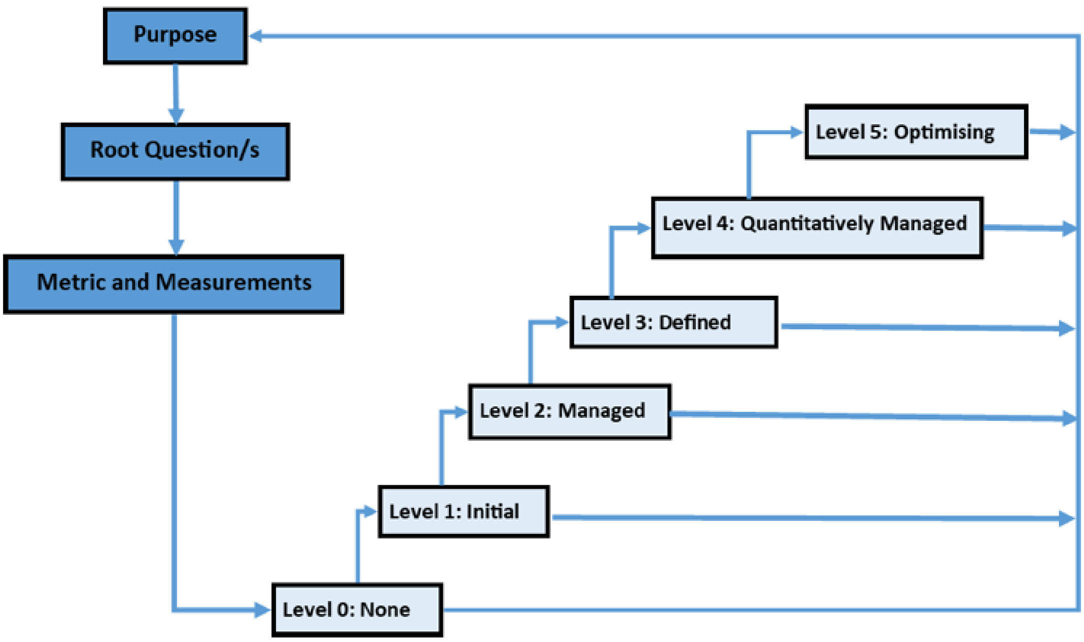


Figure 52. **Information-flow capability maturity model development process. Henshall (2019), Hayden (2010, Klubeck (2015) and Maurer (2013).**

The following steps were used to create the healthcare information-flow maturity framework

1. Define the purpose
2. Define the root questions
3. Define the information-flow metrics and characteristics based on the scoping review and case study analysis findings.
4. Define the maturity levels for each information-flow metric.

3.5.5 Stage 2: Framework Refinement

Stage 2 frame refinement had focus on refining the information-flow maturity framework through the use of Desk Study 1 using TAPS data and by conducting semi-structured interviews. Following, a Desk Study 2 with CIMS data to validate the information-flow maturity framework.

3.5.6 Phase 1 of Stage 2: Desk Study 1 – TAPS data application

Stage 2 findings resulted in an initial information-flow maturity framework and identified information-flow characteristics. This framework required application of cases to validate its use in healthcare and as such desk study 1 was used to validate the framework. The next section discusses what a desk study is, why it was chosen as well as how it was used to refine the framework.

A desk study also known as desk research or secondary research uses pre-existing data (Morris & Largan, 2019) such as published materials, published reports, statistics, online sources, government or agency reports, online journal articles, databases, libraries, conferences and even lectures and expert talks (Morris & Largan, 2019). Stickdorn et al (2018) suggests the purpose of the desk study is to identify data from research that already exists, whilst the Government of Victoria (2020) suggests that the desk study method is to review current research or information relevant to the research and to identify gaps in research. Advantages of the desk study method include confirmation on work that has previously been completed, awareness of different research and methodologies Government of Victoria (2020). Morris & Largan, 2019 also suggests that using existing data for research has benefits as it is cheap, time used to gather the data is saved, the data is available, and information is ready to be used. Government of Victoria (2020) highlights the importance of assessing how the data was gathered and that relevant data may be missed if searching was poor. Both Stickdorn et al (2018) and Travis (2016) suggest that secondary research is the first step in the systematic research process. Additionally, desk study methods are about using previously collected data which can be either quantitative or qualitative data and can be used to validate information system research such as frameworks (Mingers & Standing, 2020; Stewart et al, 1993). While some disadvantages of the desk study are suggested by Morris & Largan, 2019 and Government of Victoria (2020) and include the lack of credibility and authenticity of the existing data and that current data may not be used in the research. Additionally, Government of Victoria (2020) highlights that the quality of the data is subjective to the relevance, timeliness and transparency of the data used. Although there are disadvantages associated with desk studies, desk studies ultimately allow use of existing data to be used and as such use of pre-existing data would enable a focus on validating and refining the information-flow maturity framework. As such, the desk study method was chosen to validate the healthcare information-flow maturity framework with the TAPS study data used as pre-existing data. The Threat to Patient Safety (TAPS) study which had been used previously by Hermon and Williams (2020) to identify and map information-flow failure was chosen as it had already been applied to a framework as secondary research and that the TAPS cases had information-flow failure mapped. As this research included the development of capability maturity model, steps on applying the desk study to the capability model were required. As such,. Paulk's (1993) steps to applying a capability maturity model to an organisation were reviewed.Historically, Paulk (1993) provides six instructions on how to apply a Capability Maturity Model to an organisation for the purpose of improving the software process. Paulk's (1993) original approach includes:

1. Team selection
2. Maturity questionnaire
3. Response analysis
4. Onsite visit – reports, interviews, and documents
5. Findings – based on CMM
6. Maturity Profile.

Pualk (1993) capability maturity model application steps were combined with desk study research steps by Stickdorn et al (2018), Travis (2016), Stewart et al (1993) and Paulk (1993).

1. Define the purpose and objectives of the research
2. Select cases for Desk Study 1
    a. Identify the sources for existing data.
    b. Evaluate the reliability of the sources.
        i. Who collected the data?
        ii. When was the data collected?
        iii. How was the data collected?
        iv. What was the aim of the original study?
        v. What was the methodology used?
3. Apply the cases to the framework and measure information-flow cases
4. Analysis - complete an analysis on the framework with the cases to measure a information-flow maturity profile.
5. Identify improvements for the information-flow maturity framework

The findings of Desk Study 1 showed that the framework could be used. However, further refinement and validation was required.

3.5.7 Phase 2 of Stage 2: Semi-Structured Interviews

Semi-structure interviews, otherwise known as qualitative interviewing (Adams, 2015), are a combination of structured and unstructured interviewing techniques (Adams, 2015; Given, 2008; Pollock, 2020; Robson, 2011). Semi-structured interviews are often used in social science (Evans, 2018; Leavy, 2014), healthcare (Jamshed, 2014) and development research (Raworth et al.); for the purpose of understanding and exploring issues from a participant perspective (Robson, 2011). Wilson (2013) highlights those facts, attitudes, opinions, and information about artefacts such as tasks, flow, forms, best practices, diagrams, signs, equipment, posters, and photographs, can all be explored in a semi-structured interview.

The process of conducting semi-structured interviews begins with identification of the participants (Adams, 2015; Given, 2008; Robson, 2011). Once participants have been chosen the interviewer then produces an interview guide and develops open ended questions for use during the interview (Adams, 2015; Given, 2008; Robson, 2011). The interviews are considered flexible and conversational as the interviewer uses the interview questions as a guide to conversation with the participants (Adams, 2015; Given, 2008; Raworth et al.; Robson, 2011). Additionally, it is recommended interviews to go no longer than 1 hour, to avoid fatigue and encourage the interviewer to take the approach of listener and learner (Adams, 2015; Given, 2008; Jamshed, 2014; Raworth et al.; Robson, 2011). After the interview, it is further recommended by to record and type up the interview to avoid forgetting any information, and subsequently complete the analysis of the interviews (Adams, 2015; Given, 2008; Jamshed, 2014; Raworth et al.; Robson, 2011). Adams (2015) suggests semi-structured interviews are beneficial for one-on-one interviews, mixed method approaches and when for exploring participant perspectives. Further strengths include exploring concepts in depth with participants, exploring topics that cannot be explored with structured interviews or in focus groups, flexibility, and that the interviewer requires less training for interviews (Wilson, 2013).

The limitations of the semi-structured method are that the participants can be influenced by the interviewer's technique, interviewing bias, lack of interviewer skills or lack of interview consistency across participants (Wilson, 2013). Additionally, interviews can be time consuming, and the research can be hard to generalise if each interview is inconsistent and participants are asked different questions (Wilson, 2013). The semi-structured interview method is flexible for one-on-one interviews and useful for exploring participants perspectives on artefacts such as frameworks and was chosen for this phase of the research to facilitate expert review using one-on-one interviews to understand their perspective on information-flow, and to obtain their feedback on the healthcare information-flow maturity framework's usability, accuracy, and definitions. The following section discusses how the interviews were conducted. Information Technology experts were selected for the interviews so that the framework could be validated by experts with experience in the field. The information-flow maturity framework was provided to the interviewees during the semi-structure interviews, together with an example case study to apply to the framework. The framework was subsequently refined based on the expert feedback.

3.5.8 Phase 3 of Stage 2: Desk Study 2 – CIMS data application

The desk study approach used in Desk Study 1 was repeated in Desk Study 2. The following steps were taken during Desk Study 2.

1. Define the purpose and objectives of the research
2. Select cases for Desk Study 2.
    a. Identify the sources for existing data.
    b. Evaluate the reliability of the sources.
        i. Who collected the data?
        ii. When was the data collected?
        iii. How was the data collected?
        iv. What was the aim of the original study?
        v. What was the methodology used?
3. Apply the cases to the framework and measure information-flow cases.
4. Analysis - complete an analysis on the framework with the cases to measure a information-flow maturity profile.
5. Identify improvements for the information-flow maturity framework.

As a result of Desk Study 2, refinement of the information-flow maturity framework was informed by the application of the Clinical Incident Management System database (CIMS) cases to the framework. Important findings from the second study include refinement of the framework and what metrics could and could not be measured.

3.6 Quantity of Data Collected for each method

Research Phase	**Quantity of Data**
Scoping Review of the Literature	• 26 search terms • 9 search criteria • 164 records reviewed

	• 64 records used for the scoping review
Exploratory Case Study	• Three texts were identified from the literature review and future analysed using the case study method.
Desk Study 1 – TAPS data application	• 3 studies reviewed • 5 criteria selected • 164 TAPS cases reviewed • 8 selected and used for the study
Semi – Structures Interviews	• 30 participants contacted • 7 participants interviewed • 28 pages of transcript (14000 words)
Desk Study 2 – CIMS data application	• 12 cases used

3.7 Ethical Considerations

The National Australian Privacy Principles were followed during this research. Additionally, ethics approval from Flinders University was granted to conduct this research including interviewing the experts. It should also be noted, all information collected, analysed, and published by the Researcher was de-identified data, in which no humans or animals were harmed.

3.8 Limitations of the study

Bias was a limitation of this study as it involved the Researcher subjectively designing and developing information-flow characteristics and an information-flow framework. In addition, lack of knowledge or research experience/ skills could have impacted the final design of the information-flow framework. However, to overcome these limitations an in-depth and rigorous research design was aligned to the Design Science methodology. Further, a three-phased refinement approach (Stage 2) that included expert interviews reduced the bias of the Researcher. Additionally, the Researcher's Supervisors constantly provided feedback and review to ensure the designs of the framework were not influenced by bias or lack of knowledge.

In this chapter the theoretical perspectives and methodological approach chosen for this research were discussed. This chapter also discussed the research questions, design steps and methods used to develop, refine, and validate an information-flow maturity framework for use in healthcare. The following chapter reports on the results of applying the research design.

CHAPTER FOUR: STAGE 1 – FRAMEWORK DEVELOPMENT

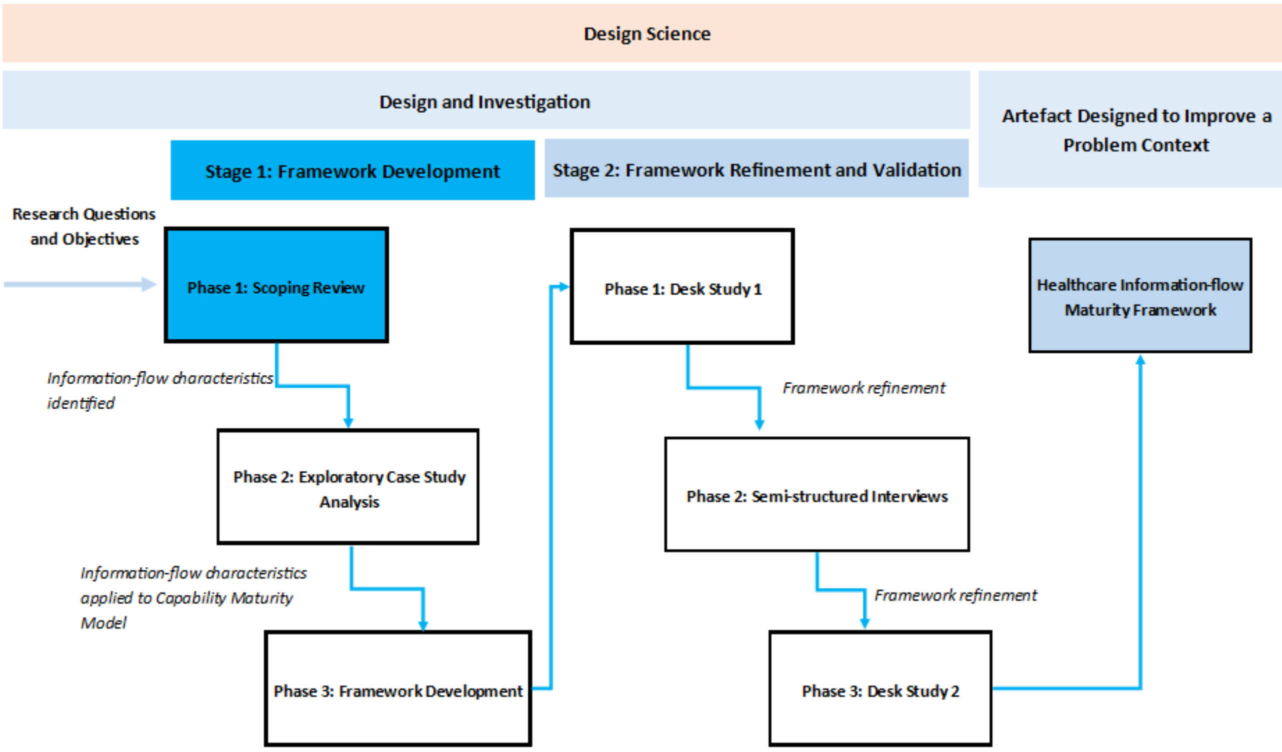


Figure 53. **Thesis Research Design Steps.**

The aim of this research was to understand and identify if an information-flow framework, for use in the healthcare domain, could be developed to measure information-flow failure, and thus identify where it could be improved. Shown in *Figure 53*, this chapter has particular focus on Stage 1: Framework Development and focused on how an information-flow maturity framework was developed through a three phased approach. Phase 1 of the framework development was the completion of a scoping review to understand what information-flow characteristics and metrics are mentioned in the literature. Phase 2 involved an exploratory case study to ascertain the methods for developing metrics, and the Phase 3 involved developing an information-flow maturity framework through the application of capability maturity modelling. Finally, the chapter concludes with a discussion on validation techniques used for the information-flow maturity framework.

4.1 Phase 1 of Stage 1: Scoping Review of the Literature

The first phase involved a scoping review of the literature to understand the established knowledge relating to information-flow metrics and the development of metrics. Accordingly, the Phase 1: scoping review of the literature five steps outlined in Chapter 3: Methodology (section 3.5.2) were followed.

4.1.1 Step 1: Define a clear review topic, objective, and sub-questions

The review topic was information-flow characteristics and metrics. Therefore, the objective of the scoping review was to understand established knowledge relating to information-flow metrics and to identify potential methods for developing information-flow metrics.

The questions asked were:

- *What are the methods for developing information-flow metrics?*
- *Can using metrics from other industries be used to develop information-flow metrics?*

4.1.2 Step 2: Develop a protocol and conduct systematic searches

The protocol used for the scoping review was a systematic search of the literature by PRISMA (Page et al., 2001) This involved defining search terms, eligibility criteria and justification for the scoping review.

*Justification for review**:*** To develop an information-flow maturity framework, understanding the established knowledge within the literature is required. This includes understanding of current metrics, and methods of developing metrics.

Search Criteria: Table 17 presents the search terms that were defined and systematically searched.

Table 18. Search Terms Defined.

Search Terms
• Metrics • Information-flow metrics • Information-flow models • Information-flow standards • Healthcare information-flow metrics • Information flow measurements • Metric development • Metric characteristics • Information flow characteristics • Information flow metrics characteristics • Information flow measures • Metric measures • Information metrics • Information measures • Metric framework • Metric model • Metric standards • Types of metrics • How to develop metrics • Software metrics • Information security metrics • Security metrics • Communication metrics

- Information-flow measurement
- Information taxonomy
- Information-flow taxonomy

According to Paez (2017) the purpose of a review of the literature is to identify all relevant evidence though an in-depth and rigorous search. Further, Paez (2017) suggests that a search of the grey literature plays an important role in reviews as they provide information that may not be found anywhere else. Paez (2017) has defined grey literature as “that which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers” (Paez, 2017, p. 233). Additionally, Paez (2017) suggests that including the grey literature can result in more reliable and evidence-based reviews with less bias. Therefore, grey literature was also categorised as acceptable and included in the search criteria for information-flow metric research. Further, initial databases that were searched were Flinders Library, Google Scholar, and IEEE database.

Following includes the search term criteria

- Peer reviewed journals,
- Articles,
- Conference papers,
- Books,
- Research dissertations,
- Articles within the last 20 years,
- Articles relevant to information-flow or metrics,
- Government reports;
- Commercial reports.

The search terms included “information flow” and “information-flow”. This was done to broaden the search as well as identify if there was a difference of meaning within the literature.

4.1.3 Step 3: Screen results that meet the search criteria

Shown in *Figure* 54 is a PRISMA flow diagram used showing the scoping review process to identify, screen, assess and include articles. The initial search found 165 articles. Following the removal of duplicates, the abstracts were screened, and full articles were assessed and included based on the search terms and search term criteria. As a result, 64 articles met the inclusion criteria (refer to Appendix A for the list of references). What is surprising is that in the literature articles mentioned information-flow metrics but in fact these referred to software or programming metrics and not information-flow metrics. In order to qualify as information-flow metrics, a criteria had been set, they had to be metrics that measured information-flow, which is defined as "the theory and understanding of how a piece of information travels to somewhere else" (Bremer, 2004). Although the search term criteria included articles within the last 20 years, certain foundational articles were also included as they were identified as significant to the research.

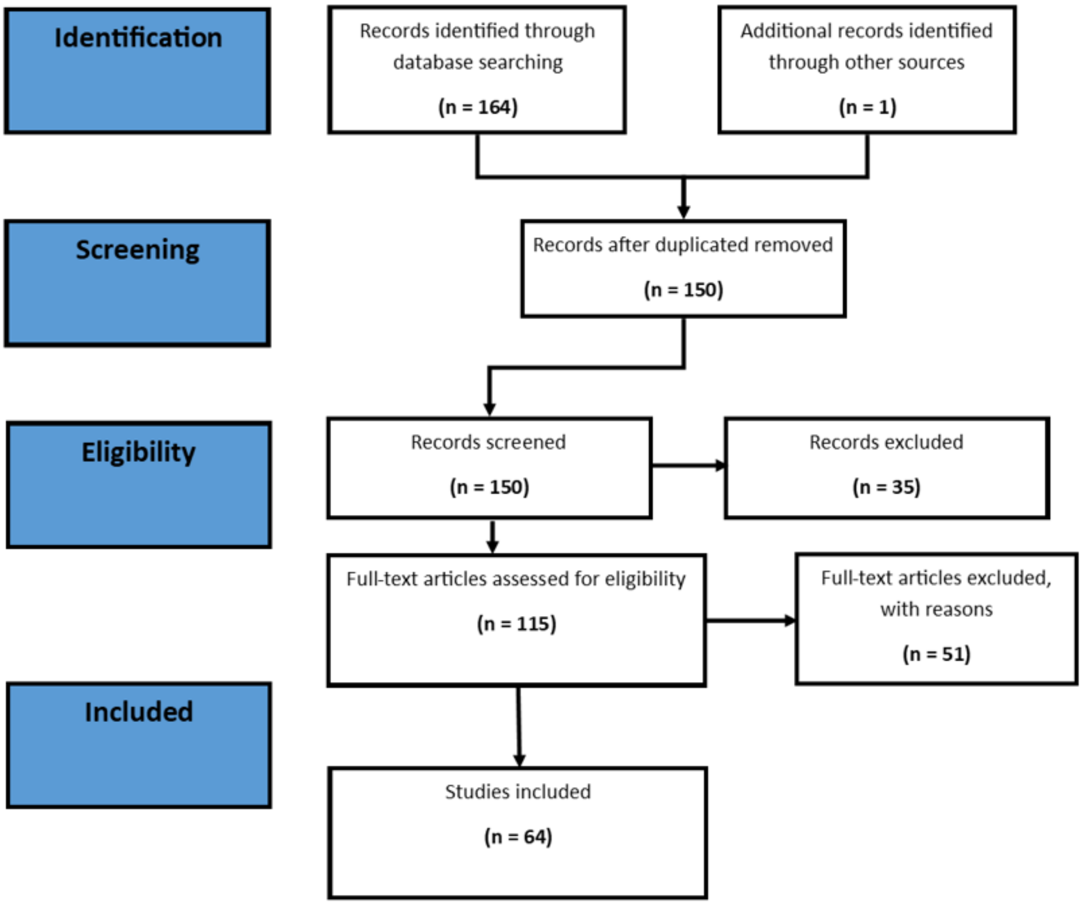


Figure 54. **PRISMA flow diagram showing articles included.**

4.1.4 Step 4: Extract and chart relevant data

Shown in *Figure 55* are the search terms and the number of relevant articles found.

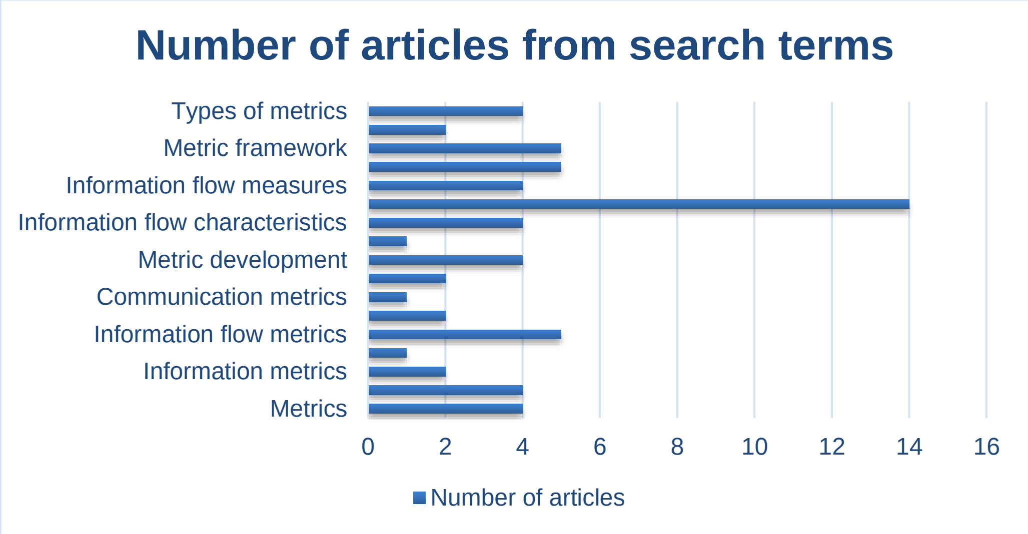


Figure 55. **Number of articles from search terms.**

It should be noted several search terms resulted in no articles being found. These searches were metric measures, information measures, metric standards, and types of measures. Additionally, *Figure 56* displays the sources of the articles that were found.

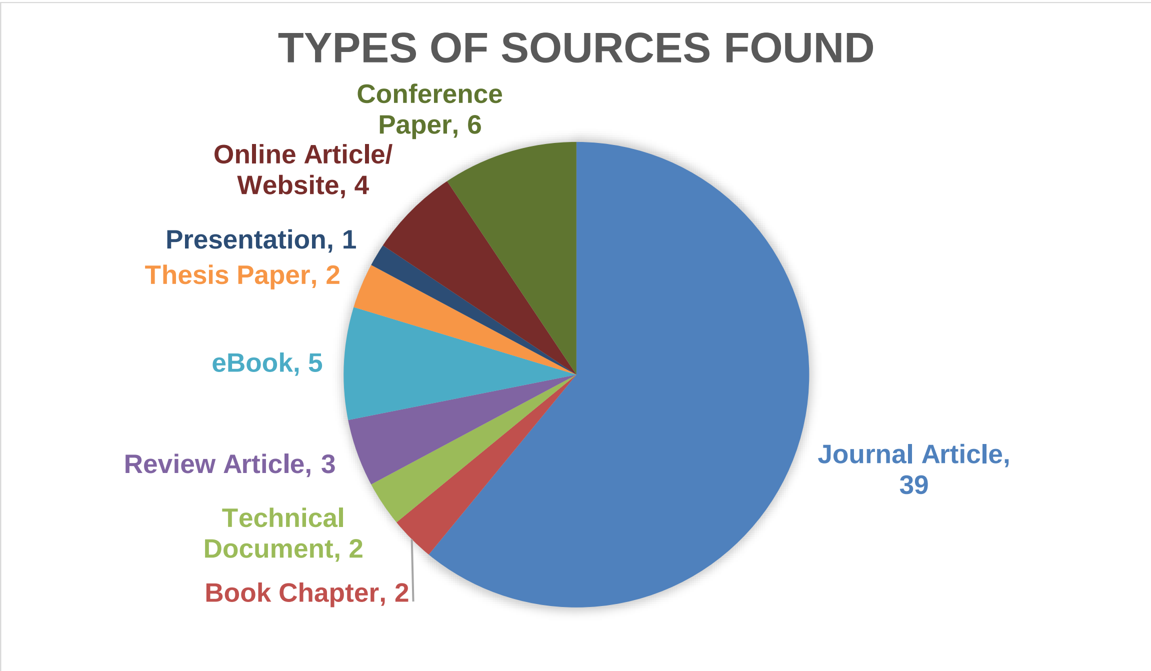


Figure 56. **Article Sources from the Scoping Review.**

Shown in *Figure 57* are the location of where the articles were found. It should be noted that the category other is a mixture of databases and sources. These articles were included to ensure journal database bias was reduced.

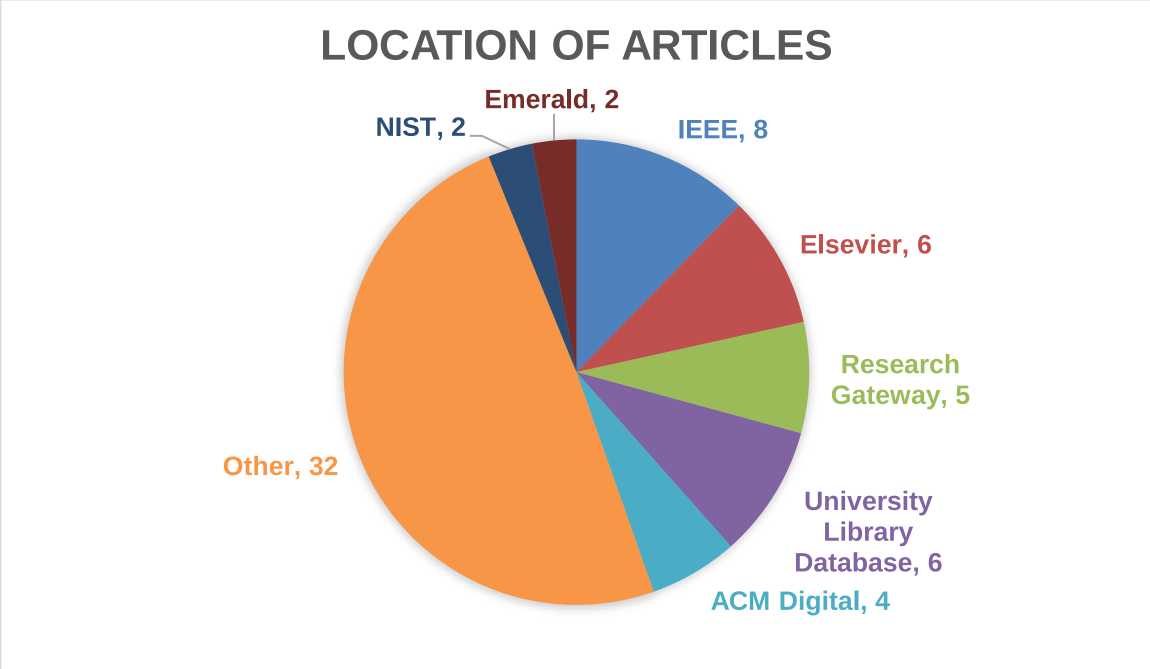


***Figure 57*. Databases and source locations that the articles were found in.**

Common Themes

Overall, it was identified that no information-flow specific metrics or developing information-flow metrics were found within the literature. Therefore, this highlights the gap in the discourse and the need for research into information-flow metrics. Shown in Table 18 are the themes identified in the scoping review.

Table 19. Scoping Review Common Themes.

Theme	***Reference***	***Total number of articles referenced***
Types of Metrics	(Hauser & Katz, 1998), (Kerzner, 2017), (Prentice et al., 2016), (Savola, 2007), (Wang, 2005), (Tariq, 2012), (Yang et al., 2011), (Pickard & Carter, 1995), (Jabbar & Sarala, 2012), (Clarkson et al., 2009), (Carney & Shea, 2017), (Dutoit & Bruegge, 1998), (Bossomaier, 2016), (Maurer, 2013), (Climate Research et al., 2005; Holman, 2009),(Glauser, 1984; Petkova et al., 2000; Rombach2),(Review, 2016; Smith, 2008),(Berander & Jönsson, 2006; Eiffel, 2018),(Spacey, 2017)	26
Purpose of Metrics	(Hauser & Katz, 1998), (Martin et al., 2015) (Kerzner, 2017),(Prentice et al., 2016) (Chew et al., 2008; Savola, 2007) (Tariq, 2012; Wang, 2005; Yang et al., 2011) (Bielova & Rezk, 2016; Galas et al., 2017),(Pickard & Carter, 1995), (Jabbar & Sarala, 2012), (Carney & Shea, 2017), (Kafura & Canning, 1985) (Dutoit & Bruegge, 1998) (Bossomaier, 2016) (Maurer, 2013) (Holman, 2009) (Climate Research et al., 2005) (Glauser, 1984), (Zonouz et al., 2015) (Parraguez et al., 2015) (Ciurea, 2009) (Petkova et al., 2000) ,(Alvim et al., 2019) (Jumarie, 1990) (Yeung, 2008) (Brath,	36

	1997) (Brath, 1997) (Yang et al., 2011) (Swanson et al., 2003) ,(Eswaran et al., 2011) (Smith, 2008) (Bose, 2004) (Spacey, 2017) (Melnyk et al., 2004)	
Choosing Metric Steps	(Hauser & Katz, 1998), (Martin et al., 2015), (Kerzner, 2017), (Review, 2016) (Smith, 2008) (Berander & Jönsson, 2006)	6
Metric Definition	(Hauser & Katz, 1998) (Chew et al., 2008) (Savola, 2007) (Wang, 2005) (Climate Research et al., 2005) (Sherif et al., 1985) (Smith, 2008) (Bose, 2004)	8
Metric Characteristics	(Kerzner, 2017) (Chew et al., 2008) (Savola, 2007) (Wang, 2005) (Tariq, 2012) (Yang et al., 2011) (Galas et al., 2017) (Bielova & Rezk, 2016) (Pickard & Carter, 1995) (Carney & Shea, 2017) (S. Henry & Kafura, 1981) (Maurer, 2013) (Holman, 2009) (Climate Research et al., 2005) (Mustafa & Khan, 2005) (blog) (Westrum, 2014) (Glauser, 1984) (Крутіна І. А.) (Tribelsky1 &) (Sherif et al., 1985) (Petkova et al., 2000) (Ciurea, 2009) (Parraguez et al., 2015) (Singh et al., 2011) (Sallie Henry, 1979) (Alvim et al., 2019) (Jumarie, 1990) (Brath, 1997) (Swanson et al., 2003) (Tang et al., 2010) (Review, 2016) (Smith, 2008) (Berander & Jönsson, 2006) (Hussain & Kutar, 2009) (Spacey, 2017) (Bose, 2004) (Melnyk et al., 2004)	39
Metric Development	(Chew et al., 2008), (Savola, 2007) (Tariq, 2012) (Freundlich & Ehrenfeld, 2017) (Klubeck, 2015) (Holman, 2009) (Climate Research et al., 2005) (Mustafa & Khan, 2005) (Rombach2) (Sherif et al., 1985) (Kitchenham et al., 1990) (Singh et al., 2011) (Abdul et al., 2008) (Brath, 1997) (Smith, 2008) (Berander & Jönsson, 2006) (EDRM, 2020) (Frakes & Terry, 1996)	19
Measurement Definition	(Smith, 2008) (Holman, 2009) (Savola, 2007)	3
Software Metrics	(Pickard & Carter, 1995) (Jabbar & Sarala, 2012) (Clarkson et al., 2009) (Kafura & Canning, 1985) (Dutoit & Bruegge, 1998) (Sherif et al., 1985) (Cook & Roesch, 1994) (Laguë & April, 2020) (Shepperd, 1990) (Kitchenham et al., 1990) (Oman & Hagemeister, 1992) (Alshammari et al., 2009) (Singh et al., 2011) (Sarala & Abdul Jabbar, 2010) (Yang et al., 2011) (Berander & Jönsson, 2006) (Frakes & Terry, 1996)	18

Interesting, 18 out of the 65 articles mentioned software metrics instead of information-flow metrics. It is important to note this research is not about software metrics but is about information-flow metrics, as such, emphasis on developing information-flow metrics is an objective of this research. Nonetheless, although these articles focused on software metrics, they were found to be relevant to characterising and developing metrics, which was subsequently used to inform the development of an information-flow metrics framework. In addition, 26 out of 64 articles mentioned the types of metrics that are used, 36 out of 64 articles discussed the purpose of metrics, 6 out of 64 articles discussed choosing the type of metric steps, 8 of 64 articles discussed metric definitions, 39 out of 64 articles discussed metric characteristics, 19 out of 64 articles discussed metric development and 3 out of 64 articles included a measurement definition. The types of metrics mentioned in the literature review can also be summarised by Spacey (2017) who mentions metric types as KPI, goal, qualitative, quantitative, actionable and information, and discusses how vanity can impact metrics by appearing to be a good measurement on the outside but not actually assist with measuring the objectives and goals first set.

The purpose of the metric

The following is a list of the metric purposes identified in the scoping review.

- To impact decisions
- Relationship to profit
- Monitoring, safety, and quality
- To keep stakeholders informed
- To establish boundaries
- To measure and improve performance
- Determine baselines
- To identify trends, accountability
- To successful outcomes
- Security assurance
- Assessment and communication
- Predication
- Policy, strategy, and control

Shown in Table 19 are the domains in which metrics were applied in, and the specific type of metrics and measures mentioned. Importantly, understanding what metrics are used in each domain is beneficial for understanding the potential metrics that can be used for information-flow metrics.

Table 20. Domains where metrics are applied.

Domain that metrics were applied in	***Metrics specific to that domain***
Financial	Market share, sales, increases, margins, customer satisfaction, projected revenue, contingent sales, forecasts
Project Management	schedules
Business	ISM, cost benefit, trust
Organisational	Informational load, mobility aspirations, security, laws of control, job satisfaction, performance, power, influence, employee orientation, attitude, direction, time, cost, intensity, structure, integration, automated, manual, products, processes, complexity
Security	Operational, management, information system
Healthcare	Knowledge discovery rate, aberrant detection analysis, cognitive mapping
IT	IT security, cloud computing, information, software, collaborative systems, information-flow, network
Government	Climate change, policy, NASA

4.1.5 Step 5: Write up evidence to answer your question

The purpose for the scoping review was to understand the existing knowledge on information-flow metrics. Therefore, two questions were posed:

1. *What are the methods for developing information-flow metrics?*

Analysis of the scoping review findings identified the types of metrics used in each domain and how they were developed. For example, Hauser & Katz (1998) stated that choosing metrics that are right for the organisation and objectives is important, and in order to choose the right metric, the metric needs to be informed by purpose and be easily understood (Kerzner, 2017). Savola (2007) suggested a systematic approach to choosing the right metric. whilst Wang (2005) used a complete analytical modelling and metrics assessment to identify metrics, and Tariq (2012) mention a framework for cloud computing security metrics. Although Tariq's (2012) framework is focused on software metrics, it was still used to identify and develop metrics as it involves metrics preparation and development. Other works, such as Freundlich and Ehrenfeld (2017), suggest that metrics are hard to develop and validate, which highlight the need to consider metric development and validation techniques in this research. Several authors created their own frameworks for metric developed. For instance, Mustafa and Khan (2005) utilised the metric development framework (MDF) to conceptualize, plan, design, validate, test and review metrics. Additionally, Smith (2008) and EDRM (2020) also mention their own metric framework, with Klubeck (2015) mentioning the Goal, Question, Metrics method (GQM). Similarly, Basil and Abdul et al. (2008) suggested the use of the business oriented metric framework to develop metrics, and stated that metrics start with the business, the vision, and the goals flow into KPI creation. A significant finding from the scoping review was that metric use was based on the domain and the purpose of the metric. Additionally, this highlighted the idea that there is no one 'right' metric and that each metric is determined by the purpose, domain, and organisation. Therefore, developing information-flow metrics is reliant on the context and purpose in which the information-flow exists.

2. *Can using metrics from other industries be used to develop information-flow metrics in healthcare?*

The research synthesised the metrics identified from the scoping review into 66 information-flow characteristics to measure information-flow. A description of the information-flow characteristics and methods to measure them are shown in Table 20. It should be noted that organisational metrics refers to metrics that are subjective to the organisation and are determined by the organisation's objectives and targets. In addition, the information-flow characteristics listed in Table 20 are the initial characteristics identified in this research following the scoping review. The review resulted in some descriptions of the characteristics, such as Complexity, Flexibility, and Improvability, being different to those that would be generally recognised and used in the English language. The characteristics have been revised through the iterative refinement process and as a result the final health information-flow maturity framework has refined characteristics that can be found in Chapter Eight.

Table 21. Initial Information-flow characteristics and how to measure.

Characteristic	***Description and relation to information-flow***	***How to measure (measurement) e.g. Key Performance Indicator (KPI)***
Acceptability	Information must have a level of acceptability. The users must be satisfied with the information inputs and outputs.	Measured through user opinions and frequency of system use e.g. Technology Acceptance Model (TAM).
-Accessibility	The ease of accessing information and having information available in the correct location.	Information availability can be measured with a KPI and through information access success rates.

Accuracy	The quality of information being correct.	Measurement through performance metric or KPI.
Adaptability	The ability for information to be used in several ways.	Measurement through organisationally determined metrics.
Addressability	The ability for a digital device to respond to another device.	Measurement through organisational metrics.
Aligned	Information supports the organisational goals.	Measurement is based on level of metric alignment with Organisational objectives.
Automatility	Information has the ability to be automated.	Measured on volume of information that is automated vs manual.
Availability	Information is readily available.	Organisation reporting to identify available information.
Capacity	The maximum amount of information.	Measurement through organisational metrics.
Compatibility	How information exists together without issue.	Measurement through organisational metrics.
Completeness	Information is not missing and is whole.	The rate of missing data entries equates to data completeness.
Complexity	How complicated the processes and information are without errors.	The rate that data is without errors and the measurement volume information sources.
Confidentiality	Information is only available to those with authorised access.	The rate of unauthorised access to information.
Concise	Information is clear and brief but comprehensive.	A subjective measurement based on users' requirements.
Consistency	Information quality is consistent.	The rate of quality information (Measurement refined in final health information-flow maturity framework).
Correlated	The state of information being connected and dependent on one another.	The volume of systems and information that can be interoperable.
Effectiveness	The effectiveness of the information-flow processes.	The rate that organisational requirements and objectives are met through information.
Efficiency	The degree to which the information is efficiently delivered.	Measured in terms of number of information requests and number of information delays.
Evidence	The availability of information and statistics.	Measured through organisational reporting and statistics.

Flexibility	The ability for the information-flow process to change with limited errors.	Measured by determining the veracity of the data that has been exposed to multiple information-flow points.
Formality	Information that adheres to standards.	Measured through comparing information with information or organisational standards.
Generality	Information that can be applied anywhere.	Measured by assessing if information is transferrable or interoperable.
Implantability	The ability for interventions and changes to not harm information-flow processes.	Measured through determining the rate of errors or rate of variances after an intervention or change has occurred.
Improvability	How information-flow can improve.	The rate at which information-flow improves over time.
Interoperability	The ability for information-flow to occur across multiple systems.	Measured through the percentage of systems that can interact with each other to support the organisational goal.
Interpretability	The ease with which information can be translated and read.	Measured through the rate of information that cannot be read against the amount of information available.
Latency	Information-flow response time.	The rate at which information responds.
Longevity	The information lifecycle and how long information is relevant for.	The rate at which information is kept up to date, retired or withdrawn.
Maintainability	The rate at which information-flow processes should be reviewed for improvement and prevention of errors.	The rate at which information-flow processes must be reviewed for improvement and prevention of errors.
Measurability	How information can be quantified in the information-flow process.	The volume and variety of information.
Mobility	The capability and efficiency of information to move within information-flow.	The rate of information being received efficiently and effectively without errors.
Modularity	The degree to which information-flow processes can be separated.	Determined by the value of information-flow that can be separated.
Mutability	The degree for information-flow processes to change.	The degree to which information is flexible.
Operability	The rate of information-flow acting functionally and reliably.	The rate of effectiveness and efficiency.

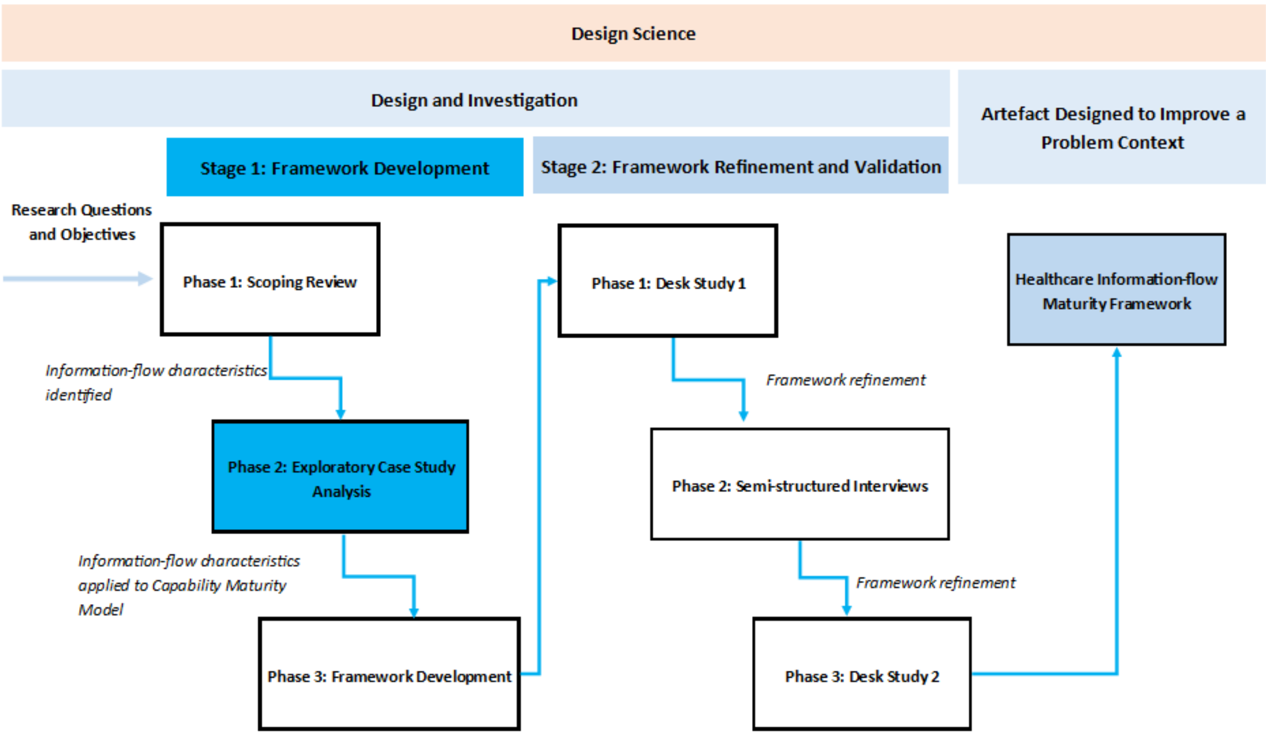
Orthogonality	Traditionally object perpendicular to one another. In the context of information flow this characteristic is indeterminant.	Non-determinable.
Ownable	What rate of information-flow processes are owned and held accountable.	The rate of organisational ownership.
Performance	Overall performance of information-flow.	The rate of effectiveness and efficiency.
Portability	Success rate for information within information-flow to be transferred from one area to another.	The degree to which information is flexible.
Progress ability	The ability for information-flow to improve and mature.	The rate at which information progresses over a period of time.
Quality	Quality refers to the information quality.	The outcome of information and if it results in objectives achieved.
Quantifiability	Ability for characteristics to be measured.	Determined by organisational goals achieved.
Redundancy	Interventions during information-flow or backup of information.	The rate of successful interventions and backups.
Relevance	How appropriate the information is for its intended use.	The rate that information was appropriate against information that was not appropriate.
Reliability	The degree to which information and processes are trustworthy.	Subjective measurement based on users trust.
Repairability	Ability for information-flow failure to be rectified.	Determined by redundancy and improvability.
Repeatability	The degree to which information-flow processes can be repeated with the same outcome.	Determined by performance, quantifiability and operability.
Safety	The degree that information-flow processes that lead to benefit or prevent harm.	Determined by the rate of failures and rate of non-failures.
Security	The state for information to be secure.	Determined by the rate of security failure.
Self-descriptiveness	Information to be self-explanatory.	The percentage of information that is general and operable.
Sensitivity	The degree to which information-flow failure can be detected.	Determined by rate of failure.
Serviceability	The ability for information to be provided. This incorporates elements of usability.	Determined by improvability, maintainability and progress ability.

Simplicity	The ability for information and information-flow processes to be understood, and will include ease of use.	Determined by general ability and self-descriptiveness.
Sociability	The ability of information to be used in other instances.	Determined by the rate of interoperability and flexibility.
Soundness	The condition and robustness of the information and information-flow processes.	Determined by measuring the quality.
Structuredness	The state of being structured.	Determined by measuring the quality.
Tele-proximity	Unknown description.	Unknown measurement
Testability	The ability for information-flow points to be tested.	Determined by rate of redundancy and evidence characteristic.
Timely	The rate that information is transferred from one point to another.	The rate that information arrived at a specified time. Determined by efficiency and availability.
Tolerance	The limit to which information-flow points and processes can fail.	The rate to which information-flow points can fail. Determined by redundancy and testability.
Traceability	Ability to map or track information-flow points and processes.	Determined by organisational information reporting.
Transparency	Ability for information-flow processes to be transparent.	Determined by availability, simplicity and flexibility.
Understandability	Quality of information being comprehensible. The information-flow processes being comprehensible.	The rate that information is understandable. Determined by simplicity, transparency, and self-descriptiveness.
Usability	The degree that the information is fit for purpose.	The rate that information is fit for use.
Validity	The quality of acceptability, which may include soundness.	The rate of acceptability and soundness.
Value	The worth of the information to the organisation.	Determined by the information outcomes and how they impact the organisation.
Volatility	The overall value that information-flow processes.	Determined by the quality and value.

Shown in Table 20 are a variety of characteristics that could apply to information and information-flow. The characteristics identified are common such as value, usability, security, and reliability. However, it is noted there are characteristics that can be considered uncommon such as teleproximity and serviceability. These characteristics identified from the Phase 1 of framework development enabled understanding of information-flow and metric development knowledge and highlight the idea that there is no universal metric. Ultimately, the development of the characteristics contributes to the development of the information-flow maturity framework. Following, Phase 2 was conducted to further explore how to develop metrics to inform and develop an information-flow maturity framework.

4.2 Phase 2 of Stage 1: Exploratory Case Study Analysis

Completion of the Phase 1 scoping review of the literature resulted in the identification of metric characteristics, metric purposes, and definitions. The following section discusses Phase 2, which conducted an in-depth document analysis using an exploratory case study method to further investigate how to develop metrics to inform an information-flow maturity framework.



The following describes the steps taken to complete the exploratory case study analysis:

4.2.1 Step 1: Identify texts to be used for the case study

Three texts were chosen for the case study on the basis that they discussed how to develop metrics. It should be noted the first text Hayden (2010) was recommended by the Researcher's supervisors, while the Klubeck (2015) and Maurer (2013) were texts that had been identified in Phase 1 scoping review of the literature. The three texts had previously been used in Phase 1 and already met the Phase 1 search inclusion criteria. Additionally, these texts were chosen as they explore designing metrics. The use of information-flow in different industries was used to ensure the framework could be used generally for information-flow, and not specifically for healthcare. Healthcare was used as the exemplar.

4.2.2 Step 2: Review each text and record key notes

All three texts were reviewed, and key concepts were recorded. Appendix B: Case Study Artefacts contains the detailed review notes for Step 2.

4.2.3 Step 3: Analyse documents

The next section shows the analysis of the cases which followed the Yin's (2012) document analysis process:

a. Purpose of metrics discussed
b. Definition of metrics
c. Industry/ area applied to/ in
d. How this gives you metric boundaries or how you can use this for the boundaries
e. Why it should be considered for information-flow metrics.

Case Study 1:

Hayden, L. (2010). *IT Security Metrics: A Practical Framework for Measuring Security and Protecting Data*.

This following case study analysis refers entirely to Hayden (2010) who describes how security metrics have been developed for use in information systems environments and defines metrics and measurement. This case study was important as it showed examples of how information system and security metrics could be developed and used. As such, the methods for developing metrics suggested in this case study were reviewed for the potential use in the health information-flow maturity framework as a method to measuring information-flow.

This case study defined a metric as “the result of a measurement process built on human and organizational activities and are not an end in and of themselves” (Hayden, 2010, p. 23). This case study also refers to a metric in the simplest definition as it states a metric is a “standard of measurement” (Hayden, 2010, p. 27). Both definitions suggest that metrics can be used in any environment that requires measurement of activities. These definitions were important to the research into information-flow as it could be used to develop information-flow metrics. In addition, as these definitions were simple, they could be applied to information-flow and not just IT security.

Review of the case study showed that metrics and measurement aim to understand both people and technology, and that metrics should be a “result of a measurement process built on human and organization activities and are not an in and of themselves" (Hayden, 2010, p. 23). The paper further discusses how to develop metrics based on your requirements and that metrics are means off organising and classifying data, and ultimately suggests that and must be alongside measurement which is defined as "the act of judging or estimating the qualities of something including both physical and nonphysical qualities, through comparison to something else" (Hayden, 2010, p. 27). These concepts were identified as applicable to information-flow metric development and were important to highlight as they identified that information-flow metrics require both human and organisational activity input.

The paper further discusses concepts and processes of measurement, measuring IT security metrics to support the decision-making process, and suggests understanding security you need to measure it. These ideas in much the same way, can be applied to understanding information-flow in healthcare as to understand information-flow it needs to be measurable. A key point made in the paper is that security metrics can improve data collection, analysis, understanding of metrics, and improve management decisions. The way in which security metrics improve understanding and decision making needs to be considered when developing the healthcare information-flow maturity framework. The paper also looks at measuring business processes and suggests they are important to measuring and controlling security processes. The method for developing metrics was significant compared to other research on metric development. The framework of significance was the Goal-Question-Metric, otherwise known as GQM. This framework is a three-step process and involves having a goal for the measurement which results in specific questions for the organisation and the finally answering the questions and achieving the goals through collection of data that is measured and answering through metrics. The GQM framework can be used to create a variety of different metrics. Therefore, this three step GQM framework could be used to develop information-flow metrics. The benefit of using this framework for information-flow development would be because it has been previously used for IT security metrics. However, one downside of the GQM is that it is tailored to each environment and project. Therefore, an information-flow metric developed from the GQM would be subjective to a particular information-flow environment. Ultimately, this means the metrics and measures would have meaning only to that environment.

Ultimately, the case study by Hayden (2010) provided insights on metric definitions and a framework on how to develop metrics. The GQM framework based on Hayden (2010) QHM project definition template (Hayden, 2010, p. 46) is applicable to information-flow and the below could potentially be an information-flow metric development method.

- Goal Components
- Questions
- Metrics
- Question

Case Study 2:

Klubeck, M. (2015). *Planning and Designing Effective Metrics*: Berkeley, CA : Apress : Imprint: Apress.

Klubeck (2015) explores developing metrics and measures for understanding and improving organisations. This case study focused on metrics in a general sense and does not apply to a specific industry. As such, this case study was important as it could be applied to information-flow and the understanding of information-flow metrics.

The important concepts taken from this case study is the idea that metric development includes 5 W's stages (what, why, when, where, who and how), and includes a method to improve the measurement through story telling. It was identified in the case study that metrics can show what was wrong with the system, how implementation worked and what changes were made. The following purposes of metrics that were highlighted in the case study are applicable to information-flow:

- To improve organisations;
- To change organisations; and
- To understand organisations.

These concepts are important as they can be used to show what is wrong with information-flow, how systems impacted information-flow and what was changed in the information-flow.

Identified in the case study was the concept of a SMART and that time, money and effort need to be considered as a baseline metric. Although SMART goals were not coined by Klubeck (2015) they are a useful way to ensure the information-flow metrics developed are specific, measurable, attainable, realistic, time-bound goals. Additionally, this case study was significant as it suggested data, information and metrics are distinct but are used together to provide insight into an organisation, and that metrics can contain other metrics and can be the full correct story of an organisation. In addition, what separated this case study from other research on metric developed was that it highlighted that there are different interpretations of metrics and that they are subjective way to view meaning and is applicable to this research as needs to be considered when developing information-flow metrics.

Steps suggested in the case study which can be used in developing information-flow metrics include creating a root question based on organisational requirements, and developing simple metrics defined on how they will and will not be used. Further, the information-flow metrics need to be repeatable and not just indicators that require interpretation.

Klubeck (2015) metrics development framework and the SMART goals could be used to develop information-flow metrics as they are a generic metric development process that could be followed to identify goals of information-flow, define information-flow terms, and then identify SMART measures.

SMART goals taken from the case study:

- Specific
- Measurable
- Attainable
- Realistic
- Time-bond

Kluebeck's (2015) Metric development framework could be applied to information-flow

1. Develop information-flow goals
2. Define information-flow terms
3. Test the root question
4. Draw
5. Identify the information, measures and data needed in information-flow
6. Collect measures and data

Case Study 3:

Maurer, C. (2013). *The measurement of information flow efficiency in supply chain management.* University of South Africa, Pretoria. Retrieved from http://hdl.handle.net/10500/8772

Maurer's (2013) research on information-flow efficiency and measures and metrics for supply chain management can be applied to information-flow as it develops measures for information-flow efficiency. Maurer (2013) describes the characters of metrics as speed of reaction, order accuracy, operational flexibility, a sustained quality, and suggests that effective communication, IT, and interoperability are key. This case study is important to information-flow research and information-flow metric development as it lists a number of master characteristics that can be applicable to the fields of business performance, financial information, information technology and software quality which could potentially be used in the information-flow maturity framework. These characteristics listed by Maurer (2013, p.327) include:

- Usefulness
- Repeatability
- Believability
- Timeliness
- Responsiveness
- Relevance
- Consistency
- Interpretability
- Accessibility
- Accuracy
- Acceptability
- Security
- Comprehensiveness

A concept that that has been taken and applied to information-flow metric developed is the idea that these characteristics cannot be measured directly. Instead, they should be referred to as indicators and be directly linked to a metric that can be measured. For example, in the case study mentions timeliness as a characteristic and suggests that it cannot be measured; the metric that can be measured and linked to timeliness would be a metric activity such as "time required to respond to the receipt of an order" (Maurer, 2013). Although the case study specifically investigated efficiency, the text is relevant to the development of information-flow metrics as it highlights that metrics cannot always be obtained by direct measurements. Additionally, based on the concepts regarding timeliness, it can be deducted that timeliness is contextual to the process it is being used in. The case study was focused on measuring information-flow efficiency and as such involves both metrics and measurement of information-flow efficiency. This is relevant to this research as this research seeks to understand and develop information-flow metrics. Another important concept taken from the case study is definitions of information and metrics. Where information is “from the effect that the absence of any of the characteristics would have on information flow efficiency.” (Maurer, 2013, p. 326). This statement is useful for this research as it can explore how these metrics and measurements impact information and explore the impact if these characteristics are removed. In addition, an interesting idea from this case study is that \ measurement is a framework, which includes the objective, indicators, and metrics to improve information-flow efficiency. Shown in *Figure 58* is an example of this measurement framework with regards to information-flow efficiency, which also show information-flow efficiency measurements can be identified through metrics and indicators. Another definition taken from the case study is the definition of measurement which is “expressed in terms of time, quantity, quality or cost” (Maurer, 2013, p. 32). Another important metric development concept is that the first step to identifying indicators and metrics for the measurement of information-flow efficiency. These concepts are applicable to information-flow metric design and use of the measurement framework could identify information-flow objectives, indicators, and metrics.

Measurement framework	**Example**
OBJECTIVE	Information flow efficiency
INDICATOR	Information integration %
METRIC	1. Average information transmission time (sec) 2. Information cycle time (hours)

***Figure 58*. Measurement Framework taken from Maurer (2013, p.326).**

4.2.4 Step 4: Compare and contrast texts

Shown in Table 21 is a comparison of the three case study texts, with the key aspects of how to develop information-flow metrics identified. Table 21 shows the objectives of the case, definitions for metrics, information, measurement, information-flow, data, what makes a good metric, whether the metric is quantitative or qualitative, and application to this research. Important definitions and meanings regarding metrics and information-flow are also summarised in Table 21. This was an important part of the case study method analysis, called cross case conclusions. Through this comparison and contrast of the documents, the Researcher identified the similarities between metric definitions and metric development methods. Interesting, the purpose of each paper was different. For example, Hayden (2010) was focused on IT security metrics, Klubeck (2015) was focused on metrics as whole but with focus on organisational metrics, and Maurer (2013) on measurements of information flow efficiency in supply chain management. Hayden (2010), Klubeck (2015) and Maurer (2013) all focused on different aspects of metrics; yet, their definition of metrics contained similarities. All three agreed that a metric is a type of standard or a measurement. Their information definitions also contained similarities, such as data having meaning. The measurement definition slightly differed as shown in Table 21. Additionally, only Maurer (2013) had a definition for information-flow. Maurer (2013) defined information-flow as "the transfer of information between two or more persons or entities, or between persons and entities, from the point of higher information content to the point of lower information content" (Maurer, 2013, p. xxix).

Moving on to the document's theory on metric development, all three documents had different approaches to developing and choosing metrics. Hayden (2010) suggested the Goal, Question Metric (GQM) method, Klubeck (2015) suggested the 5 Whys approach and Maurer (2013) insisted on the measurement framework which also included the objective, indicator, and metric. Although Hayden (2010) and Maurer (2013) had no specific definition for data, they both agreed that it was a form of information. While Klubeck (2015) defined data as "individual facts, statistics, or items of information" (Klubeck, 2015, p. 12) which is also a form of information. Further, each document had an idea on what made a good metric. Hayden (2010) suggested a good metric came from how you measured it. Klubeck (2015) suggested the Root Question and answering the root question through metrics made good metrics. While Maurer (2013) suggested a useful metric that comprises of factors such as good leadership, human, financial and computer resources resulted in a good metric. The case study document analysis was useful in understanding how to develop metrics and what consists for a good metric, and the multiple case design resulted assisted to reduce bias in the research. In summary, it is evident that there is no definition of a good metric as metrics are subjective to the objective and purpose of the measurement. Further, the case studies show there is more than one way to develop metrics and that each metric is subjective to the purpose and context of use. This idea supports the findings of the scoping review literature review which found a variety of characteristics and metrics available.

Table 22. Table comparison of the Metric Cases and relationship to this research.

Metrics	***(Hayden, 2010)***	***(Klubeck, 2015)***	***(Maurer, 2013)***	***This Research***
Objective of case	Develop IT security metrics.	Develop metrics for organisations.	Develop measurement for information flow efficiency in supply chain management.	Develop information-flow metrics for an information-flow maturity framework.
Metrics definition	Metrics provide a standard for	Metrics are made up of data, measures, and	A metric is the measurement of a	A metric is a standard of measurement. It is

	information collection and is a result. The point is to collect data that can be understood.	information. Metrics can be made up of other metrics. Metrics give full context to the information. Metrics (attempt to) tell a complete story. Metrics (attempt to) answer a root question (Klubeck, 2015, p. 22).	particular characteristic of an activity's performance or efficiency (Maurer, 2013, P. xxx).	dependent on the context, and the goal of the measurement.
Information definition	Data given context.	Information is made up of data and measures. Information can be made up of other information. Information provides additional, more meaningful context (Kluebeck, 2015, p. 22).	Information is a collection of facts organised in such a way that they have additional value beyond the value of the facts themselves (Maurer, 2013, p.xxix).	Information is data and facts within a context.
Measurement definition	Measurement is an activity that collects data to result in understanding.	Made up of data, measures add the lowest level of context possible to the data. Measures can be made up of other measures (Kluebeck, 2015, P. 22).	Measurements are typically expressed in terms of time, quantity, quality or cost (Maurer, 2013, p. 32).	Measurement is how to measure the artefact.
Information-flow definition	No definition.	No definition.	Information flow is the transfer of information between two or more persons or entities, or between persons and entities, from the point of higher information content to the point of lower information content. (Maurer, 2013, P. xxix).	Information-flow is about understanding how information communicates from one place to another. This could be from system to system, system to person or person to person. Information-flow requires understanding of information-flow dimensions and social, technology, security, governance, IT business alignment and operational context. Information-flow also requires understanding of the information-flow characteristics which

				include coverage, relevancy, usability, availability, reliability, security and quality assurance.
Metrics development	Goal Question Metric (GQM).	The 5 Why's develop goals - Define terms, Test the root question (5 tests), Draw, Identify the info, measures and data needed, Collecting measures and data.	Measurement Framework – Objective, Indicator, Metric.	Subjective assessment tool in the form of a healthcare information-flow maturity framework, to measure information-flow characteristics.
Data definition	Data is a form of information.	"Individual facts, statistics, or items of information (Kluebeck, 2015, p.12).	Data forms information.	Data is information.
What makes a good metric	How you measure it?	The Root Question. The goal of the metric is to answer the Root Question.	Useful metrics are comprised of good leadership, strategic plans, promotes strategic analysis, advances scientific progress, easily understood, quality, assess process, focus on a single metric, evolving, extensive human, financial and computational resources.	Subjective to the goal and the context.
Quantitative or Qualitative metrics	Quantitative and qualitative.	Qualitative and Quantitative.	Qualitative and Quantitative.	Quantitative and Qualitative.

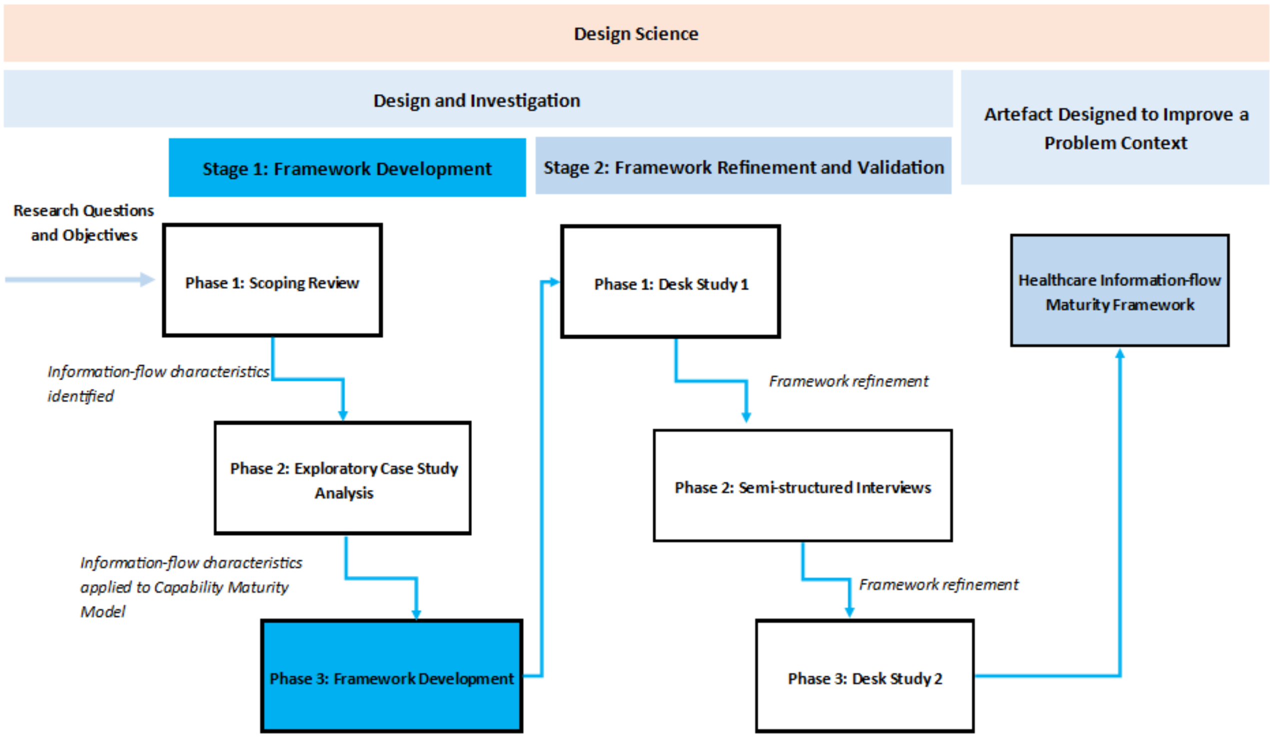
The exploratory case study analysis of three texts allowed for an in-depth analysis of how to develop metrics. As shown in the Table 21 there are several different definitions and ways to define metrics, measures, and ultimately different methods to develop metrics. Identifying the different ways to develop metrics has shown the boundaries of information-flow metric development as a broad area that is subjective to the goal and purpose of the metric.

Methods for developing metrics

There are several methods for developing metrics. There are three types of methods which were investigated in the exploratory case study analysis. These were Hayden's (2010) Goal, Question

Metric (GQM), Klubeck's (2015) the 5 Whys (Develop Goals, Define Terms, Test the root question, Draw, Identify the information, measures and data needed and collecting measures and data), and Maurer's (2013) Measurement Framework (Objective, Indicator, Metric). This next section discusses why Capability Maturity Model development for information-flow.

4.3 Phase 3 of Stage 1: Information-flow Maturity Framework Development



The scoping review of the literature and the case study analysis support the concept there are no universal metrics. This is because metrics are subjective, therefore, a universal metric for information-flow is not feasible for development. Additionally, the challenge to developing an information-flow metric is that there is no one metric that can suit all organisations. Rather each organisation requires a tailored information-flow metric to suit their organisational objectives, processes, and information-flows. Further, as previously stated by Hayden (2010), Klubeck (2015) and Maurer (2013), there are three characteristics to a metric. Firstly, the metric has a purpose, objective and ultimately answers the objective. Secondly, the metric measures the performance or efficiency or a particular activity, and lastly, it is a standard for those activities (Hayden, 2010; Klubeck, 2015; Maurer, 2013). Williams (2008) highlights that CMM is a measurement tool designed to identify process area weakness in organisational practices and processes. Therefore, an information-flow capability maturity model is not the metric itself; however, it is a measurement tool to be used to measure information-flow activities performance or efficiency. Further, Hayden (2010), Klubeck (2015) and Maurer (2013) metric development processes such as the Goal

Question Metric (GQM) or the 5 Whys could have been applied to a capability maturity model. For example, with the GQM the goal could be to improve information-flow in a particular process. The question could be how we can improve information-flow in this context and the metric would be a standard of measurement for that information-flow activity. Through an information-flow CMM, assessment of internal and external organisational process improvement for organisational information-flow can potentially result. This is because process improvement becomes disciplined and definite through the use of an information-flow capability maturity model (Williams, 2008). Becker, Knackstedt, and Poeppelbuss (2009) also highlight that an IT-CMM can result in continual improvement of IT performance; therefore, in application to information-flow an information-flow CMM can result in continual improvement of information-flow processes. The next section will discuss how an information-flow maturity framework can be developed from a capability maturity model.

4.3.1 Capability Maturity Modelling for information-flow failure

Currently, there are several capability maturity models. For example, Becker et al. (2009) suggests that from the years 1995 to 2010, there have been 1000 articles on maturity models. This was aligned with the Researcher's findings on the different types of capability maturity models and the availability of capability models on information-flow in healthcare. However, it should be reinforced that these models do not specify that they are information-flow capability models. Rather, they involve information and information-flow processes in some form. During the first stages of this research, no information-flow characteristics capability model could be found. As a result, the information-flow characteristics capability maturity model was designed iteratively, from the results of the scoping review and case studies (Baskarada et al., 2006). The capability maturity model for information-flow incorporates aspects of Hayden (2010), Klubeck (2015) and Maurer (2013) metric development processes. This is because the capability maturity model requires a purpose and objective. Hayden (2010), Klubeck (2015) and Maurer (2013) metric characteristics feed into the capability maturity model for information-flow. In addition, articles from the scoping review were used to define the information-flow characteristics, which included research articles by Ciurea (2009), Petkova et al. (2000), Sherif et al. (1985), Glauser (1984), Mustafa and Khan (2005), Climate Research et al. (2005), Bielova and Rezk (2016), Wang (2005) and Chew et al. (2008). Finally, it was important to apply research rigour, therefore, the capability maturity model was designed based on steps by Becker et al. (2009) that instruct how to design a maturity model.

The capability maturity model for information-flow identifies potential benefit because it identifies useful and ideal characteristics of information-flow. When information-flow has these characteristics, when assessed to be at their ideal level, it is suggested that information-flow will naturally result in benefit. Figure 59 demonstrates how the concepts from Hayden (2010), Klubeck (2015) and Maurer (2013) can be applied to a Capability Maturity Model (CMM) framework. This includes incorporating purpose, root questions, and metrics and measurements with the Capability Maturity Model Integration's 6 levels.

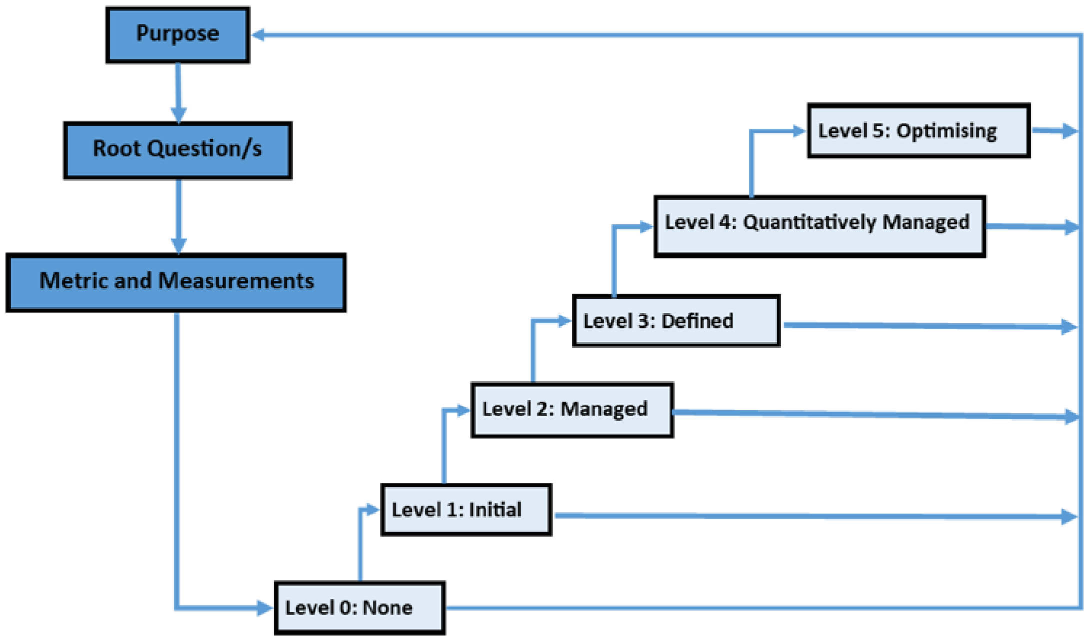


***Figure 59*. Process to develop an Information-flow Capability Maturity Model adapted from Hayden (2010), Klubeck (2015) and Maurer (2013) concepts.**

The findings from the Phase 2: exploratory case study analysis have been incorporated into *Figure 59.* This shows that the purpose, root questions and metrics inform how the CMM levels are formed. The following are the steps, adapted from the case study findings and CMMS from Kasse (2004) and Henshall (2019), used to develop a capability maturity model for information-flow:

- Step 1: Ask the purpose
- Step 2: Ask the root question/s
- Step 3: Define the characteristics you want level 5 to have and define ways to measure them with regards to information flow
- Step 4: Identify what characteristics are in the information flow and at what level. Based on the characteristics and the measurement of the characteristics, will determine what CMM information level the organisation is.

Based on these steps, Table 22 was developed for information-flow. The maturity level descriptions were completed informed by the Phase 1 and Phase 2 findings on information-flow and metrics and shows the characteristics criteria for the information-flow capability maturity model.

Table 23. Capability Maturity Model Levels for the information-flow maturity framework.

Maturity Level	***Level Description***
Level 0: None	Information-flow metric characteristics are not present.
Level 1: Initial	Information-flow is uncontrolled, unpredictable, inefficient, reactive. Characterised by constant information-flow failures.
Level 2: Managed	Information-flow is planned, measured, controlled. Information-flow processes are repeatable. Metrics for specific information-flow goals can be determined at this stage. Reduced information-flow failures.
Level 3: Defined	Information-flow is proactive. Organisation has information-flow standards. Continued reduction in information-flow failures.
Level 4: Quantitatively Managed	Information-flow is specific organisational metrics and measurements are used to predict future information-flow failures. Information-flow is controlled and measured. This level is characterised by intervention to prevent information-flow failures; therefore, resulting in reduced information-flow failures.
Level 5: Optimising	Information-flow is autonomous. Information-flow is effective, efficient, constant. Information-flow processes are improving, and information-flow failures are minimum. Data and information within information-flow processes are correct, timely, complete, and secure. Information in the information-flow process fits into Baskarada Information Quality categories (intrinsic, representational, contextual, accessibility).

Shown in Table 22 are the maturity levels and their level description in application to information-flow. This was developed based on the CMM level definitions and application from the literature review findings on information-flow. As shown Table 22, the higher the level, the more mature the information-flow, resulting in reduced information-flow failure. shown in Table 23 is the application of the information-flow CMMI levels applied to the information-flow characteristics that were found in the scoping review. This matrix depicts information-flow characteristic and depicts how that characteristic appears at level 0 to level 5. Further, a sample table is depicted in Table 23 that shows information-flow characteristic and the information-flow process in a capability maturity model. This was added to identify if there was a significant different in the information-flow characteristic and the information-flow characteristics process. The complete table is found in Appendix C.

Table 24. Excerpt of Information-flow Capability Maturity Model.

Characteristic	*Level 0: None*	*Level 1: Initial*	*Level 2: Managed*	*Level 3: Defined*	*Level 4: Quantitatively Managed*	*Level 5: Optimising*
Acceptability - Information	Information is not accepted.	Information-flow failure is consistent. Certain information-flow processes are accepted. Acceptability is reactive.	Acceptability characteristic is measured. Goals for reaching acceptability have been decided. Information-flow failure improvement.	Acceptability is actively a goal and sought. There are information standards.	Acceptability measurements and surveys or users are used to implement activities to build user trust. Interventions for building information reliability are in place.	Information is accepted. Information-flow errors are least likely as information is reliable and trusted.
Acceptability – Information-flow process	Information-flow processes are not accepted.	Information is not accepted. Users are suspicious of information. Information-flow processes are present with the highest amount of errors.	Information-flow process acceptability is measured.	Acceptability in information-flow processes have a standard.	Acceptability information-flow is improved through interventions.	Information acceptability management.
Accessibility - Information	Information is not accessible.	Processes that involve accessing particular information is an ad hoc process.	Accessibility is measured. Accessibility errors are reduced. Repeatable process.	Access for information aligns with organisational standards.	Accessibility as a metric is used to predict future accessibility errors.	Information is accessible.

4.3.2 How the information-flow maturity framework was initially developed:

A significant finding from developing the characteristics was that many of the characteristics are reliant of each other and overlap. The characteristics in Table 16 also highlight the importance of information quality as it ultimately impacts the quality of information-flow. A significant outcome of the developing the information-flow capability maturity model was that a second information-flow process maturity model had to be created. This was because it was found that there was a difference between information metric levels and information-flow process levels. For example, Information Accessibility displayed level 5 has Information is accessible. While the level 5 Accessibility in terms of Information-flow process related to Information Accessibility management. The difference being that information can be accessed as in it is available versus who can access it and what access right do they have. This highlighted the importance of terminology and semantics. Terminology and agreed definitions are an important aspect of information-flow, especially with regards to the development and use of an information-flow maturity framework. Without agreed definitions and terms meanings and interpretations will differ from organisations to organisation and person to person. Additionally, although existing information-flow models were difficult to find, information-flow was found within workflow models as the information-flow was displayed. Therefore, it was important in the development of the information-flow maturity framework to define the information-flow maturity levels and to define the information-flow characteristics and specific how to measure them.

4.3.3 Information-flow characteristics refinement

A decision was made to categorise the metrics into simpler categories due to the number of metrics (Appendix C). This was because there were 66 information-flow characteristics and 66 information-flow processes. Categorising aimed to make them clearer as many of them were related or similar. The categories were based on Williams et al (2019) and are shown in Table 24. The definitions in Table 4 definitions are from the perspective of this point in time, and with the review and refinement phases many of the definitions were changed.

Table 25. Initial refinement of Information-flow metric categories adapted from Williams et al (2019).

Category	***Metrics***
Completeness	• Capacity • Completeness • Consistency • Quality • Self-descriptiveness • Simplicity • Soundness • Structuredness

Relevancy	• Aligned • Flexibility • Generality • Longevity • Maintainability • Relevance
Usability – clinical outcomes	• Adaptability • Addressability • Compatibility • Complexity • Effectiveness • Efficiency • Interoperability • Interpretability • Mobility • Modularity • operability • performance • Safety • Serviceability • Sociability • Understandability • Usability • Value • Volatility
Availability	• Accessibility • Availability • Latency
Reliability	• Accuracy • Consistency • Portability • Redundancy • Reliability • Repairability • Repeatability • Sensitivity • Timely • Tolerance • Validity • Trust
Security	• Confidentiality • Formality • Security
Traceability – audit capability	• Correlated • Evidence

	• Measurability • Ownable • Quantifiability • Testability • Traceability • Transparency
Development	• Automatility • Implantability • Improvability • Mutability • Progressability
Other	• Orthogonality • Tele proximity

Shown in Table 24 are the refined information-flow metric categories adapted from Williams et al (2019) categories (completeness, relevancy, usability, availability, reliability, and security). Williams et al (2019), was significant to developing information-flow metrics as Williams et al (2019) had developed eight information systems maturity levels. Therefore, each characteristic was defined according to Williams et al (2019) categories. During the categorisation process it was evident that some of the metrics did not fit into any category. Hence, the category Development and Traceability were added. Development was added as many of the metrics referred to improving or automating information-flow. Traceability was added as information-flow in healthcare needs to have audit capability and many of the metrics centred around audit capability. The category usability was renamed to include clinical outcomes as it was important to highlight why these metrics are used. While other metrics that did not fit or did not have an original definition such as Orthogonality were classified into the other category. Many of the metrics that were categories were already a Williams et al (2019) category, such as security, reliability, availability, and relevancy. Many of the metrics are the same or have similar meaning, while some of the metrics overlapped. Some metrics, such as Validity, could be placed into several categories such as reliability and completeness. The categorisation of characteristics was decided based on their literature review definition and semantic meaning. This resulted in 9 categories: relevancy, usability, availability, reliability and security, development, traceability and other.

Further, as shown in Table 25, further refinement of the metric categories occurred. Completeness was renamed to coverage as it referred to data that was sufficient. These metrics came from data qualities in the literature. It is important to have data quality when looking at information-flow and data flow. Orhogonality and Teleproximity were removed from the metrics as they did not have relevance for information-flow metrics. The metric Development was changed to Quality Assurance as the metrics that fit into that category were quality assurance related. Testability was moved to

Quality Assurance as it fitted better. Traceability – audit capability was added to quality assurance. The quality longevity was moved into Reliability. All duplicate characteristics were removed. The characteristics Traceability and Audit Capability are not directly relevant to medication and pharmacy management; however, they were kept as they are important for quality assurance and reporting. Additionally, during the development of the characteristic, it was identified that some characteristics overlapped and were related to other categories Following these amendments and refinement, a final set of seven categories were assembled: Coverage, Relevancy, Usability, Availability, Reliability, Security, Quality Assurance.

Table 26. Second Refinement of Information-flow metric categories.

Initial Metric Categories and information-flow characteristics		***Refined Metric Categories and information-flow characteristics***	
Metric Category	*Information-flow characteristic*	*Metric Category*	*Information-flow characteristic*
Completeness	Capacity	**Completeness changed to Coverage**	Capacity
	Completeness		Completeness
	Consistency		Consistency
	Quality		Quality
	Self-descriptiveness		Self-descriptiveness
	Simplicity		Simplicity
	Soundness		Soundness
	Structuredness		Structuredness
Relevancy	Aligned	Relevancy	Aligned
	Flexibility		Flexibility
	Generality		Generality
	Longevity		**Longevity Removed**
	Maintainability		Maintainability
	Relevance		**Relevance Removed**
	Adaptability	Usability (Clinical Outcomes)	Adaptability
	Addressability		Addressability

Usability - clinical outcomes	Compatibility		Compatibility
	Complexity		Complexity
	Effectiveness		Effectiveness
	Efficiency		Efficiency
	Interoperability		Interoperability
	Interpretability		Interpretability
	Mobility		Mobility
	Modularity		Modularity
	operability		Operability
	performance		Performance
	Safety		Safety
	Serviceability		Serviceability
	Sociability		Sociability
	Understandability		Understandability
	Usability		**Usability Removed**
	Value		Value
	Volatility		Volatility
Availability	Accessibility	Availability	Accessibility
	Availability		**Availability Removed**
	Latency		Latency
Reliability	Accuracy	Reliability	Accuracy
	Consistency		Consistency
	Portability		Portability
	Redundancy		Redundancy
	Reliability		**Reliability Removed**
	Repairability		Repairability
	Repeatability		Repeatability

	Sensitivity		Sensitivity
	Timely		Timely
	Tolerance		Tolerance
	Validity		Validity
	Trust		Trust
			Acceptability Added
			Longevity Added
Security	Confidentiality	Security	Confidentiality
	Formality		Formality
	Security		**Security Removed**
Traceability – audit capability	Correlated	**Traceability changed to Quality Assurance (QA**)	Correlated
	Evidence		Evidence
	Measurability		Measurability
	Ownable		Ownable
	Quantifiability		Quantifiability
	Testability		Testability
	Traceability		Traceability
	Transparency		Transparency
			Improvability merged from Development
			Mutability merged from Development
			Progressability merged from Development
			Automability merged from Development
			Implantability merged from Development
			Audit Capability Added

Development	Automatility	**Development merged with Quality Assurance**	**Automatility Removed and merged with Quality Assurance**
	Implantability		**Implantability Removed and merged with Quality Assurance**
	Improvability		**Improvability Removed and merged with Quality Assurance**
	Mutability		**Mutability Removed and merged with Quality Assurance**
	Progressability		**Progressability Removed and merged with Quality Assurance**
Other	Orthogonality	**Other Removed**	**Orthogonality Removed**
	Tele proximity		**Tele proximity Removed**

4.3.4 Information-flow metric definitions:

The following defines the information-flow metric categories. The information-flow metric category definitions were adapted from the definitions in the literature and from Williams et al (2019)'s definitions.

Coverage:

The data is sufficient, not missing and is whole. The data covers the whole domain and "contains all the context required for decision making" (Williams et al, 2019, p. 3). Coverage includes data qualities such as capacity, completeness, consistency, quality, self-descriptiveness, simplicity, soundness, structuredness. Coverage is measured through understanding how much data is missing and how much data is complete.

Relevancy:

Relevancy refers to how appropriate the information is for the context. According to Williams et al (2019) interdependencies include "current, timely, correct, and sufficient" information (Williams et al, 2019, p. 3). Relevancy includes data qualities such as aligned, flexibility, generality maintainability. Relevancy is measured through understanding what information was not appropriate for the context.

Usability (Clinical Outcomes)

Usability refers to the degree for information to be fit for use. Usability also refers to how the information impact clinical outcome in terms of benefit or/and harm. Usability includes adaptability, addressability, compatibility, complexity, effectiveness, efficiency, interoperability, interpretability, mobility, modularity, operability, performance, safety, serviceability, sociability, understandability, value, volatility. Usability is measured through understanding the amount of information that is fit for use.

Availability:

Availability refers to information readily available and accessible when required. Availability includes accessibility and latency (Williams et al, 2019, p.3). Availability is measured through identifying the amount of information that is readily available and accessible.

Reliability

Reliability refers to the degree to which information is trustworthy and accurate. Reliability includes acceptability, accuracy, consistency, portability, redundancy, repairability, repeatability, sensitivity, timely, tolerance, validity, trust and longevity. Reliability measurement can be subjective based on the user's perceived trust.

Security

Security refers to the state for the information to be secure, includes confidentiality and formality. Security can be measured through understanding security failures.

Quality Assurance (QA):

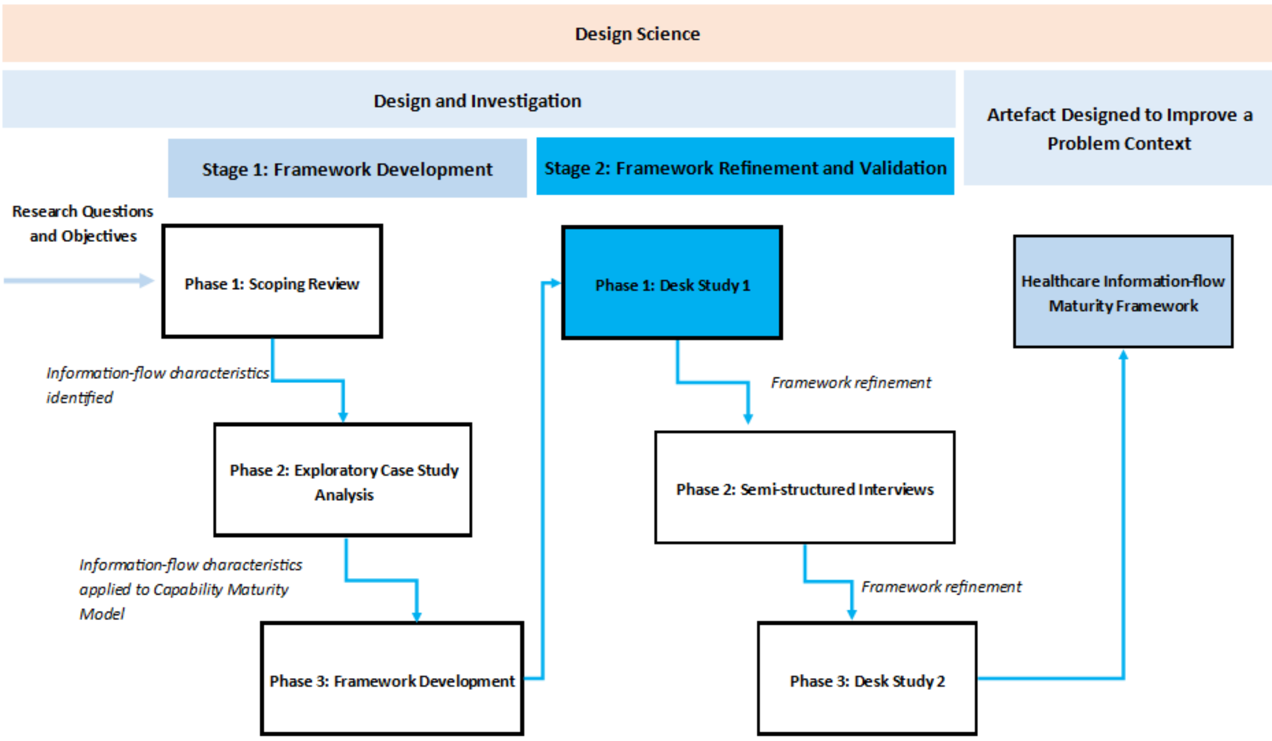
Quality Assurance refers to the continual improvement process for information-flow. Quality Assurance aims to improve information so that it is free from errors in coverage, relevancy, usability, availability, reliability, and security. Quality Assurance includes automatability, implantability, improvability, mutability, progress ability, testability, correlated, evidence, measurability, ownable, quantifiability, traceability, transparency, and audit capability. Quality Assurance be measured through reporting of key performance indicators and other performance-based measurements.

This chapter presented a scoping review of the literature that discovered the information-flow characteristics, while the case study analysis resulted in a method for developing an information-flow maturity framework in the form of a capability maturity model. The concepts from the case study texts were applied to a capability maturity model framework and the information-flow maturity levels and the information-flow characteristics defined and categorised according to information-flow metric categories. The information-flow metric categories and characteristics were developed to form information-flow maturity frameworks supporting information-flow characteristics and capability maturity matrix. However, an initial validation of the information-flow maturity framework was necessary to ensure research rigour was used to develop this framework. Therefore, the next chapter discusses how the initial validation of the information-flow maturity framework occurred with the use of information-flow data.

STAGE 2: FRAMEWORK REFINEMENT AND VALIDATION

The following three chapters (Chapters Five to Seven) focus on the framework validation and refinement, consisting of three phases. The framework refinement commences in the first phase which validates the framework by working through the framework and analysing the TAPS cases. The second phase continues the validation of the framework through semi-structured interviews with experts in information systems, medication management research and process improvements. The third phase involves final validation of the framework through application of the Clinical Incident Management System database (CIMS cases). Through the three phases of refinement, the healthcare information-flow maturity framework was iteratively validated and refined. The next section discusses the first phase of framework refinement.

CHAPTER FIVE: PHASE 1 OF STAGE 2 - DESK STUDY 1



The previous chapter developed the initial information-flow maturity framework (capability maturity matrix and information-flow characteristics) through three creation phases that included a scoping review, case study analysis and capability maturity modelling.. This chapter focuses on an initial validation of the information-flow maturity framework using the Threat to Patient Safety (TAPS) cases used in the preliminary information-flow research. In this phase the information-flow metrics and their characteristics were refined to further develop the information-flow maturity framework. Additionally, this chapter discusses the development of an information-flow maturity calculator and explains how using the information-flow maturity calculator was used to initially validate and refine the information-flow framework. The following section discusses Desk Study 1's approach taken to validate the framework.

Desk Study 1 Approach

The steps taken to conduct Desk Study 1's approach to do the first validation and refinement of the maturity framework were:

1. Define the purpose and objectives of the research;
2. Select cases for Desk Study 1;
3. Apply the cases to the framework and measure information-flow cases;
4. Analysis - complete an analysis on the framework with the cases to measure an information-flow maturity profile; and
5. Identify improvements for the information-flow maturity framework.

The next section includes a discussion on the steps and what was concluded during Desk Study 1.

5.1 Define the purpose and objectives of the research

Becker et al. (2009) suggests models require validation through different methods to ensure they are complete and accurate. Validation methods include case study analysis, interviews, focus groups, real-life application, and applicability checks with practitioners. Therefore, for the initial validation, a desk study with real-life information-flow cases was chosen to assess usability, validate and refine the information-flow maturity framework.

5.2 Select the cases for Desk Study 1

The cases for the Desk Study 1 were chosen by reviewing several data sources that matched the initial desk study data criteria. Shown in Table 26 were the three data sets that were reviewed as potential candidates for the initial desk study.

Table 27. Potential data for the Desk Study 1.

Potential Data to validate framework	***Rationale for use***
Data used by Vreede et al (2019) to review medication errors that are new or likely to occur more frequently with electronic medication management	• Medication error cases within an electronic medication management system. • Cases were not readily available for use. • Cases have not been mapped to information-flow.
Data used by Redley (2012) to study reported medication errors for after introducing an electronic medication management system	• Medication error cases within an electronic medication management system. • Cases were not readily available for use.

	• Cases have not been mapped to information-flow.
Threat to Patient Safety (TAPS) (Makeham, 2008)	• Medication error cases that have previously been mapped on the information-flow framework. • Pre-existing cases that have already been mapped to information-flow. • Secondary research cases that are ideal for desk study.

Stickdorn et al (2018), Travis (2016), Stewart et al (1993) and Paulk (1993) secondary research data questions include identifying the data sources and evaluating the data source reliability. As such, these data questions were used to review the potential data set in Table 26. The data in Table 26 was also reviewed against the criteria for the Desk Study 1. The criteria included:

- Pre-existing data sets that can measure information-flow.
- Data that is freely available.
- De-identifiable data.
- Data that did not require effort to identify the information-flow
- Data that could be measured and used in the healthcare information-flow maturity framework.

From Table 26, the Threat to Patient Safety (TAPS) study was chosen as the data source on the basis it met the criteria such as consisting of pre-existing secondary research cases that had been previously used to map information-flow. As such, the TAPS cases information-flow were assessed as measurable against the information-flow maturity framework. The TAPS cases consisted of 164 GP error cases. These cases were reviewed, and eight cases were chosen for the Desk Study 1. These cases were selected since they had a full information-flow mappings and consisted of different types of information-flow failures. For example, two cases related to information-flow failure in GP desktop administration, two cases related to information-flow failure during patient diagnosis, two cases related to information-flow during patient treatment and two cases related to information-flow failure post-treatment/ follow up. Each case was categorised as ‘good’ or ‘bad’ information-flow. The TAPS cases were then analysed through the healthcare information-flow maturity framework, which included use of the information-flow maturity calculator to measure the maturity level.

5.3 TAPS cases analysed through the healthcare information-flow maturity framework

The information-flow maturity calculator was developed in an excel spreadsheet and forms part of the information-flow maturity framework. As capability maturity models are a subjective assessment tool used to measure maturity, an accurate, consistent, and quantifiable method to measure the information-flow cases was required. The calculator was developed to ensure information-flow maturity assessment could be repeated and reliable as there would be a standard method to measure the information-flow maturity existed. Therefore, the information-flow maturity calculator was designed to assist in the measurement of maturity levels. The information-flow maturity calculator was developed based on the information-flow metrics and the characteristics that had been articulated in the framework development phases (Chapter Four). The calculator was also informed by the information-flow capability maturity model. Shown in *Figure 60* is the initial design of the calculator, which included instructions on how to use the calculator, metric definitions and a tab that could calculate the average maturity level for each metric based on the measurement level of the characteristics. The TAPS cases were used on the information-flow calculator and maturity level was identified through assessing if any of the information-flow characteristics were present, and then selecting the maturity rating from Level 0 to Level 5 (level 0 meaning non-present and Level 5 meaning optimised). *Figure 60* illustrates the developed capability maturity model with a Total Maturity Score. In the initial design of the capability maturity model a matrix system was developed to calculate the information-flow maturity level. For example, in *Figure 60*, Coverage as an information-flow metric and its associated characteristics are illustrated. Each characteristic would be scoring a rating from 0-5 based on the characteristic maturity. The total scores would result in the Total Maturity Score. As Coverage had 7 characteristics it was calculated that the smallest score would be 0, while the highest that could be scored would be 35.

Metric Characteristics Maturity Calculator

Coverage	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5	
Capacity							
Completeness							
Quality							
Self-Descriptive							
Simplicity							
Soundess							
Structured							
Total Maturity Score							
Coverage Maturity Level							

Coverage Maturity Level Calculation Key	
Maturity Level	**Total Maturity Score**
Level 0	0
Level 1	1 to 7
Level 2	8 to 14
Level 3	15 to 21
Level 4	22 to 28
Level 5	29 to 35

Figure 60. **Initial Information-flow Maturity Calculator.**

Appendix D contains the full Desk Study 1 table which shows the TAPS cases applied to the information-flow calculator, the information-flow metric and information-flow characteristic maturity ratings, and the justification for those ratings. Shown in *Figure 61* and Table 27 is the Case Study #1 from the TAPS cases chosen that were applied to the information-flow maturity framework and is an excerpt of Desk Study 1.

5.3.1 Desk Study 1 Example - TAPS Case study 1

Category - Admin "good"

Case study # 1

Report No. 75: Topical steroid prescription item out of stock with pharmacy, GP not made aware resulting in patient having to return for different prescription.

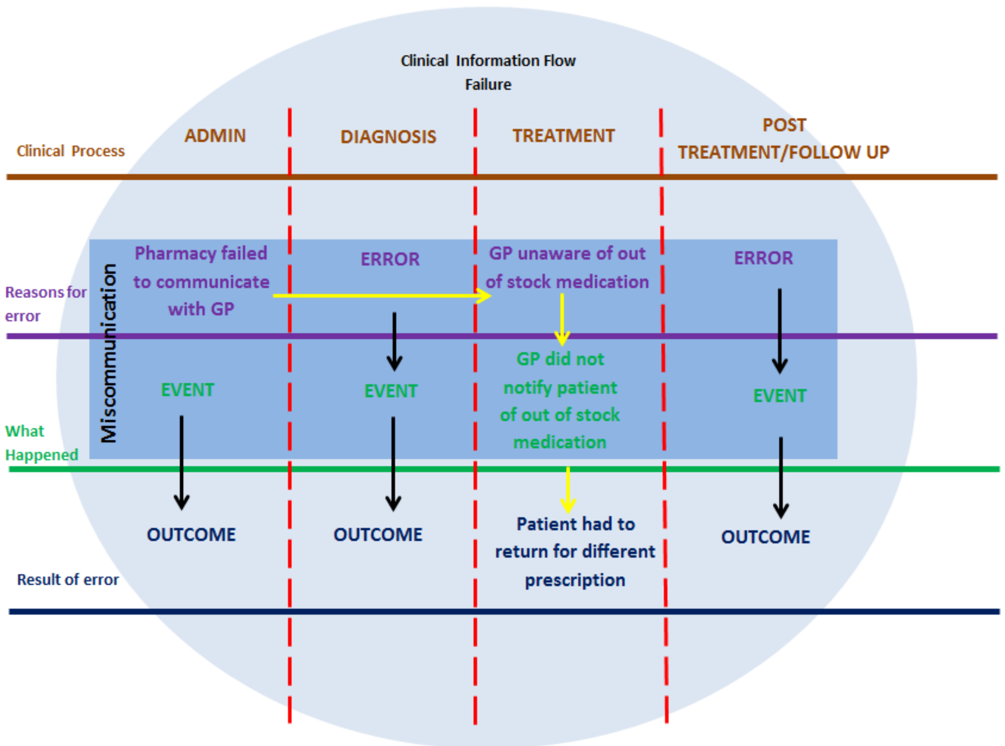


Figure 61. **Desk Study 1 Example - TAPS Case Study 1.**

5.3.2 Information-flow Maturity Ratings:

Table 28. TAPS Case Study 1 Information-flow Measurements.

Metric Characteristic		***Level Rating***	***Why it was given that Level Rating***
Coverage	Capacity	Level 1	Within this information-flow there is some information present. Therefore, it has not been listed as a 0. However, more data could have been used within the information-flow to prevent the error. The pharmacy failing to communicate with the GP, and the GP not communicating with the patient are data that is missing from this information-flow. If that data was available in this information-flow the error could have been prevented. The CMM level 1 for Initial includes information-flow that is inefficient. Information-flow in Case Study #1 is inefficient; therefore, the maturity level was categorised as 1.
	Completeness	Level 1	This is categorised as a 1, as there is some information. However, information is missing from the information-flow. Information being whole within the context and not missing, is a significant aspect and definition of the completeness quality.
	Quality	Level 1	This information was not fit for purpose or fit for use as impacted patients' medication. The information within the information=flow was not of quality because there was missing information and lack of communication.
	Self-Descriptive	Level 2	A retrospective view of the information-flow events depicts the information-flow failure clearly. Therefore, this has been categorised as a 2, which is Managed.
	Simplicity	Level 2	The information-flow events were easily understood; in particular, the information-flow failure was a simple failure and not complex. Hence, Simplicity is categorised as a 2.
	Soundness	Level 1	The information condition and robustness are present at minimum. This is because information failed to be communicated twice in this information-flow failure.
	Structured	Not enough Information	Listed as a 0 because there is not enough information in the information-flow, to suggest if the structure of the information could improve understanding and utility. Rather, the Researcher believes, there are several interventions that could be in place to prevent this error.
	Overall Coverage Level	**Level 2**	**Overall a level 2 for managed Coverage. Although the information was available, the failure occurred when communication between the Pharmacist to GP and GP to Patient did not occur. At current a Level 2, this information-flow case has several levels of potential improvement.**

Relevancy	Aligned	Level 0	The information-flow failure did not support the organisational goals, which is Patient care. Therefore, this is listed as a 0.
	Flexible	Level 1	The information was able to change; however, there were some errors present.
	Generalisability	Level 1	This information-flow failure of miscommunication and not communicating can be applied to general information-flow situations.
	Maintainability	Not enough information	There is not enough evidence in the case to suggest the information could over a time improve and meet tasks. There is a possibility for interventions to be included. However, this was not stated in the information-flow.
	Overall Relevancy level	**Level 1**	**Relevancy is listed as a 1, as the information was not correct, timely, current or sufficient, which is the opposite of Relevancy.**
Usability	Adaptability	Not enough information	There is not sufficient information in the information-flow to suggest this information could be used in different contexts.
	Addressability	Level 1	Although there was information-flow failure, the patient was still able to seek treatment through a different prescription.
	Compatible	Not enough information	This has been placed as a 0 as insufficient information is available. What information is required to adhere to quality frameworks and which specific frameworks.
	Complexity	Level 1	The information was relevant to the context. However, categorised as a 1 because of lack of communication to the GP and to the Patient.
	Effectiveness	Level 1	There is some effectiveness as the Patient was able to seek treatment in the end. This is categorised as some effectiveness qualities available.
	Efficient	Level 0	Based on the information-flow there is no efficiency present as there was failure to communicate and to achieve desired outcomes.
	Interoperable	Not applicable	Not relevant to the current case.
	Interpretability	Not enough information	Insufficient information available to decide if the information presented to the pharmacy, GP or Patient has an interpretability quality.
	Mobility	Level 0	Same as the efficient quality. However, in mobility, both capability and efficiency were not present.
	Modularity	Not enough information	This information-flow failure case does not show if the information could be separated.

	Operability	Level 1	The information was not functional, reliable or fit for use. However, the Patient was able to get treatment. Therefore, some operability quality is present.
	Performance	Level 1	As the result was the Patient being treated and the focus is Patient care, Performance has been categorised as a 1.
	Safety	Level 1	The result was benefit to the Patient as they were treated. However, the information-flow processes were not intentionally leading to benefit as there was information-flow failure.
	Serviceable	Level 1	Although there was information-flow failure through lack of communication, the information was useable and resulted in patient treatment.
	Sociability	Not enough information	Insufficient information available to decide if this information could be used in other instances or contexts.
	Understandable	Level 1	The information was understandable. The issue in this information-flow was the lack of information and lack of communication.
	Value	Level 1	The patient was able to be treated. However, if the patient could not be treated and this impacted their care and safety, this would significantly impact the organisational goals.
	Volatility	Level 1	The information itself did not provide value as information was missing. However, the context of the information-flow that relates to the Patient has value.
	Fit for Use	Level 1	Some of the information was fit for use as the Patient was able to get a different type of medication.
	Functionality	Level 1	The result was the patient receiving treatment. Therefore, a 1 was categorised.
	Overall Usability Level	**Level 1**	**Overall Usability level is a 1. This indicates there are some basic qualities of usability found in the information-flow case. Additionally, the clinical outcome resulted in the Patient being treated. However, the information-flow points to treatment were lacking information and had contained miscommunication. Therefore, this usability is uncontrolled, unpredictable and inefficient.**
Availability	Accessibility	Level 1	Information was present. However, it is missing.
	Latency	Not enough information	Information providing the response time of the information-flow points are not available.

	Overall Availability Level	**Level 1**	**Some qualities of information availability were present. However, these were at a minimum, with the qualities being uncontrolled, unpredictable, and inefficient.**
Reliability	Accuracy	Level 1	The information was not 100% free from errors. There were some accurate qualities available as the lack of medication available was rectified through use of a different medication.
	Consistency	Level 0	The information quality was not consistent within the information-flow.
	Portability	Not enough information	Not enough information is available.
	Redundancy	Level 0	No interventions were listed.
	Repairability	Not enough information	Insufficient information stating what could have been done to prevent this error.
	Repeatability	Not enough information	The information-flow contained errors. There is insufficient information to show this same outcome would occur without impacting patient care or safety.
	Sensitivity	Level 1	Miscommunication and lack of communication resulted in information-flow failure.
	Timely	Not enough information	Insufficient information to state the information was provided in a timely manner.
	Tolerance	Not enough information	Not enough information present to measure the limit to which the information-flow points fail.
	Validity	Level 1	The result was for the patient to get a different prescription. It appears that the patient accepted this information as they received a different prescription.
	Trust	Level 1	The information was not reliable or at a satisfactory/ acceptable level. However, there are measures of trust through the GP trusted the Pharmacy information and Patient trusted the GPs information. However, this information was incorrect; therefore, Trust is measured at Level 1.
	Longevity	Not enough information	Difficult to measure. Not enough information.
	Overall Reliability Level	**Level 1**	**Some reliability qualities are present. However, it is at a minimum, with information-flow unpredictable and inefficient.**
Security	Confidentiality	Level 1	Information was available to individuals with correct access. This was at a minimum.

	Formality	Not enough information	Not information such as which standards and quality frameworks. Therefore, difficult to measure.
	Overall Security level	**Level 1**	**Some security qualities were present at a minimum.**
Quality Assurance	Automobility	Not enough information	No evidence to show the information is automated.
	Implantability	Not enough information	No evidence to show interventions were placed.
	Improvability	Not enough information	No evidence to show any improvement.
	Mutability	Not relevant	Not relevant to this information-flow case.
	Progress	Not enough information	No evidence to show that progress was being made in the information-flow.
	Testable	Not enough information	No evidence to show that information points were being tested for failure.
	Correlated	Level 1	The information is depended on one another. The lack of communication impacted the information-flow points.
	Evidence	Not enough information	Insufficient information available to show statistics.
	Measurability	Level 1	Some qualities can be given a capability maturity level rating. This is a quantifiable measurement. However, the way the level is measured is subjective and qualitative.
	Ownable	Not enough information	Insufficient information regarding if the information was ownable or the information-flow was accountable.
	Quantifiable	Level 1	Similar to Measurability. Some qualities could be given a capability maturity rating level. However, from the information-flow case, there is insufficient information to measure certain qualities.
	Traceability	Level 2	The information-flow points could be mapped within the context.
	Transparency	Level 1	Information from an information-flow mapping perspective was transparent.
	Consistency	Level 1	The information quality was not consistent within the information-flow.
	Audit Capability	Level 1	From the information-flow case, the qualities can be measured and then tracked to assess performance.

	Coverage Quality	Level 1	The information at a minimum was fit for purpose and resulted in patient treatment.
	Overall Quality Assurance Level	**Level 1**	**Some Quality Assurance qualities present at a minimum.**

5.4 Analysis

Shown in Table 28 is a summary of the TAPS Desk Study 1 maturity ratings. Noting that metrics that could not determine a rating were marked as not measurable.

Table 29. TAPS Desk Study 1 Maturity Ratings.

Case Study Number	***Clinical Process Point***	***Patient Outcome***	***Coverage Level***	***Relevancy Level***	***Usability (Clinical Outcomes) Level***	***Availability Level***	***Reliability Level***	***Security Level***	***Quality Assurance Level***
#1	ADMIN	No patient harm	Level 2	Level 1	Level 1	Level 1	Level 1	Level 1	Level 1
#10	ADMIN	Patient harm	Level 1	Level 0	Level 1	Not measurable	Level 0	Level 1	Level 1
#72	DIAGNOSIS	Patient harm	Level 1	Level 0	Level 1	Level 1	Level 1	Not measurable	Level 1
#148	DIAGNOSIS	Patient harm	Level 1	Level 0	Level 0	Not measurable	Level 0	Not Measurable	Level 1
#11	TREATMENT	No patient harm	Level 1	Level 1	Level 1	Level 2	Level 1	Not measurable	Level 1
#3	TREATMENT	Patient harm	Level 1	Level 0	Level 0	Not measurable	Level 0	Not measurable	Level 1
#75	POST TREATMENT/ FOLLOW UP	Unknown	Level 1	Level 0	Level 0	Not measurable	Level 0	Not measurable	Level 1
#53	POST TREATMENT/ FOLLOW UP	Patient harm	Level 0	Level 0	Level 0	Not measurable	Level 0	Not measurable	Level 0

Table 29 identified that characteristics are measurable. Desk Study 1 revealed there were several information-flow characteristics that could not be measured due to lack of information or lack of relevance to the information-flow TAPS case. Therefore, in this initial assessment they were marked as Level 0 on the basis that the definition for Level 0 is that the characteristic “is not present”. However, it was then determined that this may have the potential to alter the overall maturity level rating. Therefore, any characteristics that did not have sufficient information or were not relevant were marked with “not relevant” or “insufficient information”. Interestingly from Desk Study 1, it was found 6 out of 8 cases had an overall Security metric which was not measurable, while 5 out of 8 had the metric Availability not measurable. A closer inspection as to why Security and Availability had the most non measurable levels revealed it was because the TAPS cases either did not provide information to assess this metric or the metric characteristic was not relevant to the information-flow case. The Security metric characteristics confidentiality and formality are useful in terms of information-flow security, however, during the application of the TAPS cases to the framework it was shown there were not relevant to reducing information-flow failures that resulted in patient harm. While the metric Availability has accessibility and latency as characteristics, that relate to information being in the correct location and the information-flow response time, Desk Study 1 showed a limitation with the TAPS cases as information was not available to assess the characteristics. This was because there was limited information in the individual TAPS cases. Overall, Desk Study 1 provided useful insight to what metrics and information characteristics were relevant to information-flow cases and that characteristics may potentially influence information-flow but at this time cannot be measured.

Interesting to note that prior to validating against the capability maturity model TAPS cases, the cases 1, 72, 11 and 75 were initially deemed as “good” information-flow. However, after applying the TAPS cases to the information-flow maturity framework, it was confirmed that TAPS case 72 resulted in patient harm, while it is unknown if the patient was harmed in case 75. Additionally, all the “bad” information-flow cases confirmed that the patient had been harmed because of information-flow failure. It is also interesting to note that in TAPS case 1 and 11 there were metrics that were rated a level 2. This is considered a high level for a case with information-flow failure. This also raised the question if metrics levels can be high will this guarantee patient safety or can metrics be high, and the patient still harmed; unfortunately, the TAPS cases do not answer this question extensively. Further information-flow cases that contain “good” and “bad” information-flow were required to be tested on the information-flow maturity framework to answer this question. This also raised questions about benefit from improved information-flow and what were the promoters of ‘good’ information-flow. Nonetheless, from the information-flow failure, an idea of what “good” information-flow can be pictured. In an ideal scenario, the information-flow would not have failures or errors. Nonetheless, there is also acceptable information-flow; where failures are minimal, and interventions are involved that either prevent errors or result in near misses. An important factor to be considered is the ultimate impact on the patient and the organisation’s goals. The promotors of “good” information-flow are qualities that ultimately promote patient safety and reduce information-flow failures that could result in patient harm from medication errors. Reflecting on the information-flow qualities and metrics, these could be used as information-flow promotors. When these qualities are present and used correctly, the maturity level will be high. Therefore, it can be assumed the information-flow will be good information flow. This also highlighted the importance of standard terminology in information-flow and healthcare.

Table 30. Information-flow Measurable Characteristics.

Metric Category	Metric Characteristic	TAPS Case #1	TAPS Case #10	TAPS Case #72	TAPS Case #148	TAPS Case #11	TAPS Case #3	TAPS Case #75	TAPS Case #53
Coverage	Capacity	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Completeness	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Quality	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Self-Descriptive	Measurable	Measurable	Measurable	Not Relevant	Measurable	Measurable	Measurable	Not Relevant
	Simplicity	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Not Relevant
	Soundness	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Not Relevant	Not Relevant
	Structured	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Measurable	Measurable	Insufficient Information	Measurable
Overall Coverage Maturity Level		Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Relevancy	Aligned	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Flexible	Measurable	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable
	Generalisability	Measurable	Insufficient Information	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Maintainability	Insufficient Information	Measurable	Not Relevant	Not Relevant	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information
Overall Relevancy Maturity Level		Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Usability	Adaptability	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Addressability	Measurable	Insufficient Information	Not Relevant	Measurable	Not Relevant	Measurable	Measurable	Insufficient Information
	Compatible	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Complexity	Measurable	Measurable	Not Relevant	Not Relevant	Not Relevant	Insufficient Information	Insufficient Information	Not Relevant
	Effectiveness	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Efficient	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Interoperable	Not Relevant	Measurable	Not Relevant	Not Relevant	Not Relevant	Insufficient Information	Insufficient Information	Not Relevant
	Interpretability	Insufficient Information	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Not Relevant
	Mobility	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Modularity	Insufficient Information	Measurable	Measurable	Measurable	Insufficient Information	Measurable	Insufficient Information	Measurable
	Operability	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Performance	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable

	Safety	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Serviceable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Sociability	Insufficient Information	Insufficient Information	Not Relevant	Measurable	Measurable	Insufficient Information	Not Relevant	Insufficient Information
	Understandable	Measurable	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Insufficient Information
	Value	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Volatility	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Fit for Use	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Functionality	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Overall Usability Maturity Level		Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Availability	Accessibility	Measurable	Insufficient Information	Measurable	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Latency	Insufficient Information	Insufficient Information	Insufficient Information	Not Relevant	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
Overall Availability Maturity Level		Measurable	Not Measurable	Measurable	Not Measurable	Measurable	Not Measurable	Not Measurable	Not Measurable
Reliability	Accuracy	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Consistency	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Portability	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Insufficient Information	Insufficient Information	Measurable
	Redundancy	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Repairability	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Insufficient Information
	Repeatability	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information
	Sensitivity	Measurable	Measurable	Not Relevant	Measurable	Measurable	Insufficient Information	Measurable	Measurable
	Timely	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Measurable	Insufficient Information	Measurable	Measurable
	Tolerance	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Insufficient Information	Measurable	Measurable
	Validity	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Trust	Measurable	Measurable	Measurable	Not Relevant	Measurable	Measurable	Measurable	Measurable
	Longevity	Insufficient Information	Insufficient Information	Not Relevant	Not Relevant	Measurable	Measurable	Measurable	Measurable
Overall Reliability Maturity Level		Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Security	Confidentiality	Measurable	Insufficient Information	Not Relevant	Not Relevant	Not Relevant	Insufficient Information	Not Relevant	Not Relevant

	Formality	Insufficient Information	Measurable	Not Relevant	Not Relevant	Insufficient Information	Insufficient Information	Not Relevant	Not Relevant
Overall Security Maturity Level		Measurable	Measurable	Not Measurable	Not Measurable	Not Measurable	Not Measurable	Not Measurable	Not Measurable
Quality Assurance (QA)	Automobility	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Implantability	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Improvability	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information
	Mutability	Not Relevant	Measurable	Insufficient Information	Insufficient Information	Measurable	Insufficient Information	Insufficient Information	Insufficient Information
	Progress	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information
	Testable	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Measurable	Measurable	Measurable	Measurable
	Correlated	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Evidence	Insufficient Information	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Measurability	Measurable	Insufficient Information	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Ownable	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Insufficient Information	Measurable
	Quantifiable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Traceability	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Transparency	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Consistency	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Audit Capability	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
	Coverage Quality	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable
Overall Quality Assurance (QA) Maturity Level		Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable	Measurable

5.5 Identify improvements for the information-flow maturity framework

5.5.1 Information-flow metrics and characteristics refinement

Following the measurement of the TAPS cases information-flow, the information-flow characteristics were refined. The first step was to identify whether there were specific characteristics that only related to information-flow. Shown in the Table 30 is the information-flow characteristic, the definition and a third column which demonstrates how this characteristic relates to other characteristics. This was important in identifying how other characteristics could potentially inform or impact information-flow. Additional characteristics such as Functionality and Fit for Use were added to the framework as it was realised these characteristics were missing and contributed to information-flow. Although it should be mentioned these characteristics were not specifically mentioned in the literature review, the themes of functionality and quality of use were highlighted in the scoping review, case study analysis and Desk Study 1. It was also recognised that these characteristics can fit into several metrics' categories. However, for classification purposes they were only categorised once. Additionally, it was decided that metrics could be selected based on the situation and information-flow context. This resulted from the TAPS cases where characteristics in Security and Availability could not be measured because of the information-flow context. Rather than removing these metrics they were kept as they could be used in future information-flow measurement. Additionally, it was questioned if other characteristics such as interoperable should be removed. However, it was through that some characteristics could potentially be identified as an influencing factor for information-flow, and therefore kept as a characteristic. Based on the TAPS cases it was also identified that may characteristics overlap, and that the measurement could be used for many characteristics. The characteristic Ownable was changed to Custodian as the term Custodian incorporates all of the Ownable characteristics. It was also revealed how important the characteristic Timely was, and the characteristic repeatability was questioned as to whether different users would measure the maturity differently.

Table 31. Information-flow characteristics relationships.

Characteristics	***Definition***	***Relates to***
Simplicity	The ability for information-flow to be understood.	Usability and Understandable
Soundness	The condition and robustness of the information-flow.	Structured
Completeness	Information within information-flow is whole.	Availability and consistency

Structured	Organisation and state of the information-flow to improve understanding and utility.	Value and fit for use
Flexibility	The ability for information-flow to change within the context with limited errors.	Structured
Maintainability	Resource requirement over time to improve and meet tasks within information-flow.	Repairability
Complexity	Relevant structure and appropriate to the context.	Simplicity and Structured
Effectiveness	The ability for information-flow process to be effective within the context and in relation to organisational goals.	Efficiency
Interoperable	Information-flow is interoperable.	Flexibility and Modularity
Mobility	The capability and efficiency of information-flow.	Capability and efficiency.
Modularity	The ability for information-flow to be separated.	Structured and Flexibility
Operability	The ability for information-flow to be functional and reliable.	Functionality and reliability
Performance	Overall performance of information-flow.	Value
Safety	The outcome of information-flow that leads to benefit.	Value
Understandable	The quality of the information-flow being comprehensible.	Simplicity
Value	The worth to the organisation and in relation to the organisational goals.	Volatility
Volatility	The overall value of information-flow.	
Latency	Information-flow response time.	Consistency and reliability
Portability	Ability for information-flow to be transferred to another context.	Structured and flexibility
Repairability	Ability for information-flow failure to be prevented.	Maintainability
Repeatability	The degree to which information-flow can be repeated with the outcomes, without error.	Reliability

Sensitivity	The degree to which information-flow causes errors.	Tolerance
Tolerance	The limit to which information-flow points can fail.	Sensitivity
Trust	The information within information-flow is reliable and satisfactory to users.	Reliability, Efficiency and Effectiveness
Longevity	Information-flow lifecycle.	Repairability and Maintainability
Automobility	Information-flow has the ability to be automated.	Flexibility
Implantability	The ability for interventions and changes to not harm information-flow.	Tolerance
Improvability	The ability for information-flow to improve.	Reliability,
Mutability	The degree for information-flow to change.	Complexity and Modularity
Measurability	The ability for information-flow measurements to be quantifiable.	Evidence and Quantifiability
Quantifiable	The ability of information measurements and qualities to be measured.	Measurability
Traceability	Ability to map or track information-flow points.	Evidence, quantifiable and measurability
Audit Capability	Ability for information-flow performance to be tracked and reported on.	Evidence, Traceability, measurability and Quantifiable
Coverage Quality	The information-flow is fit for purpose. Suitable to a task and within the scope, and appropriate to the domain (context).	Completeness, Reliability, Effectiveness, Efficiency

Further refinement of the information-flow metric characteristics allowed the naming conventions to become simpler. Additionally, in the Coverage metric, the characteristic consistency was removed, while the characteristic fit for use and functionality were added to the category Usability. It should be noted within the maturity model TAPS assessment there were qualities identified that influence information-flow but could not be measured. Additionally, some qualities do not detect anything bad or good but are simply a form of measurement. For example, many of the Quality Assurance qualities such as automobility are not a negative quality. During the TAPs analysis it was found that the maturity levels were similar. This was most likely because of the limited information within the TAPS cases. It is important to note that some of the qualities such as interoperable and portability needed to be revised as it was problematic to measure them in the TAPS cases. Many of the characteristics in Quality Assurance are qualities that could be used to improve the information-flow rather than identify what the maturity level is now. These qualities are used for post review, for example, repairability, repeatability and tolerance. Other metrics such as compatible and formality rely on specific frameworks to inform their measurements. This can only be measured when specific frameworks for the context are defined. Applying the TAPS cases to the information-flow maturity framework through Desk Study 1, resulted in validation of the maturity model as most of the characteristics could be measured to provide a maturity level rating. This was significant as it enabled the information-flow to be maturity assessed and therefore, could potentially resulting in further improvements and higher maturity levels. This would ultimately, reduce information-flow failure that result in patient harm and improve patient safety through identifying what qualities need improving. Nonetheless, Desk Study 1 identified that both information-flow maturity framework and characteristics would require refinement to improve usability of the information-flow maturity framework.

Table 31 is a refinement of the information-flow metrics and their characteristics while Table 32 shows a reined information-flow capability maturity model.

5.5.2 Refined information-flow characteristics

Table 32. Refined information characteristics as a result of Desk Study 1.

Metric Category	***Information-flow characteristic***	***Definition***
Coverage	Capacity	The maximum amount of data that can be processed in the context.
	Completeness	Information is not missing and is whole within the context.
	Quality	Quality refers to the information quality and includes fit for purpose and use.
	Self-Descriptive	Information is self-explanatory.
	Simplicity	The ability for to be understood. Incorporates ease of use.
	Soundness	The condition and robustness of the information.
	Structured	Organisation and state of the information to improve understanding and utility.
Relevancy	Aligned	Correct contextual attributed and supports organisational goals.
	Flexible	The ability for the information to change with limited errors.
	Generalisability	Information that can be applied anywhere.

	Maintainability	Resource requirement over time to improve and meet tasks.
Usability	Adaptability	The ability for the information to be used in different contexts.
	Addressability	The ability for information to respond to internal and external factors.
	Compatible	Ability for information to be adhere to quality frameworks.
	Complexity	Relevant structure and appropriate to the context.
	Effectiveness	The effectiveness of the information within the context.
	Efficient	The degree to which the information is efficient.
	Interoperable	Information is interoperable. Common or mappable ontology.
	Interpretability	The ease of how information can be translated and read.
	Mobility	The capability and efficiency of information.
	Modularity	The ability to which information can be separated.
	Operability	The ability of information to be functional, reliable, and fit for use.
	Performance	Overall performance of information within the context.
	Safety	The degree that information-flow processes that lead to benefit
	Serviceable	The ability for information to useable.
	Sociability	The ability of information to be used in other instances or contexts.
	Understandable	The quality of information being comprehensible.
	Value	The worth of the information to the organisation and in relation to the organisational goals.
	Volatility	The overall value that the information provides.
	Fit for Use	The right Information is available to the right person, at the right place at the right time, in the right format.
	Functionality	The ability for information to be fit for use and to serve the organisational goals.
Availability	Accessibility	The ease of accessing information and having information available in the correct location.
	Latency	Information-flow response time
Reliability	Accuracy	The quality of information being correct and free from errors.
	Consistency	Information quality is consistent

	Portability	Ability for information to be transferrable from one context to another.
	Redundancy	Interventions to prevent information from errors or failure.
	Repairability	Ability for information failure to be prevented.
	Repeatability	The degree to which information can be repeated with the same outcomes, without error.
	Sensitivity	The degree to which information causes errors.
	Timely	The ability for information to be used within a relevant context.
	Tolerance	The limit to which information points can fail.
	Validity	The quality of acceptability. Incorporates soundness.
	Trust	The information to be reliable and for it to be at a satisfactory/ acceptable level.
	Longevity	The information lifecycle and the period for which information is relevant for.
Security	Confidentiality	Information is available to those with correct access
	Formality	Information that adheres to standards and quality frameworks.
Quality Assurance	Automobility	Information can be automated.
	Implantability	The ability for interventions and changes to not harm information.
	Improvability	The ability for information to improve.
	Mutability	The ability for information to change structure.
	Progress	The ability for information to improve and mature.
	Testable	The ability for information points to be tested for failure.
	Correlated	The state of information being connected and dependent on one another.
	Evidence	The availability of information and statistics.
	Measurability	The ability for information measurements to be quantifiable.
	Ownable	Information is owned and held accountable within contexts.
	Quantifiable	The ability of information measurements and qualities to be measured.
	Traceability	Ability to map or track information within the context.

	Transparency	Ability for information to be transparent.
	Consistency	Information quality is consistent.
	Audit Capability	Ability for information performance to be tracked and reported on.
	Coverage Quality	The information is fit for purpose. Suitable to a task and within the scope, and appropriate to the domain (context).

Shown in Table 32 is the refined capability maturity model.

Table 33. Refined Capability Maturity Model for Information-flow.

Characteristic	*Level 0: None*	*Level 1: Initial*	*Level 2: Managed*	*Level 3: Defined*	*Level 4: Quantitatively Managed*	*Level 5: Optimising*
Coverage	Coverage is not present.	Some Coverage characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Coverage characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Coverage characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Coverage is optimised. Coverage data characteristics are fully evident in the information-flow.
Relevancy	Relevancy is not present.	Some Relevancy characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Relevancy characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Relevancy characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Relevancy is optimised. Relevancy data characteristics are fully evident in the information-flow.
Usability (Clinical Outcomes)	Usability is not present.	Some Usability characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Usability characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Usability characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Usability is optimised. Usability data characteristics are fully evident in the information-flow.
Availability	Availability is not present.	Some Availability characteristics are present at a minimum.	Majority of Availability characteristics are evident, measurable,	Organisation starts to actively engage Availability characteristics into	Metrics and measurements are used to predict information-flow failures.	Availability is optimised. Availability data characteristics

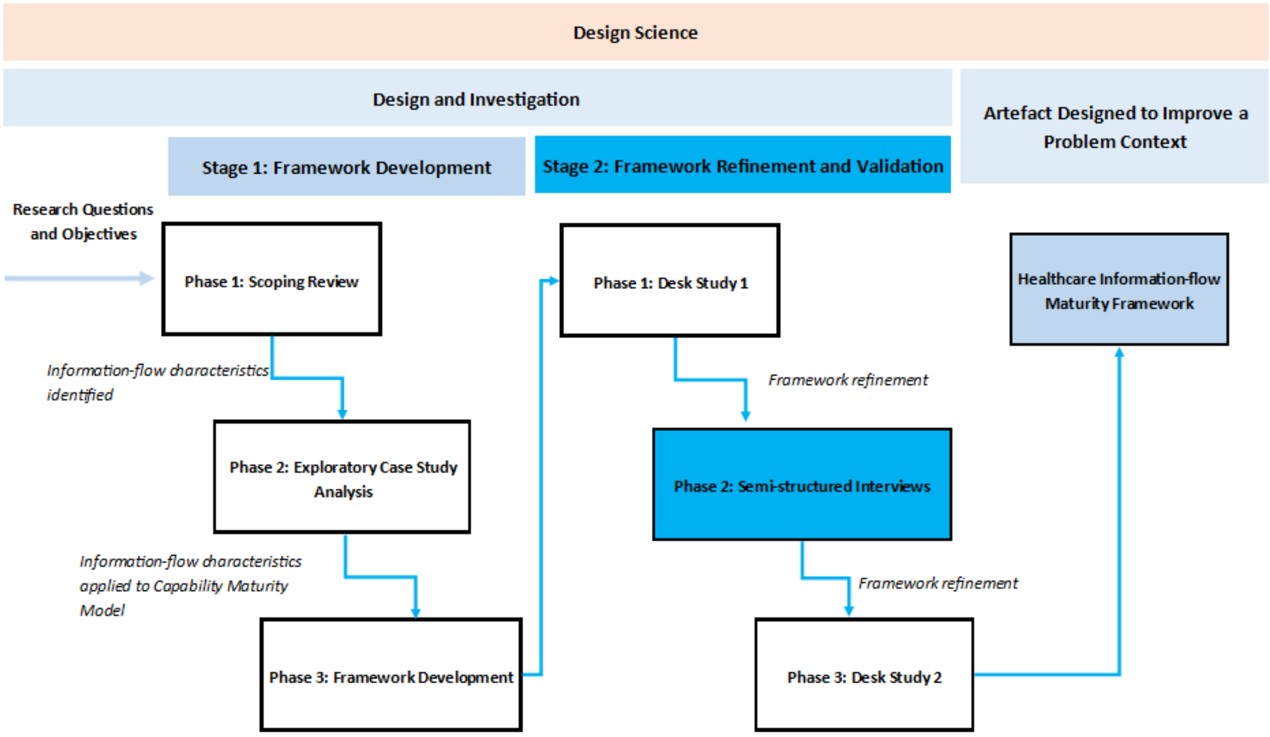
		The information-flow is uncontrolled, unpredictable, and inefficient.	and repeatable. Naturally results in reduced Information-flow failures.	information-flow. Continued reduction in information-flow failures.	Proactive intervention is used to prevent information-flow failures.	are fully evident in the information-flow.
Reliability	Reliability is not present.	Some Reliability characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Reliability characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Reliability characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Reliability is optimised. Reliability data characteristics are fully evident in the information-flow.
Security	Security is not present.	Some Security characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Security characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Security characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Security is optimised. Security data characteristics are fully evident in the information-flow.
Quality Assurance	Quality Assurance is not present.	Some Quality characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Quality characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Quality characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Quality Assurance is optimised. Quality Assurance data characteristics are fully evident in the information-flow.

5.5.3 Refining the Information-flow Maturity Calculator

At this stage of the research an information-flow characteristics were developed along with a maturity calculator to score those characteristics. Both these items form the information-flow maturity framework. Initial versions of the information-flow maturity calculator included a formula to get an average score based on the measurement levels. However, it was concluded that some metric characteristics may not be needed for some information-flow situations. Therefore, a refinement of the calculator occurred to include in the information-flow maturity calculator an instruction tab, the capability maturity model, metric and characteristic definitions and the maturity calculator. The instructions tab explained how to use the calculator. In the Capability Maturity Model tab, the maturity model from Chapter 4 is displayed and included the 7 metrics (coverage, relevancy, usability, availability, reliability, and security). While in the Metric definitions tab had the definitions of each of the metrics and their characteristics. The Maturity calculator tab was designed to include the metrics and their characteristics. Within the metric level column there was an option to select the different levels from 0 to 5. However, if a level could not be determined there was an option for not measurable. The justification column included not relevant, insufficient information and influencing factor or other (justification that does not have a category). While the improvement activities column was added to assist in identifying recommendations for that information-flow characteristic. The information-flow maturity framework remained an assessment tool that took on several refinement stage to result in an information-flow maturity calculator that is research informed, tested and validated through methods of Desk Study and methodology Design Science.

In summary, this chapter focused on validating and refining the information-flow maturity framework through Desk Study 1, using the TAPS cases that were used in the previous research by Hermon and Williams (2020). An information-flow maturity calculator was developed as a tool to measure the information-flow characteristics and assess if each information-flow characteristic could be assigned a maturity rating and forms the information-flow maturity framework. This resulted in the initial validation of the information-flow maturity framework and identified improvements for the frameworks refinement. The next chapter focusses on validation of the information-flow maturity framework through semi-structured interviews with experts in the discourse.

CHAPTER SIX: PHASE 2 OF STAGE 2 - SEMI-STRUCTURED INTERVIEWS



In the previous chapter, the healthcare information-flow maturity framework was evaluated using Desk Study 1. This applied eight TAPS cases to the information-flow maturity framework, to assess if an information-flow maturity level could be determined, and to provide an initial validation and refinement of the framework. A key result of this evaluation was the identification of the information-flow metrics that could be measured or not measured, and the importance of improving those measurements. Desk Study 1 raised questions about the subjectivity of the assessment tool and the data definitions accuracy. Consequently, this chapter focuses on assessing how experts in information-flow, metrics and process improvement would use the framework. Semi-structured interviews were identified as the most appropriate type of interview method to validate and refine the framework. These interviews resulted in further refinement of the framework and validation for real-life use. The following section explains the method and processes used in semi-structured interviews and elaborates on the justification for using semi-structured interviews for expert feedback and refinement of the healthcare information-flow maturity framework.

6.1 Research Steps

To refine the healthcare information-flow maturity framework and develop an information-flow improvement use guide, semi-structured interviews with experts was necessary. The interviewees were experts who were process managers and coordinators and were asked about their perspectives on the information-flow maturity framework. This required the experts to complete a case study against the healthcare information-flow maturity framework and provide feedback. Case study #10 from the TAPS cases was chosen and the rationale is provided below. Prior to the interviews, Interview Questions and an Interview Guide were developed (refer to Appendix E). Participants were asked about their background and demographic questions, and information-flow and metrics questions. Subsequently they were asked to review the information-flow metrics in the framework, a worked example and complete the healthcare information-flow maturity framework to identify the worked examples information-flow maturity.

30 potential participants were identified from the literature or known to the researcher. They were selected based on their role and expertise, such as researcher, process manager and clinical registrar. Process, information systems roles and clinical roles were required for be interviewed as their input into information-flow and healthcare would be of value for refining the information-flow maturity framework. The 30 participants were approached to participate in interviews, of which 25 responded. However, out of the 25 participants who responded, only 7 returned the consent form.

The participants were chosen based on their publication history within the literature and their roles. The following roles were identified from the participants:

- Health IT and application support
- Data base support
- Health Consulting (project and process management)
- Clinical application specialist
- Health Informatician
- Associate Professor (maturity models for healthcare)
- Health informatician/researcher

After the interviews, the interview data was organised and analysed in NVivo. NVivo was selected as the results and analysis tool, on the basis that it allows the analysis of text and audio for qualitative data analysis.

Reason for selecting TAPS case study #10

Case study #10 was selected as the worked example, on the basis it included a selection of information-flow characteristics as well highlighted insufficient information. This case study also has characteristics that were thought to be missing, from the Researchers' analysis, and characteristics that were not measurable. It provided a real-life scenario in which information-flow can result in poor patient outcomes. The interviewees were asked to review the worked case study example that had already been completed by the Researcher, to compare the results and obtain their feedback on the use of the healthcare information-flow maturity framework. The interviews were important and played a role in refining the healthcare information-flow maturity framework and for providing input into the development of a guide that shows how to improve information-flow maturity levels once they have been identified.

Ethics

Low risk ethics approval was granted by the Flinders University Ethics committee to conduct semi structured interviews (Ethics & Biosafety, Project ID: 4259, Low Risk Approval).

6.2 Interview Results

During the interview, notes were taken manually, and audio recorded using Zoom. Following the interviews, the data was transcribed, organised, and analysed in NVivo. Codes within NVivo were created to assist with exploring themes from the interviews. As the semi-structured interviews were flexible and conversational in nature, some of the interview questions were not asked by the interviewer. For example, participant 7's interview was a discussion on how to develop a maturity capability framework for information-flow. As a result, the healthcare information-flow maturity framework was not completed by participant 7. Additionally, in some of the interviews the participants had already answered the several of the interview questions in response to one question. Shown in *Figure 62* shows the hierarchy of the themes identified from the interviews. Although only 7 participants returned the consent form, this resulted in saturation of the answers.

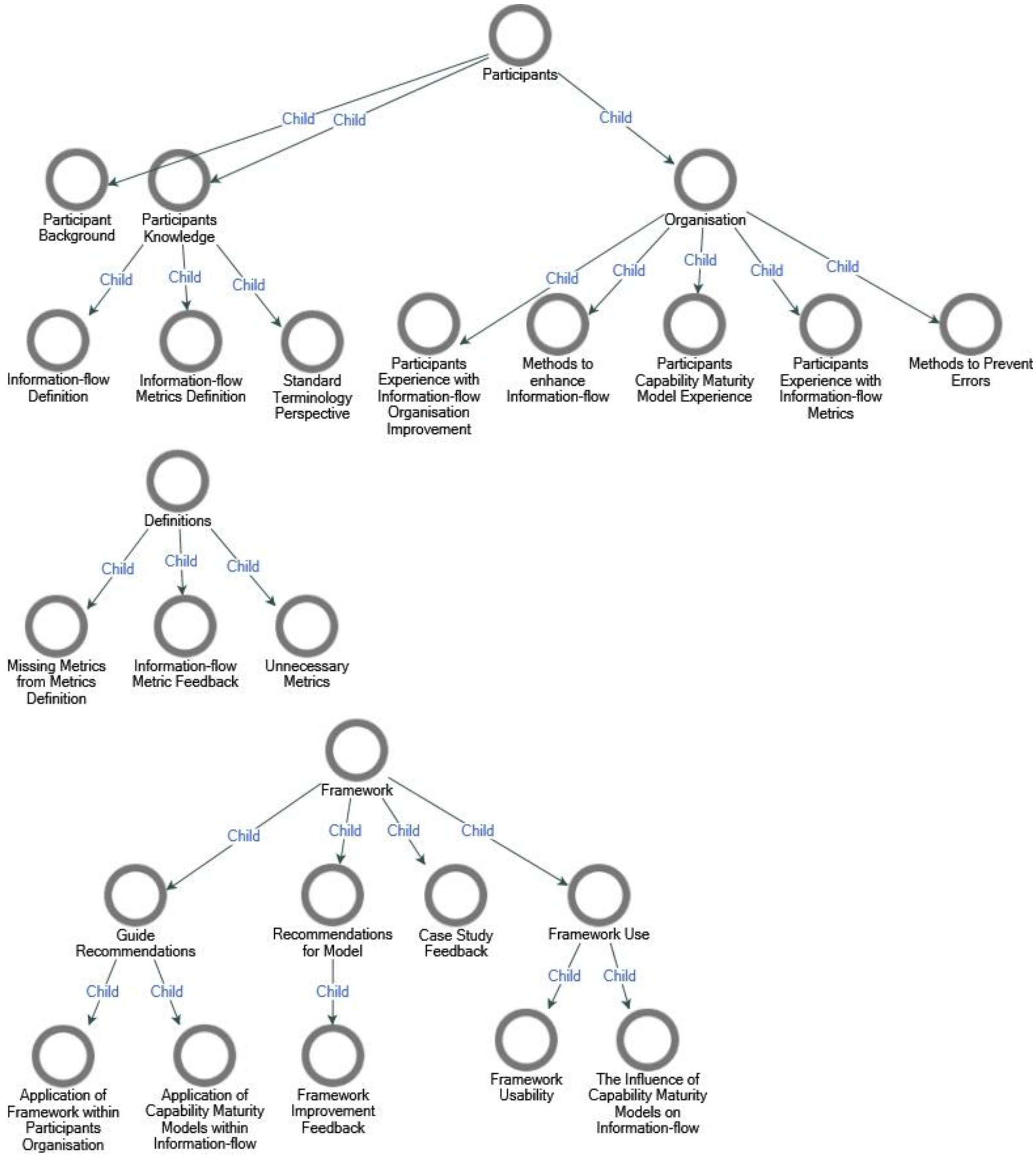


Figure 62. Themes identified from the Interviews.

The themes were categorised into Participants, Definitions and Framework. Within each of these themes are sub-themes. The theme Participants included sub themes such as organisation, participant background and participant knowledge. Following, these sub themes are further themes that are categorised specifically. The definition theme referred to data about the information-flow metrics definitions and had sub-themes that include information-flow metric feedback, missing metrics from metrics definitions and unnecessary metrics. While the Framework theme had sub-themes as case study feedback, framework use, guide recommendations and recommendations for model. Shown in Table 33 are the number of times a theme was discussed during the interviews. While shown in Table 34 are the participant definitions for information-flow and information-flow metrics. This had significance on the findings as it enabled the Researcher to identify what themes saturated the interviews, and as result feedback that contributed to the refinement of the healthcare information-flow maturity framework was identified.

Table 34. Number of times themes were references in interviews.

Theme Name	**Sub-theme Name**	**Number of Interview References**
Participants		
	Organisation	130
	Methods to enhance Information-flow	32
	Methods to Prevent Errors	32
	Participants Capability Maturity Model Experience	18
	Participants Experience with Information-flow Metrics	21
	Participants Experience with Information-flow Organisation Improvement	27
	Participant Background	35
	Participants Knowledge	40
	Standard Terminology Perspective	14
	Information-flow Metrics Definition	11
	Information-flow Definition	15
Total for Participants		***205***
Definitions		
	Information-flow Metric Feedback	60
	Missing Metrics from Metrics Definition	4
	Unnecessary Metrics	1
Total for Definitions		***65***
Framework		
	Case Study Feedback	61
	Framework Use	71
	Framework Usability	69
	The Influence of Capability Maturity Models on Information-flow	2
	Guide Recommendations	48
	Application of Capability Maturity Models within Information-flow	10
	Application of Framework within Participants Organisation	38
	Recommendations for Model	28
	Framework Improvement Feedback	28
Total for Framework		***208***

The following section discusses the themes such as participants, definitions and framework that was discussed during the interviews.

6.2.1 Theme: Participants

The participants were originally selected because of their expert knowledge in either health informatics, ICT systems, clinical information systems or process improvement. Participants expert knowledge was initially confirmed through identifying their experiences and backgrounds. For example, Participant 7 described their experience in the industry of "health informatics, as a health informatician. I have worked with health IT systems for 20 years now and have designed and implemented systems, so I have looked at information-flow in that context". With Participant 4 had experience in "clinical applications specialist as in health for 15 years, working in medication safety, hospital EMRS and medication management". While Participant 3 described their experience in "technical improvement for data and engagement projects". Participant 3 had a vast experience in "developing and improving processes".

6.2.2 Theme: Definitions

Table 34 shows the definitions of information-flow and metrics that the participants were asked.

Table 35. Participant Definitions.

Participant	***Definition of Information-flow***	***Definition of information-flow metrics***
Participant 1	"Flow that has to be followed in order to provide information. Part of the communication process. To provide information across teams. To ensure information is communicated".	"Information flow metrics can be through emails. It can help the organisations to shift from project to product. Used to observe the information within the system. Different types of metrics. Object oriented metrics, software metrics, obstruction metrics".
Participant 2	"The flow of information from any part of a system. (computer, telecommunication, person). Flow that comes from any flow of any entity".	"Our measuring, system of measurement that is predefined that determines the success that determines correct measures that was delivered/ communicated. The information-flow is intact, secure, not altered in any shape or form".
Participant 3	"The transfer and the communication of data both systems whether informal and formal".	"I would define the metrics as key data to indicate to performance for information flow and effectiveness of the information flow".
Participant 4	"The flow of information within and between systems. Chemical sense to support patient outcomes/ decision making. To improve patient safety within this context".	"Measure how the information-flow within the contexts".

Participant	*Definition of Information-flow*	*Definition of information-flow metrics*
Participant 5	"I guess you want to capture some aspect if the information makes it there. Whether or not it makes it there a to b n tact, if there's errors, time, valid. If you are doing metrics, you want to capture, does it arrive, does it arrive late? Does it arrive in tact?"	No definition provided.
Participant 6	"Depends on which perspective – organizational or patient side. Concerns of the passing on of data/ information or intelligence through a particular workflow. Related to the patient journey. Serves different stakeholders. – physicians, nurses, General practicians, patients".	"The measurable part of something that concerns information-flow. There are different options. The return time of documents. How many times a documents is accessed – availability - related to flow".
Participant 7	"Two elements of info-flow: Technology, social, physical structures – how information interacts with the artefacts – meaning to be transitioned from state to another state. How it achieves your objective from one to the next".	"What do you want to achieve? Metrics – dependent on what you want to measure Structural and social relations – how to they relate to one another?"

As evident in Table 34, all the participants were able to define information-flow. Although each participant had a different definition; shared concepts such as the idea the information-low involves data/information moving from one part to another, and that information-flow involves communication and systems were mentioned. Additionally, all participants were able to provide a definition of information-flow metrics. Participants were asked to define information-flow and information-flow metrics to confirm a definition and to identify how definitions defer according to expert. Additionally, 6 out of the 7 participants included the term measurement in their definition, while participant 1 mentioned the term "observe". This aligns with Haydon's (2010) definition of metrics as "some standard of measurement" and Haydon's (2010) definition of measurement as "the act of judging or estimating the qualities of something.", which could be extend to participants 1 definition which includes observing a quality of something. Surprisingly, none of the participants currently used information-flow metrics within their organisation. 3 out of the 7 participants advised their organisation potentially used information-flow metrics but their role did not specifically use them. While the other 4 out of 7 participants were involved with research or process improvement for organisations. Further, 4 out of the 7 participants had no direct experience with capability maturity models, while 3 of the 7 participants had previously developed Maturity Models. Whilst some participants had no direct experience with Capability Maturity Models or Information-flow metrics, their experiences and knowledge were still valuable to this research as they were able to provide insights into understanding the information-flow metrics framework which had been develops and provide feedback on the information-flow metrics definitions.

An important finding from the interviews were the methods used to prevent errors in information-flow. For example:

- learning through mistakes
- manual validation, integrity checks
- error checking/ proofing
- HL7 messaging
- communication techniques
- verifying data

The methods used to prevent errors in information-flow were evident in Participant 3's answers "the concept that we applied [to prevent errors in information-flow] were 6 sigma. Examples of developing operations templates, using field validation, using drop downs in order to check for errors and using metrics to check for errors".

Similarly, the methods to improve information-flow within organisations included:

- communication
- teams dedicated to enhancing flow
- adhering to standards
- code sensing
- technologies
- retrospective modelling
- application layer maturity
- strategy
- policy
- organisational processes
- people
- Culture
- IT business alignment
- Governance
- information technology
- security
- privacy

Enhancing and improving information-flow was evident in Participant 3's answers to "propose a lot of method to enhance [my clients] information-flow". Participant 3 also suggested using "error proofing, systems and data base level infrastructure improvements" for information-flow improvement.

The methods to prevent errors and improve information-flow were a significant finding of the interviews, as they provided insights on how the healthcare information-flow maturity framework could be further refined. Interesting, Participant 4 highlighted that prevention of errors does not enhance information-flow and that enhancing information-flow is separate concept. Not surprisingly, most participants agreed that standard terminology was important for communication and understanding of terminology. However, standard terminology should be within context and should not be over constrained or complicated as per Participant 4's definition of information-flow metrics "Measure how the information-flow within the contexts". Having discussed the participants knowledge, a discussion on the participants experience with the information-flow metrics framework is explored.

6.2.3 Theme: Framework

Information-flow metrics

The metric definitions feedback illustrated that the definitions were a comprehensive list that could be easily understood. However, it was highlighted that not all the metrics would be relevant, and the type of metrics used depended on the information-flow context, and what is being measured; resulting in the relevant metrics selected for each use case. Secondly, the idea that the metrics needed an organisational and information-flow context and required real life examples to prevent misinterpretation was highlighted. For example, Participant 1 suggested "the definition Interoperable was difficult to understand". Thirdly, the metric definitions would need to be refined as some participants advised the definitions did not match the term. For example, Participant 3 suggested the "metrics definitions for Timely, Correlated and Volatility did not match the terms". Alternative suggestions for definitions were not suggested. Further, both participant 2 and 3 suggested some of the definitions overlap. For example, Participant 3 highlighted the "definitions fit for use and functionality overlap in definitions". Additionally, participant 3 advised that overlap is not necessarily a negative concept but that overlap needs to be acknowledged. This finding is not new as it was previously mentioned during the development of the information-flow metrics, first refinement of the metrics and during Desk Study 1. Lastly, participant 4 highlighted some of the definitions cannot be measured in terms of "good or bad" such as correlated and testable. Similarly, this result was captured in Desk Study 1, and the metrics that cannot be deemed good or bad were kept as they contribute as information-flow characteristics and are attributes of information-flow itself.

Case Study Worked Example feedback

All the Participants agreed the worked example was that the case study did not have sufficient information to complete the measurements for the metrics. Unsurprisingly, this aligns with Desk Study 1 results that sufficient information and correct context is required for application of the information-flow maturity framework. As a result of insufficient information, the case study was open to interpretation and many metrics were measured based on assumption rather than evidence. However, the participants in general were able to understand the information-flow within the case study on the basis the Interviewer asked each participant "did you clearly understand the worked example present. If not, what would make this clearer". As such feedback from the participants included "the instructions were clear. The worked example was clear" (Participant 10. The feedback on the use of the capability maturity framework itself was mixed. Participant 1 found the framework easy to use. However, participants 2 and 5 advised the framework was not intuitive for users. Additionally, it was suggested by participant 6 and 7 that the framework requires context, understanding of domains and organisations to develop definitions and create a case study for the framework.

The themes that emerged from the interviews were then analysed. The following section the analysis of the interview themes.

6.3 Analysis

The questions asked resulted in themes such as participant experience, definitions and feedback relating to the framework and worked case study example. The semi-structured questions and worked case study were important to validate and refine the health information-flow maturity framework.

As such, the case study worked example highlight that that metrics are about monitoring, and that detailed and top levels of information-flow context need to be amended to refine the framework. For example, social, technological, quality, safety, processes, operational, organisational resources, organisational strategy and policy, people and culture, IT business alignment factors need to be acknowledged and incorporated into the framework as part of information-flow context. Additionally, advice for an improvement guide consisted of examples of use cases, a data quality subset, automation for reporting and ensuring both technology and processes are mature.

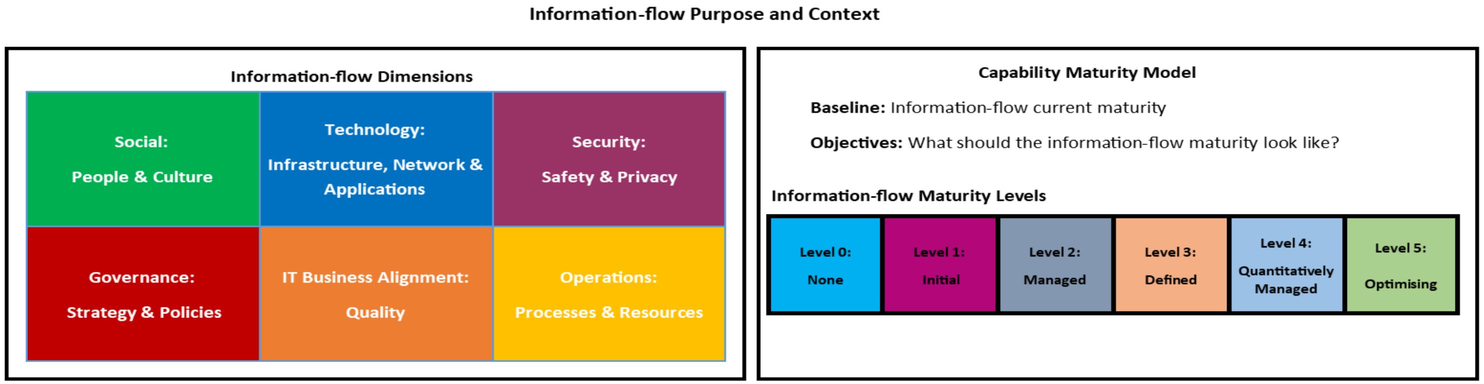
From the results, it was identified that the participants agreed that the information-flow metric definitions were a comprehensive list; however, the definitions along with the healthcare information-flow maturity framework required refinement as there was no context or examples. As such, this identified the requirement for the healthcare information-flow maturity framework to be intuitive. Ultimately, as highlighted by the participants, enhancing information-flow needs a multifaceted approach in order measure the information-flow maturity. This requires understanding of organisational and information-flow context which incorporates influencing factors such as social, technological, security, governance, IT business alignment, and operations. Additionally, once the maturity has been measured, specific interventions or methods can be implemented to achieve a higher level of maturity. In conclusion, recommendations for the healthcare information-flow maturity framework are summarised into three key aspects.

1. Understand the context of individual information-flow
2. Refine information-flow definitions
3. Create a case study with complete data

Following categorisation and analysis of the results the framework was refined.

6.3.1 Framework Refinement

The refinement of the healthcare information-flow maturity framework began with adding the information-flow dimensions to the context. Shown in *Figure 63* is the information-flow context, purpose and influencing factors which must be initially answered to form the context and environment of the individual information-flow. Following the information-flow context, determining where the information-flow maturity currently is, and the desired maturity is determined through measuring information-flow maturity levels in the healthcare information-flow maturity framework. The information-flow maturity levels are measured by assessing what characteristics of information-flow the organisation wants to measure and subsequently improve upon. The information-flow characteristics are determined based on the information-flow context and influencing factors as these factors represent what informs organisational information-flow.



Information-flow Characteristics

Coverage	Relevancy	Usability	Availability	Reliability	Security	Quality Assurance
◆ Capacity	◆ Aligned	◆ Adaptability	◆ Accessibility	◆ Accuracy	◆ Confidentiality	◆ Automobility
◆ Completeness	◆ Flexible	◆ Addressability	◆ Latency	◆ Consistency	◆ Functionality	◆ Implantability
◆ Quality	◆ Generalisability	◆ Compatible		◆ Portability		◆ Improvability
◆ Self-Descriptive	◆ Maintainability	◆ Complexity		◆ Redundancy		◆ Mutability
◆ Simplicity		◆ Effectiveness		◆ Repairability		◆ Progress
◆ Soundness		◆ Efficient		◆ Repeatability		◆ Testable
◆ Structured		◆ Interoperable		◆ Sensitivity		◆ Correlated
		◆ Interpretability		◆ Timely		◆ Evidence
		◆ Mobility		◆ Tolerance		◆ Measurability
		◆ Modularity		◆ Validity		◆ Custodian
		◆ Operability		◆ Trust		◆ Quantifiable
		◆ Performance		◆ Longevity		◆ Traceability
		◆ Safety		◆ Bias		◆ Transparency
		◆ Serviceable				◆ Consistency
		◆ Sociability				◆ Audit Capability
		◆ Understandable				◆ Coverage Quality
		◆ Value				◆ Data Lineage
		◆ Volatility				
		◆ Fit for Use				
		◆ Functionality				

Figure 63. **Information-flow context within the healthcare information-flow maturity framework.**

6.3.2 Refining metrics definitions and adding examples

From reflection on the interview data analysis, the healthcare information-flow maturity framework was refined into a professional report which included the purpose and how to use the healthcare information-flow maturity framework. Additionally, the characteristic Bias was added to Reliability and Data Lineage was added as a characteristic to Quality Assurance. Additionally, definitions for Timely, Correlated, Interoperable and Volatility were refined to match their terms. Further, examples of how to measure the characteristic and what a taxonomy “good/bad/neutral” characteristic looks like was added to the healthcare information-flow maturity framework. An example of this using the characteristics of Capacity, Completeness and Quality, are given in Table 34.

Table 36. Refined Information-flow characteristics with taxonomy added.*

Information-flow Characteristic	***Definition***	***How to Measure***	***Taxonomy: good/bad/neutral***
Capacity	The maximum amount of data that can be processed in the context.	Reporting tools/ functionality within information systems.	**Neutral**
Completeness	Information is not missing and is whole within the context.	The rate in which there is missing or incomplete data. Quality Checking.	**Good** – information is not missing within the context. If information is missing, it does not impact the information-flow outcomes. **Bad** – information is missing within the context.
Quality	Quality refers to the information quality and includes fit for purpose and use.	Quality/ error checking	**Good** – Information meets organisations quality standards. **Bad** – information does not meet organisations quality standards.

***Taxonomy:** Whether the characteristic can be measured in terms of good or bad, or if the characteristic is a neutral attribute of information-flow. This can change based on the information-flow context.

A result of the semi-structured results and analysis also resulted in the development of health information-flow maturity framework instructions. The following is the guide developed as a result of the interviews. The guide is for framework to outlines the steps, instructions, scope and requirements, and an improvement stage were developed for the healthcare information-flow framework.

1. Preliminary Questions for using the healthcare information-flow maturity framework:

To use the healthcare information-flow maturity framework and the following information is required.

Information-flow context: Understanding of how the following factors influence individual information-flow.

- Social: People & Culture
- Technology: Infrastructure, Network & Applications
- Security: Safety & Privacy
- Governance: Strategy & Policies
- IT Business Alignment: Quality
- Operations: Processes & Resources

2. Measuring Information-flow

The organisation needs to understand the purpose of measuring and improving information-flow maturity. The organisation decides what characteristics will be measured based on the organisation and information-flow context, which were identified in the preliminary questions. Once the characteristics have been selected the information-flow maturity can be measured.

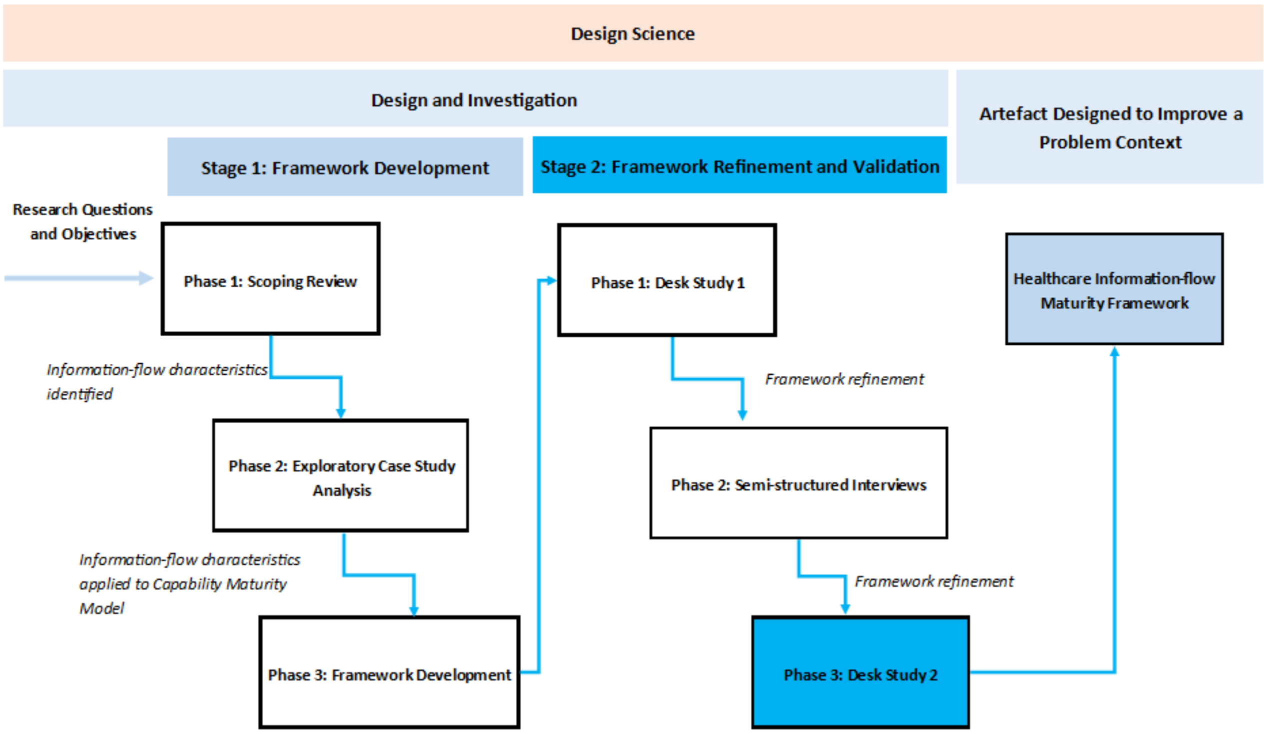
3. Improving Information-flow

Once the information-flow metrics and characteristics have been measured and a maturity level has been identified, improvement objectives can be decided. The following actions can be taken to improve information-flow maturity. Information-flow measurement with the healthcare information-flow maturity framework can begin again once improvement activities have commenced.

- Reporting automation for monitoring
- Data quality frameworks
- Actions to mature organisational dimensions
- Technology improvements
- Interventions

In this chapter, semi-structured interviews were completed to assess how experts in information-flow, metrics and process improvement would use the healthcare information-flow maturity framework. The interviews resulted in further refinement of the healthcare information-flow maturity framework and information-flow characteristics and validated the justification for a healthcare information-flow maturity framework. As a result, a guide on using the information-flow maturity framework and guide for information-flow maturity improvement was developed (Appendix G). The following chapter focusses on the Phase 3 of the framework refinement and validation, which includes Desk Study 2 to apply another real-life data set to the already refined healthcare information-flow maturity framework.

CHAPTER SEVEN: PHASE 3 OF STAGE 2 - DESK STUDY 2



The previous chapter refined the health information-flow maturity framework through feedback from experts. As a result, the healthcare information-flow maturity framework was improved by creating a user guide that included improvement opportunities improvement. This chapter details Desk Study 2 which was used to validate the health information-flow maturity frameworks' ability to identify information-flow maturity levels.

The Desk Study 2 method was a duplicate of Desk Study 1 which consisted of a combination of steps by Stickdorn et al (2018), Travis (2016), Stewart et al (1993) and Paulk (1993) and can be found in Chapter 3.5.8.

The Desk Study 2 method structure used includes the following steps:

1. Define the purpose and objectives of the research.
2. Select cases for Desk Study 2.
    a. Identify the sources for existing data.
    b. Evaluate the reliability of the sources.
        i. Who collected the data?
        ii. When was the data collected?
        iii. How was the data collected?
        iv. What was the aim of the original study?
        v. What was the methodology used?

3. Apply the cases to the framework and measure information-flow cases.
4. Analysis - complete an analysis on the framework with the cases to measure an information-flow maturity profile.
5. Identify improvements for the information-flow maturity framework.

7.1 Define the purpose and objectives of the research

As shown in Chapter 5, a validation of Desk Study 1 was completed by applying the TAPs data to the framework. Although the TAPs data allowed for Desk Study 1 validation, there were challenges using the data. As a result, several information-flow characteristics had insufficient information available to make an assessment, and thus highlighted the importance of capturing the correct information for research and reporting. Therefore, criteria were developed for Desk Study 2, based on the information missing from Desk Study 1, and several data sets were reviewed for application to the Desk Study 2. This section discusses the Desk Study 2 approach, which includes criteria and the several data sources that were assessed for suitability for the Desk Study 2.

7.2 Select cases for Desk Study 2

The Desk Study 1 data set (TAPS) included incident data on what happened, to whom it happened and the outcome. To an extent, the TAPS data set was suitable for application to the information-flow framework on the basis that identifiable information-flow characteristics could be measured and led to further refinement of both the framework and individual information-flow characteristics. However, there were challenges in using the TAPS data set. For example, the TAPS data did not contain in-depth information or information-flow contexts or dimensions such as the processes, people or networks, and as such many of the information-flow metrics characteristics could not be identified in the TAPS cases. As a result, those information-flow characteristics could not be measured. Therefore, to ensure the framework was validated with rigour, the data set Desk Study 2 needed to include a variety of information-flow contexts. Additionally, as Desk Study 2 was secondary research, the data set needed to be freely available, open source, ideally within the last five years (recent), and de-identified.

Shown in *Figure 64* are Wiele’s (2016) reporting app Institute of Medicine (IOM) guideline used for incident reporting for reporting app compliance. The reporting app IOM guidelines were reviewed, and aspects aligned with the information missing from TAPS cases for the initial validation. As such, the following data criteria requirements were developed.

Desk Study 2 Data Criteria Requirements:

- Description of the event
- In what part of the information-flow did the error occur?
- Who (roles and functions) were involved?
- Why did the event occur?
- What was the outcome of the event?
- Were there any interventions?

IOM Guideline	Reporting Interface Prompts	Report Records Contain
Discovery		
1. Who discovered/reported the event? (roles, not names)	Yes	Yes
2. How?	Yes	Yes
The Event Itself		
3. What happened? (Type of event)	Yes	Yes
4.Where in the care process was it discovered/did it occur?	Yes	Yes
5. When did the event occur?	Yes	Yes
6. Who was involved? (functions, not names)	Yes	Yes
7. Why did it occur? (Dominant cause based on preliminary analysis)	Yes	Yes
8. Risk assessment:		
8a. Severity	Yes	Yes
8b. Preventability	No	No
8c. Likelihood of recurrence	No	No
9. Narrative of the event, including contributing factors.	Yes	Yes
Ancillary Information		
10. Product information (blood, devices, drugs, etc. that were involved).	[1]	[1]
11. Patient information (age, gender, ethnicity, diagnosis, procedures, and comorbid conditions)	[2]	[2]
Detailed Causal Analysis (if deemed necessary)		
12. Technical, organizational, and human factors associated with the Eindhoven model (RCA).	NA	[3]
13. Recovery factors that can occur at each point for near misses.	NA	No
14. Corrective actions that were taken to recover from the incident.	NA	No
15. Patient outcome as a result of the corrective actions taken.	NA	No
16. Whether a similar case has recently been investigated.	NA	Yes
Lessons Learned	NA	No

Figure 64. **Reporting Guidelines taken from Wiele (2016, p. 29).**

A search for data sets that were medication error related and that would fit the Desk Study 2 criteria was undertaken. However, there were a few challenges in finding data sets to review as there were not many freely available data sets for secondary research. Additionally, the medication reports found referred to adverse event reports and as such information-flow failures were not specifically reported. Further, these adverse event reports did not contain specific information that would fit the search Desk Study 2 criteria, such as what happened, and the clinical role involved. It was also found that some of the databased had large, unlinked information, and as such could not be used. Listed in Table 36 are the data sets that were reviewed, the justification for Desk Study 2 use, and why or why not they were chosen.

Table 37. Potential Desk Study 2 data sets.

Data Source	***Justification for inclusion in Desk Study 2***	***Chosen***	***Why it was/ was not chosen***
Data used in the study by Maurer, C. (2013). The measurement of information flow efficiency in supply chain management	This study tested scaled and metrics through a case study. That case study could have been applied to the framework.	No	The data was previously used in a research project.
Redley (2012). Reported medication errors for after introducing an electronic medication management system	A retrospective analysis of 359 incident reports drawn from the period of the 1st of May 2005 to the 30th April 2006, across two hospital sites of a single not-for-profit private health service located in Melbourne. These incident reports could be used in the framework.	No	Was not chosen due to ethics challenges.
Vreede, mgrath and Clifford 2019. Review of medication errors that are new or likely to occur more frequently with electronic medication management	8 Victorian hospitals with eMMs participated in a retrospective audit of reported medication incidents from their incident reporting databases between May and July 2014.	No	Was not chosen due to ethics challenges.
Carvalho, rocha and Abreu (2017). HISMM – hospital information system maturity model – a synthesis	Survey carried out via questionnaire to 46 hospital information system experts, interviews with hospital information system managers.	No	Was not chosen due to ethics challenges.
Adverse Event Reporting System (AERS) (U.S Food & Drug Administration, 2023)	Shows adverse events for medications. Freely available and deidentified data.	No	Does not specify what happened. No context or descriptions.
Database of Adverse Event Notifications (DAEN) (Department of Health and Aged Care, 2023)	Shows adverse events for medications. Freely available and deidentified data.	No	Does not specify what happened. No context or descriptions.
Healthcare Cost and Utilization Project (AHRQ, 2022)	Data is available. Hospital encounters.	No	Cost to purchase data. Unsure what the data looks like. Data would need to be manually searched. The Researcher would need to learn how to

Data Source	Justification for inclusion in Desk Study 2	Chosen	Why it was/ was not chosen
			complete data base searches. Not adverse event specific.
Medical Information Mart for Intensive Care (MIMIC 3, 2023)	Data is available. Database has encounters.	No	Data had separate rows and columns. No way of linking and identifying information-flow errors.
Network of Patient Safety Databases (NPSD) (AHRQ, 2022)	Feely available and no cost. Includes extent of harm and event type.	No	Does not show individual reports. Just overall. Unable to get individual as it is not available.
Datix Clinical Incident Management System (CIMS) (Department of Health, 2022)	Incident reports.	No	Was not chosen due to ethics challenges.
Your safety in our hands in hospital (Department of Health, (2012-2021)	Incident reports of CIMS.	Yes	Detailed incident reports that resulted in a coronial investigation. Freely available, open source and de-identified.

Initially, data sets such as DEAN and the AERS were identified as suitable on the basis that they showed sufficient adverse events for medications. However, on further review, the data did not show what caused the error and the outcome. Therefore, identification of where in information-flow this error occurred, and subsequent information-flow measurement would not be possible. In comparison, the NPSD had a freely available dashboard for adverse patient events. However, this data was inappropriate for Desk Study 2 as individual reports could not be accessed. The MIMIC3 had a freely available database on the whole patient journey. However, it did not specify errors in the journey; therefore, the data would have needed to be individually filtered and analysed to get patient journeys. Another issue with the MIMIC3 data was that it was only from 2012, with the preference being more recent data for Desk Study 2.

The 'Your Safety in our hands in hospital' report consisted of a yearly report on patient safety surveillance in WA hospitals, published from 2012 to 2020. Incidents that are detailed in this report contain incident reports from the CIMS and other databases. An initial sense check identified that the incidents listed in detail in the 'Your Safety in our hands in hospital' report matched the data criteria required for the Desk Study 2.

Within the "Your Safety in our hands in hospital" Department of Health (2012-2021) report the following data qualities were mentioned.

- Institutional environment
- Relevance
- Timeliness

- Accuracy
- Coherence
- Accessibility
- Interpretability

These data qualities highlighted in the "Your Safety in our hands in hospital' report were reviewed and compared to the current information-flow maturity framework metric categories and information-flow characteristics. As shown in Table 37, the data qualities reviewed did not need to be added to the current information-flow on the basis that they were already part of the current information-flow metrics.

Table 38. Data qualities in Your Safety in our hands in hospital report.

Your Safety in our hands in hospital	***How they apply to the current framework***
Institutional Environment	Forms the information-flow context and refers to the information-flow dimensions.
Relevance	Captured in metric Relevancy.
Timeliness	An information-flow characteristic of the metric Reliability.
Accuracy	An information-flow characteristic of the metric Reliability.
Coherence	Not specifically listed in the current framework. However, characteristics of Coherence are found in the characteristic understandable which is part of the metric Usability, and consistency which forms the Reliability metric.
Accessibility	An information-flow characteristic that forms the Availability metric.
Interpretability	An information-flow characteristic which forms the Usability metric.

Additionally, the incidents had already been analysed with information aggregated and de-identified. Therefore, these incidents were chosen as they fit the search criteria for Desk Study 2. Subsequently, each published year was reviewed, and incidents were reviewed and selected based on the Desk Study 2 Data Criteria Requirements. Composite cases and incidents that did not meet the Desk Study 2 Data Criteria Requirements were removed, and as such resulted in 12 report case studies were identified as suitable.

Report Case Study Number	Description
Report 1 Case Study	Mr A (November 2011) Mr A was a 27 year old male who died on 12 October 2007. The deceased suffered from chronic paranoid schizophrenia, complicated by treatment resistance, non-compliance with medication and use of illicit substances and alcohol. At the time of his death, he was admitted as an involuntary patient at Graylands Hospital within the meaning of the Mental Health Act 1996 and was being transferred to a secure ward. While issues were raised at the inquest in respect of whether the restraint process and methods used were optimal, the Coroner noted that, as a result of his serious mental illness, the deceased was behaving in a manner which required some form of restraint. The Coroner noted that the death was an unexpected result and was unintended on the part of those involved in restraining the deceased. The Coroner made five recommendations relating to the monitoring of drug and alcohol usage among patients by means of searching; implementing restrictions for access to alcohol and illicit substances for involuntary patients on open wards; and the review of restraint procedures and training programs. It was determined that the cause of death was consistent with cardiac arrhythmia during restraint. The Coroner found that death occurred by way of misadventure.
Report 2 Case Study	Mr B (January 2012) Mr B was a 38 year old male who died on 27 April 2008. At the time of his death he was incarcerated at Acacia Prison. The deceased had a known history of polysubstance abuse, self harm and paranoid schizophrenia with fixed delusions. He was found in his cell with deep wounds to his arms during a cell check. Resuscitation efforts failed to revive him. In the time leading up to his death, the deceased was undergoing mental health treatment but compliance was intermittent. The deceased seemed to respond well to treatment whilst on medication. Periods of medication non-compliance coincided with a decline in mental health which occasionally warranted his admission to the Frankland Centre at Graylands. He was non-compliant with his medication in the 12 days leading up to his death. The Deputy State Coroner made four recommendations relating to the facilities and treatment for incarcerated persons with mental illness. Death occurred as a result of exsanguination due to penetration of arm veins. The Deputy State Coroner found that death arose by way of suicide.
Report 3 Case Study	Ms T (March 2012) Ms T was a 63 year old female who died on 14 February 2006 at St John of God Hospital Bunbury. The deceased had been diagnosed with Acute Lymphoblastic Leukaemia (ALL) in early 2004 however, this was revised to the more aggressive and non-curable Prolymphocytic Leukaemia (PLL) in June 2004. The deceased was undergoing treatment at Fremantle Hospital but resided in Bunbury. The deceased was admitted to Bunbury Regional Hospital with a diagnosis of neutropaenic sepsis and died two days later. 51 The Deputy State Coroner noted that during the course of the evidence it became apparent that there were two miscommunications which, when taken together, contributed to the perception of a catastrophic outcome for the deceased. These miscommunications were related to patient education about diagnosis, and obtainability of blood products outside the metropolitan area. The Coroner made seven recommendations relating to strategies to raise patients' awareness of their diagnosis and treatment protocols, strategies for the communication of diagnoses to other health practitioners and tools for the ordering of blood products for remote areas. A post mortem was not carried out, however the Coroner did not dispute the cause of death recorded on the death certificate and found that death arose by way of natural causes.
Report 4 Case Study	Mr E (March 2012) Mr E was a 25 year old man with an approximate eight year history of illicit drug use and consequent mental health issues, which had deteriorated in the preceding six months prior to death. The deceased presented to Bentley Mental Health Unit the day of his death (31 July 2007) but he left the hospital before being assessed by the psychiatrist. The Armadale Community Emergency Response Team (CERT) and the Police were notified. The Police attended the residence that evening for a welfare check. He was found deceased by his father later that same evening. The Coroner made seven recommendations relating to the opportunities for further training and development for triage duties in mental health facilities, availability of security staff, defining set criteria and responsibilities for responding to a mental health crisis

Report Case Study Number	Description
	and communication of policies to staff. The Coroner determined that death arose by way of suicide. Death was caused by ligature compression of the neck.
Report 5 Case Study	Miss L (April 2012) Miss L was born prematurely at 35 weeks gestation at Dalwallinu Hospital in the early hours of 20 March 2008. Transfer to an obstetric hospital was attempted but did not occur for a number of reasons. There were no apparent complications from the emergency delivery. Arrangements were made to transfer mother and baby to Northam Hospital, the nearest maternity facility. Observations were undertaken once whilst in the care of Dalwallinu Hospital, which indicated an elevated heart rate and high temperature. These observations were overlooked and no follow up observations were performed. Mother and baby were transferred via volunteer ambulance officers to Northam just after midday on 20 March 2008, where Miss L was found unresponsive upon arrival at Northam two hours later. Despite urgent treatment Miss L died that afternoon. The Coroner made four recommendations in relation to the auditing of observations and medical notes, raising awareness of the Newborn Emergency Transport Service (NETS) and the induction and ongoing support of visiting medical practitioners. Miss L died as a result of perinatal Pneumonia in association with untreated meconium aspiration. The Coroner found that death arose by way of misadventure.
Report 6 Case Study	Ms S (August 2012) Ms S was a 62 year old female with a history of depression and intermittent violent behaviour, who on the day of her death had been involved in a heated domestic dispute with her housemate. The police and ambulance service were called to the house and Ms S was taken to Albany Regional Hospital. Ms S was not able to receive a psychiatric review and declined to be admitted to hospital but agreed to attend a session with her psychologist an hour later, which she kept. On returning home, Ms S entered into a further argument with her housemate which deteriorated into physical violence. Ms S left and drove to a cliff where she proceeded to jump to her death. A note was found in her car indicating the disposal of her property. The Coroner found that death arose from suicide and made recommendations relating to implementation of written protocols around the discharge of patients from ED who required psychiatric review. The Coroner stated that a psychiatrist should attend the ED for patient review (if requested to do so), in the event that a plan cannot be agreed between the treating doctor and psychiatrist.
Report 7 Case Study	Mr R (October 2012) Mr R was a 15 year old male who died on 17 November 2012 as a result of cerebral ischaemia due to a blocked ventricular peritoneal (VP) shunt and obstructive hydrocephalus. Mr R was born with congenital abnormalities which resulted in severe intellectual disability, cerebral palsy and epilepsy. Mr R's parents, concerned about him becoming unwell, took him to Fremantle Hospital where his VP shunt was examined and found to be "compressible but tense." On the afternoon following discharge two days later, Mr R had a seizure something that had not happened in some years. His parents took him to Princess Margaret Hospital (PMH) and requested a CT scan to enable assessment of his VP shunt. His VP shunt was examined but a CT scan was deemed to be unnecessary. The patient was discharged. The following day, while still unwell and vomiting, Mr R was taken back to Fremantle Hospital. Another request by the family for a "CT scan was refused." Mr R was administered morphine due to increasing pain, which resulted in him collapsing. Mr R was then intubated and transferred to PMH. It was then identified that the VP shunt was blocked and the patient underwent surgery to lower intracranial pressure. After the surgery, it was deemed that Mr R's "condition was such that he was unable to survive without medical technology." Once life support was removed Mr R passed away. The State Coroner recorded that death arose by way of misadventure and made several recommendations to the Director General of Health which related to the development of clinical guidelines and consumer information about VP shunts, policy for the retention and accessibility of cranial CT scans, timely review of CT scans by those with the appropriate expertise and

Report Case Study Number	Description
	raising awareness of this case among physicians to highlight the need to exercise caution when treating paediatric patients with VP shunts.
Report 8 Case Study	Ms K (December 2012) Ms K was a 38 year old female who died on 10 November 2012, as a result of bilateral pulmonary thromboembolism. Ms K had a complex medical history and had recently been diagnosed with an underlying pro-thrombotic disorder at Bunbury Regional Hospital. However, her treating teams at SCGH, where Ms K had undergone surgery for the removal of a pancreatic tumour, were not aware of this. Ms K's recovery was complicated and she was hospitalised for several months which resulted in her transfer to the SCGH Rehabilitation Unit where she continued on anti-coagulation therapy. On day five of her stay Ms K was found collapsed and unresponsive in bed and transferred to Royal Perth Hospital (RPH), however resuscitation was not successful. The Coroner determined that death arose by way of natural causes. The Coroner recommended that SCGH consider developing a service to provide specialist advice in relation to patients with increased risk of deep vein thrombosis, and pulmonary embolism.
Report 9 Case Study	Ms A (January 2013) Ms A was a 60 year old female who died on 29 October 2010 as a result of multi-organ failure following haemorrhage from penetration of her left femoral artery during a coronary angiography procedure. After being discharged, Ms A complained of increasing pain and bruising over the next three days and presented to her GP for review. Extensive bruising and haematoma and significant pain were noted and Ms A was prescribed analgesia and antibiotics and was sent home. Ms A's condition continued to deteriorate and two days later she was taken by ambulance to Armadale Kelmscott Memorial Hospital (AKMH) where she had a cardiac arrest secondary to hypovolaemic shock. Resuscitation was carried out at AKMH and Ms A was transferred to RPH where she underwent surgery to control bleeding from the angiogram puncture site. Several further surgeries and aggressive treatments were undertaken but, she developed ongoing complications including extensive ischaemic necrosis of the bowel, respiratory failure and renal failure. She died from these complications seven days after her procedure. The Coroner stated "this death was unnecessary and could have been avoided had the deceased contacted her treating experts… or had she returned to [hospital]." The State Coroner recommended that discharge summaries be provided by all public and private patients having angiograms to document the extent of any haematoma, bleeding, pain level and medications at the time of discharge and that a discharge summary should be provided to the patient's general practitioner.
Report 10 Case Study	Ms L (May 2013) Ms L was a 55 year old female who underwent a successful gastric banding procedure in February 2008, which resulted in weight reduction. In November 2009 Ms L was feeling unwell and consulted her GP complaining of "ear ache and vomiting and was adamant that her lap band was not to blame." Ms L was advised to go to hospital but declined however, she did agree to attend if her condition did not improve. Ms L was found the following day in bed and unresponsive. Paramedics called to the home could not resuscitate the deceased. The Deputy Coroner found that death resulted from aspiration of gastric contents in association with gastric necrosis in a lady with a lap band device and that death arose by way of misadventure. The Coroner also recommended that education programs be developed to inform junior doctors and GPs about the potential risks, side effects such as excessive vomiting and the long term management associated with bariatric surgery.
Report 11 Case Study	Ms F (September 2013) Ms F was a 27-year-old woman who was a member of staff at a metropolitan teaching hospital. Whilst on a shift at work in December 2009, she locked herself in the staff toilet and injected a fatal quantity of fentanyl. Colleagues discovered her shortly afterward, unresponsive; she could not be resuscitated. The cause of death was opiate toxicity and the coroner concluded that the manner of death was by accident. The Coroner found it most likely that Ms F had removed some of the fentanyl solution from the patient controlled analgesia device in a patient's room. Fentanyl is a controlled drug

Report Case Study Number	Description
	under Schedule 8 of the Poisons Act 1964. The Coroner commented on a gap in security that exists at the point of administration; however found that there was insufficient evidence to allow him to recommend a step that would be effective and economically feasible to deal with that gap.
Report 12 Case Study	Mrs W (September 2013) Mrs W suffered from ill-health that limited her mobility and rendered her housebound. In spite of a poor prognosis, cataract surgery was scheduled to improve her quality of life. She was known to have an allergy to sulphonamides which was documented on several of her notes in the medical record, and she wore a red alert ID band to draw attention to it. The surgeon had asked about allergies in the pre-surgery consultation; however, this did not include a discussion about sulphas as these were not intended to be used. The planned trabeculectomy to lower Mrs W's intraocular pressure was no longer a viable option and medication was prescribed instead. The surgeon was unaware of the deceased's allergy and the significance of the red ID band. Mrs W was resuscitated following her collapse within 10-15 minutes of taking the sulphonamide medication; she initially improved but then suffered a cardiac arrest and died. The coroner made recommendations relating to raising awareness of the importance of documenting the exact nature of allergies, and existing protocols used to communicate that the patient has an allergy (such as the red ID band).

The incidents selected were detailed and included lessons learned as they had been exposed in a coronial investigation. The selected incidents were applied to the information-flow maturity framework until saturation, which is to get the same result consistently. As such the process went through a maturity review to keep getting the same answer consistently, which resulted in a valid answer.

7.3 Apply the cases to the framework and measure information-flow cases

The 12 report case studies that detail incident cases that resulted in a patient's death and a coronial investigation. As such, the 12 report cases were used on the information-flow calculator and the cases were used on the information-flow calculator and maturity level was identified through assessing if any of the information-flow characteristics were present, and then selecting the maturity rating from Level 0 to Level 5 (Level 0 meaning non-present and Level 5 meaning optimised).

The following is excerpt of a report case study followed by the measurement results (Table 38). Appendix F contains the full report case studies and the detailed Desk Study 2 results. It should be noted that even without all information-flow characteristics presents, measurement from the information-flow calculator tool can be calculated. This is due to each metric category containing several information-flow characteristics that can be measured from level 0 to level 5.

Report 1 case study

Mr A (November 2011) Mr A was a 27 year old male who died on 12 October 2007. The deceased suffered from chronic paranoid schizophrenia, complicated by treatment resistance, non-compliance with medication and use of illicit substances and alcohol. At the time of his death, he was admitted as an involuntary patient at Graylands Hospital within the meaning of the Mental Health Act 1996 and was being transferred to a secure ward. While issues were raised at the inquest in respect of whether the restraint process and methods used were optimal, the Coroner noted that, as a result of his serious mental illness, the deceased was behaving in a manner which required some form of restraint. The Coroner noted that the death was an unexpected result and was unintended on the part of those involved in restraining the deceased. The Coroner made five recommendations relating to the monitoring of drug and alcohol usage among patients by means of searching; implementing restrictions for access to alcohol and illicit substances for involuntary patients on open wards; and the review of restraint procedures and training programs. It was determined that the cause of death was consistent with cardiac arrhythmia during restraint. The Coroner found that death occurred by way of misadventure.

Table 39. Report 1 case study results.

Metric Category	***Metric Characteristic***	***Metric Level***	***Justification***
Coverage	Capacity	Level 2	
	Completeness	Level 1	
	Quality	Level 3	
	Self-Descriptive	Level 3	
	Simplicity	Level 2	
	Soundness	Not Measurable	Not Relevant
	Structured	Level 4	
Overall Coverage Maturity Level		Level 3	
Relevancy	Aligned	Level 0	
	Flexible	Level 1	
	Generalisability	Level 2	
	Maintainability	Not Measurable	Not Relevant
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 3	
	Addressability	Level 1	
	Compatible	Level 1	
	Complexity	Not Measurable	Insufficient Information
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 2	
	Interpretability	Level 2	
	Mobility	Level 0	
	Modularity	Level 1	
	Operability	Level 2	
	Performance	Level 1	
	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 2	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 2	
	Latency	Level 3	

Overall Availability Maturity Level		Level 2	
Reliability	Accuracy	Level 2	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 0	
	Repeatability	Not Measurable	Insufficient Information
	Sensitivity	Level 1	
	Timely	Level 1	
	Tolerance	Level 0	
	Validity	Level 2	
	Trust	Level 1	
	Longevity	Level 1	
	Bias	Level 1	
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 2	
	Formality	Level 2	
Overall Security Maturity Level		Level 2	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 2	
	Correlated	Level 1	
	Evidence	Level 3	
	Measurability	Level 3	
	Custodian	Level 3	
	Quantifable	Level 3	
	Traceability	Level 4	
	Transparency	Level 5	
	Consistency	Level 1	
	Audit Capability	Level 5	
	Coverage Quality	Level 3	
	Data Lineage	Level 5	
Overall Quality Assurance (QA) Maturity Level		Level 3	

Table 39 shows the maturity level results of report case study after analysing and processing using the information-flow maturity framework. The cases selected were used to test the framework through identifying what information-flow characteristic was present in the case. Interestingly, all incident information-flow metric categories could be measured and assigned a maturity level rating. There were no metric categories with ‘not measurable or insufficient information’. However, within incident cases, there were information-flow characteristics that could not be measured due to being not relevant or acted as an influencing factor. Overall, the highest maturity rating was recorded as level 3, which was found in the metric category’s Coverage and Quality Assurance. In contrast the category Quality Assurance had the highest incident cases with the highest maturity ratings. This was due to the sufficient detail in the incident reports. Although there was sufficient information-flow context, many of the metric categories still measured level 0. For example, case study 2's Usability category was measured at level 0 on the basis that there was no evidence of usability. The metric categories Reliability, Relevancy and Usability had the most level 0 ratings. While the average maturity rating was a level 1, this was not a surprise; these were report case studies in which information-flow failure resulted in an adverse patient outcome.

Table 40. Maturity levels of each incident report.

Case Study Number	***Coverage Level***	***Relevancy Level***	***Usability (Clinical Outcomes) Level***	***Availability Level***	***Reliability Level***	***Security Level***	***Quality Assurance Level***
1	Level 3	Level 1	Level 1	Level 2	Level 1	Level 2	Level 3
2	Level 2	Level 1	Level 0	Level 1	Level 1	Level 1	Level 3
3	Level 2	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
4	Level 1	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
5	Level 1	Level 0	Level 0	Level 1	Level 0	Level 1	Level 1
6	Level 2	Level 1	Level 1	Level 2	Level 1	Level 1	Level 2
7	Level 1	Level 1	Level 1	Level 1	Level 1	Level 0	Level 2
8	Level 1	Level 0	Level 1	Level 1	Level 1	Level 1	Level 1
9	Level 0	Level 0	Level 0	Level 0	Level 0	Level 1	Level 1
10	Level 1	Level 1	Level 1	Level 0	Level 0	Level 1	Level 2
11	Level 0	Level 0	Level 0	Level 1	Level 0	Level 0	Level 1
12	Level 1	Level 1	Level 1	Level 1	Level 0	Level 1	Level 1

7.4 Analysis

All the report case studies resulted from a death of a patient. Although the report case studies resulted in poor patient outcomes, they contained adequate information for Desk Study 2. This was because they had resulted in a coronial investigation requiring detailed information about the event. As such, each incident resulted in an investigation and recommendations. This resulted in the Quality Assurance metric, such as audit capability and transparency, measuring a high maturity level (level 2 to level 4 were measured). However, although the information-flow context was sufficient, the information-flow failure had an impact on the patient's quality of life or directly resulted in the patient's death. Therefore, the other information-flow metrics characteristics were shown to be rated level 0 to level 2, depending on the incident and the characteristic that was being measured. It should be noted that the low ratings do not reflect the amount of information but the maturity rating itself.

Additionally, Desk Study 2 highlighted that as the information-flow maturity framework is a subjective process, there were two different parts of the framework on measuring the maturity ratings of the incidents. The first perspective assessed the information-flow failure events and rated the information-flow characteristics based on the information-flow failure and the result of the failure. While the second perspective assessed if the incident had sufficient information. These two perspectives were evaluated, and as the intention of the information-flow maturity framework was to improve the information-flow, the information-flow characteristics would be based on the information-flow context, which included the information-flow failure events and outcomes of the events which impacted patient safety or care. This highlighted the need to emphasise identifying the objectives of the information-flow maturity framework assessment in the instructions guide.

What information-flow attributes could not be measured?

Shown in Table 40 are the report case studies and the information-flow characteristics that could not be measured. It should be noted that each case was unique and that a characteristic not measurable in one case could be measured in another case. For example, in Report Case Study 1, soundness and maintainability were measured as not measurable as they were not relevant to the information-flow context. While complexity in case study 1 did not contain sufficient information for measurement. Interestingly, bias appeared as a characteristic that could not be formally measured as it was an influencing factor. This demonstrated the importance of the information-flow context and the objective of the measuring the information-flow. Further, as shown in Table 38, there were five incident cases that had information-flow characteristics that could not be measured.

Table 41. Characteristics that could not be measured.

Incident Case Study Number	***Information-flow Attribute***	***Reason it could not be measured***
Report Case Study 1	• Soundness • Maintainability • Complexity • Repeatability	• Not relevant • Not relevant • Insufficient information • Insufficient information
Report Case Study 2	• Interoperable • Repeatability • Bias • Mutability	• Insufficient information • Insufficient information • Influencing factor • Insufficient information
Report Case Study 3	• Generalisability • Bias • Correlated	• Insufficient information • Influencing factor • Insufficient information
Report Case Study 6	• Bias	• Influencing factor
Report Case Study 11	• Generalisability • Interoperable • Understandable • Repeatability • Bias	• Insufficient information • Not relevant • Insufficient information • Insufficient information • Influencing factor

The results of Desk Study 2 confirmed the characteristics from Desk Study 1, and as a result of the CIMS incident case application, the information-flow maturity framework was validated. Further, Desk Study 2 resulted in further refinement of the information-flow maturity framework.

7.5 Identify improvements for the information-flow maturity framework

Information-flow Maturity Framework Refinement

An important finding of Desk Study 2 was that not all information-flow characteristics are necessary for measuring maturity. This concept was previously highlighted in the semi-structured interviews and in Desk Study 1. Therefore, within the information-flow maturity framework guide, the instructions were revised to ensure that the information-flow maturity framework remained an assessment tool. Therefore, it would be up to the user to decide what information-flow characteristics are needed. For example, the characteristic Bias is not necessary for all information-flow contexts as it would be considered an influencing factor or not measurable. Additionally, the previous Hermon model was added as a tool to assist with mapping information-flow and identifying information-flow failure.

Additionally, the required and optional characteristics were added to enable the framework to be usable. This approach required the incident cases to be reviewed in terms of what could be measured and what could not be measured. This revealed that characteristics could be measured when there was information-flow context available. Information-flow characteristics that could not be measured were due to insufficient information, not measurable because they were influencing factors or not relevant. Characteristics marked as not measurable were considered optional characteristics as they have no impact on the overall maturity calculation. As shown in Table 41, there are required characteristics and optional characteristics.

Table 42. Required and optional information-flow characteristics.

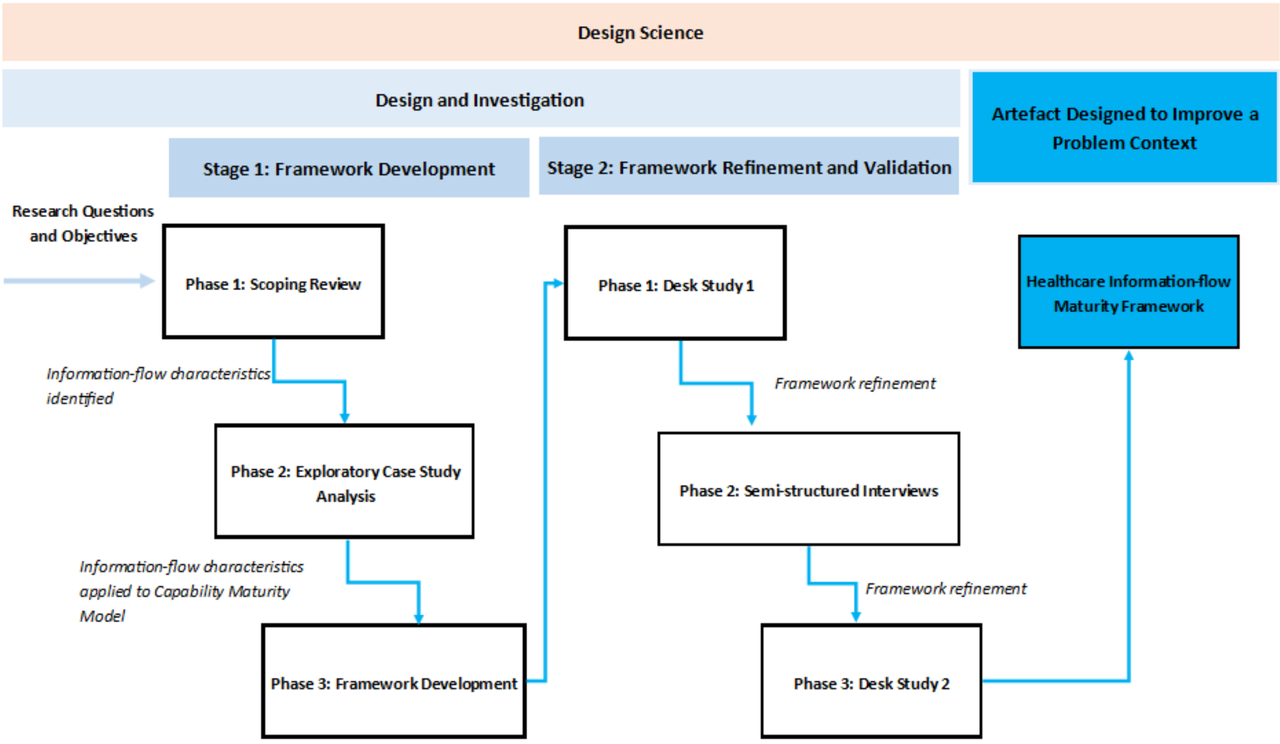
Metric Category	***Required Characteristic***	***Optional Characteristic***
Coverage	• Completeness • Quality • Self-Descriptive • Capacity	• Simplicity • Soundness • Structured
Relevancy	• Flexible • Aligned	• Generalisability • Maintainability
Usability	• Adaptability • Compatibility • Effectiveness • Interpretability • Mobility • Operability • Performance • Safety • Serviceable • Understandable • Value • Votality • Fit for Use • Functionality	• Addressability • Complexity • Interoperable • Modularity
Availability	• Accessibility • Latency	• N/A
Reliability	• Accuracy • Consistency • Portability • Redundancy • Repairability • Sensitivity • Timely • Tolerance • Validity	• Repeatability • Bias

	• Trust • Longevity	
Security	• Confidentiality • Formality	• N/A
Quality Assurance	• Improvability • Progress • Testable • Evidence • Measurability • Custodian • Quantifiable • Traceability • Transparency • Consistency • Audit Capability • Coverage Quality • Data Lineage	• Automobility • Implantability • Mutability • Correlated

This chapter described the validation of the information-flow maturity framework through Desk Study 2. Search criteria were developed from Desk Study 1 TAPS data gaps. Data from 'Your Safety in our hands in hospital' report contained incident cases that had resulted in patient death and a coronial investigation, and these report case studies were identified as suitable for Desk Study 2 as they fit the search criteria and had enough information to complete against the information-flow maturity framework. Subsequently, 12 incident cases were measured using the information-flow maturity framework and information-flow characteristics were further refined. This resulted in the refinement of the healthcare information-flow maturity framework instructions and overall framework. A key finding of Desk Study 2 was that not all information-flow characteristics are required to measure information-flow maturity. This led to the establishment of required and optional information-flow characteristics for each of the information-flow metric categories, and the final validation of the information-flow maturity framework for healthcare.

CHAPTER EIGHT: DISCUSSION

The final healthcare information-flow maturity framework was developed through the research phases in Stage 1 and Stage 2. This chapter focusses on the post-design and investigation step of the design science methodology and discusses the healthcare information-flow maturity framework and other artefacts of the research resulting from Stage 1 - framework development and Stage 2 - framework refinement and validation.



The research outcomes were a healthcare information-flow maturity framework and an updated definition of information flow:

8.1 Updated Information-flow Definition

The following updated definition of information-flow was derived from the aggregation of the literature review, and results of the case study analysis and semi structure interviews.

> ***Information-flow is how information is communicated from one place to another.*** *This could be from system to system, system to person, person to person or person to system, and is defined by the information-flow characteristics coverage, relevancy, usability, availability, reliability, security and quality assurance*.

This updated definition of information-flow requires also understanding of information-flow dimensions such as the social, technology, security, governance, IT business alignment and operational context in which information-flow exists. Previous information-flow definitions in the literature did not provide a succinct definition of information-flow that defined it by characteristics and included information-flow context. An updated information-flow definition was required to include systems, people, and characteristics of information-flow. This revised definition highlights the fundamental characteristics needed for information-flow, which are a result of the research scoping review, case study analysis and semi-structured interviews. As such, this definition defines the characteristics of information-flow and is an updated and unique definition that is founded on information systems research. Another important aspect of this information-flow definition is that it takes into consideration the overall information-flow context such as information-flow dimensions.

8.2 Healthcare Information-flow Maturity Framework

The primary outcome of this research was the healthcare information-flow maturity framework which enables the ability to measure information-flow characteristics, and as such can be used to measure information-flow maturity in order inform improvement activities. This framework is designed to measure individual information-flow maturity levels and identify recommendations for improving individual information-flows. Although this framework was originally developed for use in healthcare, with medication and pathology information-flow used as examples, it has application across multiple information-flow environments. This information-flow maturity framework is a metric assessment framework and is not prescriptive.

The five artefacts comprising the healthcare information-flow maturity framework (see Appendix G) are:

Artefact 1 - Set of instructions on how to use the framework

Artefact 2 - Information-flow Capability Maturity Matrix

Artefact 3 - Supporting explanation of each information-flow characteristics

Artefact 4 - Calculator tool for the maturity score

Artefact 5 - Suggested Improvement Table

Steps for using the Healthcare Information-flow Maturity Framework

1. Decide → **2. Select** → **3. Measure** → **4. Use** → **5. Reflect**

#	Steps	Description
1	**Decide**	Decide what information-flow (or process) is of concern.
2	**Select**	Select the characteristics that should be measured.
3	**Measure**	Measure selected characteristics against the Capability Maturity Matrix.
4	**Use**	Use the Calculator Tool to obtain an overall maturity score.
5	**Reflect**	Reflect on what could be improved and how using the suggestions table can be used to capture and track an action plan.

The following section discusses each of the steps in the healthcare information-flow maturity framework.

8.2.1 Decide what information-flow (or process) is of concern

The first step in using the healthcare information-flow maturity framework is to decide what information-flow or process is of concern and requires measurement. This is done through identifying the information-flow context and is dependent on the organisation's information-flow and key areas of concern that require information-flow maturity measurement and improvement. Individual information-flows found in the information-flow dimensions can be selected if information-flow or processes of concern are unknown.

The information-flow dimensions include the following areas:

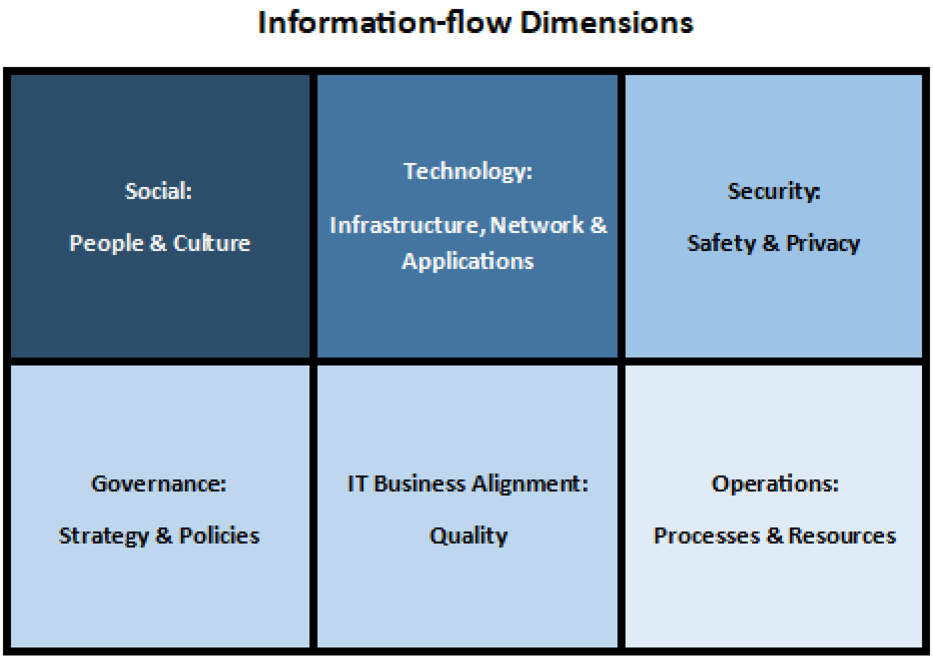


Figure 65. Information-flow Dimensions identified in this research.

The information-flow dimensions are important for understanding the healthcare information-flow maturity framework. Starting with the information-flow purpose and context, it is necessary to understand the context that the information-flow resides in. Factors that impact individual information-flows include the information-flow dimensions, these are social, technology, security, governance, IT business alignment and operations. The capability maturity model has been designed to measure information-flow within this contextual matrix. The next step is to select the information-flow characteristics appropriate to measure the selected information-flow process.

8.2.2 Select the characteristics that should be measured.

The next step is to decide what information-flow metrics and characteristics to measure. The Capability Maturity Matrix (Artefact 2) Is used to select the characteristics, as it shows the information-flow metrics that can be measured. The Capability Maturity Matrix includes metrics such as coverage, relevancy, usability, availability, reliability, security, and quality assurance. Each metric has six maturity levels. These levels range from Level 0 to Level 5, with Level 0 referring to no information-flow characteristics present and Level 5 referring to Information-flow characteristics optimised.

- Level 0: No information-flow maturity present
- Level 1: Initial information-flow maturity present
- Level 2: Managed information-flow maturity present
- Level 3: Defined information-flow maturity present
- Level 4: Quantitatively Managed information-flow maturity present
- Level 5: Optimised information-flow maturity present

The last step of information-flow maturity assessment is the information-flow characteristics.

Within each Information-flow metric are information characteristics which define the metric's category:

Coverage	Relevancy	Usability	Availability	Reliability	Security	Quality Assurance
Capacity	Aligned	Adaptability	Accessibility	Accuracy	Confidentiality	Automobility
Completeness	Flexible	Addressability	Latency	Consistency	Functionality	Implantability
Quality	Generalisability	Compatible		Portability		Improvability
Self-descriptive	Maintainability	Complexity		Redundancy		Mutability
Simplicity		Effectiveness		Repairability		Progress
Soundness		Efficient		Repeatability		Testable
Structured		Interoperable		Sensitivity		Correlated
		Interpretability		Timely		Evidence
		Mobility		Tolerance		Measurability
		Modularity		Validity		Custodian
		Operability		Trust		Quantifiable
		Performance		Longevity		Traceability
		Safety		Bias		Transparency
		Serviceable				Consistency
		Sociability				Audit Capability
		Understandable				Coverage Quality
		Value				Data Lineage
		Volatility				
		Fit for Use				
		Functionality				

Figure 66. Information-flow characteristics identified from this research.

The supporting characteristic’s explanation (Artefact 3) for each of the information-flow characteristics should be reviewed to determine what characteristics of each metric should be selected for measurement. The information-flow characteristics include examples of what constitutes desirable or undesirable information-flow and recommendations on how to measure the characteristics.

There are two options for selecting the metrics.

1. Metrics and/ or characteristics to measure are known.

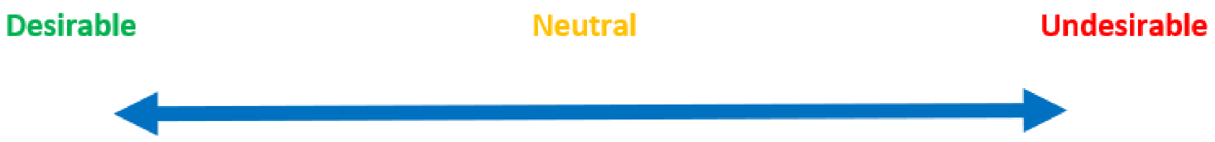
Using the Capability Maturity Matrix, the metrics are selected based on organisations information-flow area of concern/ information-flow dimensions.

2. Metrics and/ or characteristics to measure are unknown.

Where the characteristics are unknown the metrics and or characteristics to measure have yet to be determined as the area of concern is unknown. In this instance measuring all of the metrics and characteristics can be undertaken in order to get a baseline assessment of the information-flow context. Alternatively, selecting characteristics based on information-flow desirability can also be completed by using the characteristics taxonomy scale.

Taxonomy Scale:

The taxonomy scale represents the extremes of desirable and undesirable information-flow characteristics. As such, each characteristic can be positioned on this scale as desirable, neutral (an influencing factor) or undesirable.



8.2.3 Measure selected characteristics against the Capability Maturity Matrix.

The Information-flow Capability Maturity Matrix can be used to identify an organization’s current information-flow maturity and what needs to change in order to reach a target level of information-flow maturity.

This step is to assess the selected characteristics against the Capability Maturity Matrix to get a maturity level for both the characteristics and its parent metric.

Baseline maturity level - This requires identifying and measuring a baseline set of metrics for information-flow maturity. If a baseline is not known, use of the calculator tool (Artefact 4) can assist in determining a baseline measurement.

Objectives - The objectives of measuring the specific information-flow metrics will need to be assessed and a target information-flow maturity should be determined.

To measure the selected metrics and characteristics, use of the Calculator Tool is required.

8.2.4 Use the Calculator Tool to obtain an overall score.

The healthcare information-flow maturity calculator tool (Artefact 4) is an assessment tool designed to measure the maturity of individual information-flows. The healthcare information-flow maturity calculator contains all the information-flow metrics and related characteristics. The calculator is used by assessing the metric level rating from level 0 to 5 to each of the information-flow characteristics. Once all the characteristics are rated, an average metric rating can then be calculated. This calculator is used to assist measurement of information-flow characteristics and can also provide evidence for information-flow areas that need to be improved.

8.2.5 Reflect on what could be improved and using the suggestions table to capture and track an action plan.

Once an overall score has been determined and the information-low maturity rating has been determined, the suggested improvement table (Artefact 5) can be used as a guide to identify potential information-flow improvement recommendations and to record the action plan for improving maturity levels. The metrics can then be re-measured by repeating steps 3-5.'

Summary

The healthcare information-flow maturity framework assists measurement of information-flow maturity, with the purpose of improving information-flow. This framework contains five artefacts developed during Stage 1 – framework development and Stage 2 – framework refinement and validation. From this an evidence-based framework has been developed which is different to other frameworks in the literature as it includes an accessible information-flow capability maturity matrix and supporting characteristics. This framework is an improvement on current frameworks available as it is having been specifically designed for information-flow. This chapter described the healthcare information-flow maturity framework and how to use it, that was developed from the research. The next chapter presents the conclusion of the research and final remarks.

CHAPTER NINE: CONCLUSION

9.1 Learning and Reflection

This chapter summarises, and reflects this research, using a formalised system of logical arguments to examine the research questions. In addition, this chapter discusses the significance and impact of this research and how it has contributed to the broader Information Systems Theory of research, scholarship, and practice.

9.2 Summary of research undertaken

In Chapter Two, a detailed literature review identified themes and gaps in the information-flow literature, such as the lack of information-flow research in healthcare, the use of communication and workflow as a proxy for information-flow and the confused and overlapping models for information-flow. The importance of the literature review chapter was to identify gaps in the literature. Shanks (1999) information system theory model on practice was applied, and a three-stage framework development and three-stage framework refinement approach was selected to develop and validate the healthcare information-flow maturity framework. The three-stage framework development consisted of a scoping review, case study analysis and capability maturity matrix development (refer to Chapter Four). The three-stage framework development resulted in the initial identification of the key information-flow characteristics and associated information-flow maturity framework. Subsequently, in Chapters Five, Six and Seven the three-stage framework refinement consisting of Desk Study 1, semi-structured interviews with experts and Desk Study 2, resulted in the information-flow maturity framework being refined and validated through three iterations.

An Information Systems Theory (IST) theoretical framework and Design Science as an information systems methodology was chosen for this research. Design Science was a suitable methodology as it is used to solve real-world problems using knowledge context, investigation, and design in an iterative approach. This research used real world factual data and as such an objective paradigm was also selected. An objective paradigm was evident during each of the phases of this research, and in particular for developing an information-flow framework that can identify desirable and undesirable characteristics to measure information-flow in healthcare and ultimately improve information-flow. *Figure 65* illustrates how a Design Science Methodology was used to develop the information-flow maturity framework.

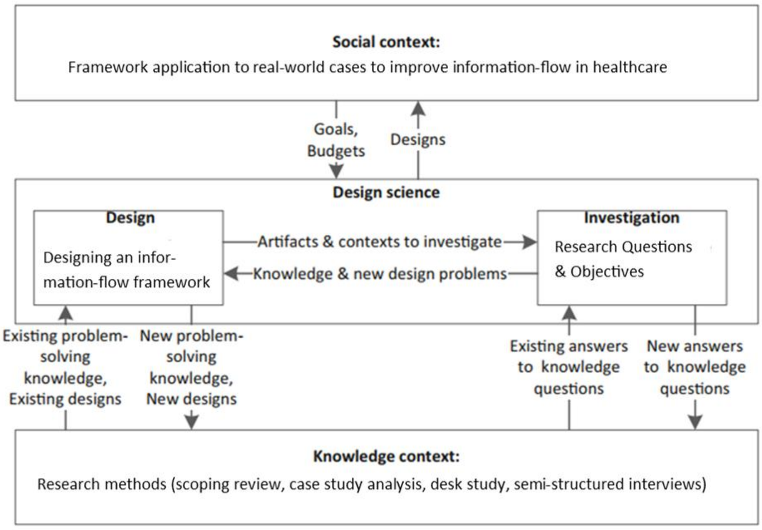


Figure 67. **Design Science Methodology to develop the healthcare information-flow maturity framework.**

9.2.1 Conduct of research

The following research questions were posed at the start of the research:

Research Question: *Can a healthcare information-flow framework be developed that can identify information-flow failure and demonstrate the framework's effectiveness in healthcare?*

Sub Question: *How can healthcare information-flow metrics be identified and measured?*

This research involved analysis of information-flow to develop an information-flow metric framework that could identify and assess what information-flow characteristics are considered desirable and undesirable. This research also required analysis of current information-flow frameworks to identify whether an information-flow framework could measure information-flow, on the basis that an improved understanding of clinical information-flow changes could inform the development of ways to avoid failure and improve the effectiveness of communications.

The considerations set the scope of this thesis, which aimed to develop an information-flow framework for healthcare that could identify and assess information-flow maturity. The purpose of the healthcare information-flow maturity framework is to measure information-flow so that improvement areas could be identified to ultimately result in reduced information-flow failure and improved information-flow within the healthcare context. As such, research methods and techniques that were appropriate for answering the research questions were used. The research used the Design Science Methodology in two stages. Stage 1 used a three-phased framework development approach in which a scoping review of the literature discovered the information-flow characteristics. At the same time, the case study analysis resulted in a method for developing an information-flow maturity framework in the form of a capability maturity model. The concepts from the case study were captured in a capability maturity model framework. Subsequently, information-flow maturity levels and the information-flow characteristics and metrics were defined and categorised. Stage 2 used a three-phased framework refinement approach; the information-flow maturity framework was validated and refined through Desk Study 1, semi-structured interviews, and Desk Study 2. As a result, an information-flow maturity framework was developed and refined to measure information-flow maturity.

9.2.2 Conceptual significance of the research

Information Systems Theory (IST) frameworks and theories were explored during this research. In particular, the conceptual significance of this research revolves around the use of, and development of, Information Systems Theory by Shanks (1999) and identifies the contribution of this theory to creating knowledge and scholarship. Shanks (1999) explores meaning from data, information from perception, knowledge, and experience. This Theory was a significant factor in the research as it provided a theoretical basis for the way in which individuals can interpret information and data, which was important for defining and measuring information-flow. *Figure 66* shows how this research is derived from Information Systems Theory and how the methods, problems and frameworks contributed to scholarship, practice, and research.

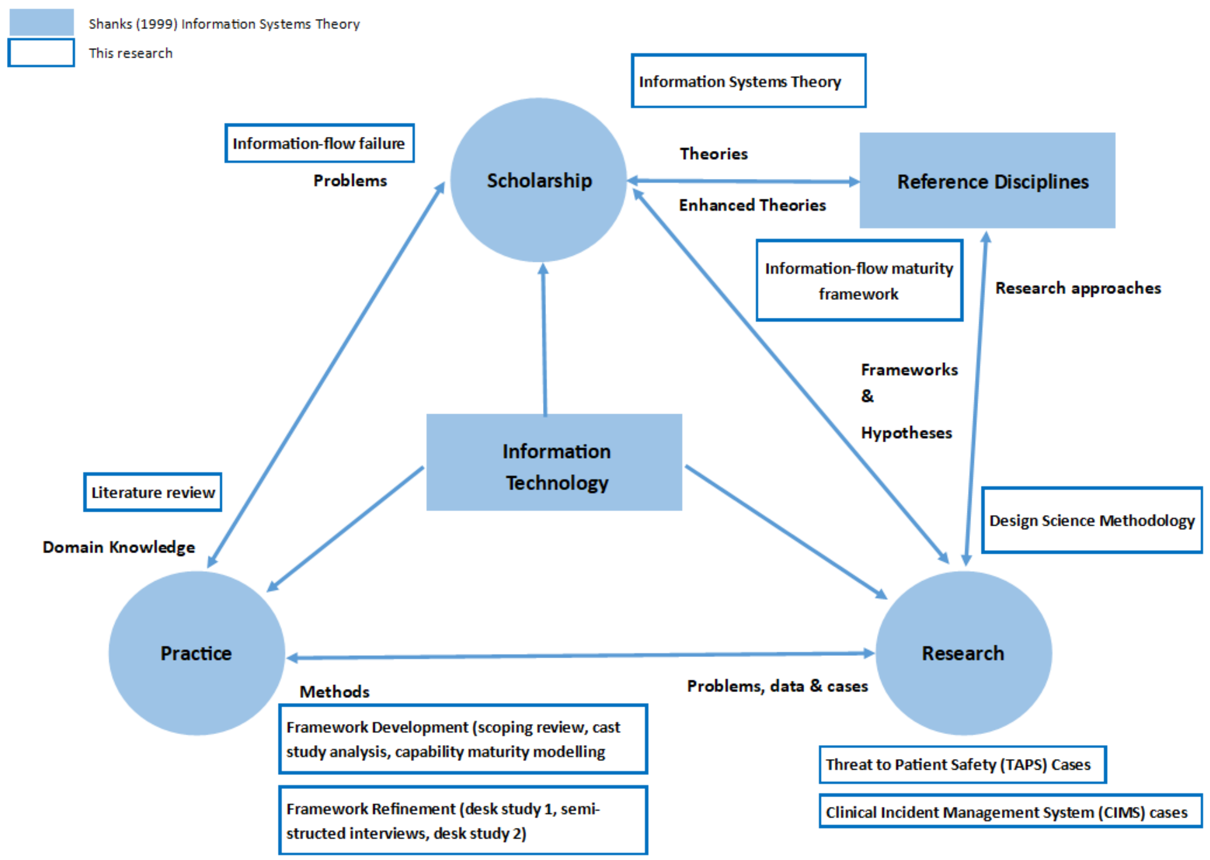


Figure 68. **Where this research fits in Information Systems Theory adapted from Shanks (1999).**

9.2.3 Contribution to Knowledge

This research contributes to existing literature and research on information systems theory and information-flow. The research resulted in an updated definition of information-flow which extends the existing literature definitions of information-flow. In addition, new knowledge relating to the characteristics of information-flow now exists because of this research. This research used Design Science research methodology to answer the research questions, and to develop the information-flow qualitative metrics as well as develop the healthcare information-flow framework. The development of an information-flow maturity framework with desirable and undesirable information-flow characteristics is new knowledge. This research has resulted in innovative practice and theory relating to information-flow characteristics as well as contributing to work on capability maturity modelling. This work has bridged the gap where comprehensive information-flow characteristics were previously not available and measurable for healthcare.

9.2.4 Contribution to Scholarship

This research contributed to scholarship through engaging in complex problem situations in which Design Science methodology was required to solve those problems. The application of a Design Science methodology, that used methods such as scoping review, case studies, desk study and semi-structured interviews, resulted in developing an information-flow maturity framework that can measure desirable and undesirable information-flow characteristics within healthcare. An updated definition of information-flow was developed through this research. This updated definition can help students and practitioners of information systems design and analysis define and identify information-flow accurately. This definition can also be used as a foundation for further information-flow research and be used to assist in building knowledge relating to information-flow definitions and characteristics. The definition is also useful for organisations and/or standards bodies who are looking to adopt information-flow improvement as an activity. In addition, the use of information-flow metrics in healthcare and in particular, medication and pathology use cases as exemplars, demonstrated capability maturity modelling for information-flow to be a valuable, new method for information-flow research. Adoption of the methods and tools described in this thesis will facilitate further work in information-flow research.

9.2.5 Practical significance of the research

Using healthcare medication and pathology errors as an exemplar, the consequences of information-flow failure and impact on patient safety were identified along with the financial costs to the healthcare system. For example, information-flow failure may be caused by human error omissions/ commission, which can result in medication errors. Measuring and understanding information-flow allowed identification of desirable and undesirable information-flow characteristics so that information-flow failure could be negated. The information-flow maturity framework has the potential to be used by process administrators and improvement officers to measure their organisations' current information-flow maturity to inform improvement activities. Additionally, the information-flow maturity framework can be applied to different organisations and domains. While opportunities relating to the medication error exemplar include use during reporting and post-incident investigation of medication errors to further understand the undesirable information-flow characteristics that result in errors. This framework has application and relevance to address common issues in healthcare caused by information-flow failures, and the subsequent effect of those on patient safety using a maturity model to assess and improve healthcare information-flows and is likely to have a significant impact on patient outcomes, morbidity, and mortality.

9.2.6 Presentation of the research

The following peer reviewed articles and posters were published as outcomes from the research included in this PhD thesis:

1. Hermon, R & Williams, P.A. H. (2013). A Study on Information Induced Medication Errors. 2nd Australian eHealth Informatics and Security Conference, held on the 2nd-4th December, 2013 at Edith Cowan University, Perth, Western Australia SRI Security Research Institute, Edith Cowan University, Perth
2. Hermon, R (2019). Information-flow Points of Failure: A Systematic Review of Medication Use Cases. Poster Presented at the 2019 Health Informatics Conference, Melbourne
3. Hermon, R & Williams, P.A. H. (2020). Points of Failure: A systematic review of information-flow using medication use cases. Proceedings of the 53rd Hawaii International Conference on System Sciences (pp.3862- 3870). Hawaii: HICSS

9.2.7 Personal learning and reflection

In reflection, this research process was a personal learning journey and required all six learning levels of Bloom's revised taxonomy. Anderson and Krathwohl (2001) suggest the six learning levels are remember, understand, apply, analyse, evaluate, and create. Evidence of these levels can be seen throughout the thesis chapters. For example, in the literature review remember, understand, analyse, and evaluate were required to appraise the literature, categorise articles and support the identification of what is missing in the literature. While create was necessary for a Design Science methodology and was used during the creation of information-flow characteristics and the healthcare information-flow framework. This in turn resulted in the creation of a new artefact that is based on analysis and evaluation of evidence.

This research journey required the development of communication, presentation, critical thinking and writing skills. This research enabled the opportunity to develop as a researcher through the adoption and use of information system methodologies such as Design Science as well as the ability to conduct scoping reviews, case study analysis, framework development, maturity model assessments, desk studies and refine interview techniques. In addition, this research enabled the development of skills for reviewing and developing information-flow maturity characteristics, and capability maturity models as well as identifying information-flow maturity through the use of the information-flow maturity framework on medication and pathology exemplar case studies. This PhD resulted in the learning, awareness, and the development of skills for research. Through critique by peers of publications and required thesis presentations, the ability to challenge and provide evidence and justification for arguments has been learnt. In addition, exploration of this topic has resulted in identification and greater understanding of the gaps and concerns of the healthcare industry relating to medication and pathology errors.

9.2.7 Limitations

Bias was a limitation of this study as it involved the Researcher subjectively designing and developing information-flow characteristics and an information-flow framework. In addition, lack of knowledge or research experience/ skills could have impacted the final design of the information-flow framework. However, to overcome these limitations an in-depth and rigorous research design was aligned to the Design Science methodology. Further, a three-phased refinement approach (Stage 2) that included expert interviews reduced the bias of the Researcher. Additionally, the Researcher's Supervisors constantly provided feedback and review to ensure the designs of the framework were not influenced by bias or lack of knowledge.

9.2.8 Future research

Future research on the use of the framework including a before- and after interventional study with an organisation, would further underline the capability enabled by the information-flow maturity rating to improve information-flow quality. Although this framework was centred on healthcare information-flow, the information-flow qualities can be identified in any organisation and future research could include further validation of the framework or use of the framework in information-flow improvement research relating to non-healthcare fields. Future research relating to information-flow improvement as a form of process improvement or maturity improvement in organisations could also be investigated. Research identifying the types of information-flow characteristics found in areas of information-flow failure could assist in researching characteristics that are designed to prevent information-flow failure.

9.2.9 Final Comments

This thesis developed a healthcare information-flow framework that could be used to identify information-flow failure and subsequent improvement. This required the development of information-flow characteristics to demonstrate the effectiveness of categorisation and measurement of information-flow in healthcare. Through a Design Science methodology and several different methods including desk study research, case study research and semi-structured interviews, a healthcare information-flow maturity framework was devised. This healthcare information-flow maturity framework has been refined and validated throughout the research process and has the potential to be used during the reporting and post-incident investigation of information-flow failure both within and outside of healthcare.

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APPENDICES

Appendix A: Scoping Review Artefacts

Scoping Review Results

Search Term	Author	Notes	Source location	Source Type
Metrics				
	(Hauser & Katz, 1998)	• Metrics are used by firms for laudable reasons • Metrics include market share, sales increases, margins, customer satisfaction, projected revenue, contingent sales, forecasts. • Metrics impact decisions • Theory: measure and you become it • Correct metrics for firm is needed • A good metric is precise, tied to profit, applicable to all and encourages effort. • Good metrics empower an organisation • 7 steps to choosing a metrics include • Customer • Value • Interrelationships	European management journal	Journal article

		• Linkages • Correlations • Involve everyone • Seek new paradigms		
	(Martin, McKee, & Dixon-Woods, 2015)	• Formal metrics for monitoring safety and quality • Soft intelligence "process and behaviours associated with interpreting soft data". • Article focuses on soft intelligence rather than metrics	Elesevier	Journal article
	(Kerzner, 2017)	• Metrics value must be understood to be used correctly • Related to project management metrics • Metrics keep stakeholders informed • Establish boundaries, measure performance, determine baselines, • Measure through RI and KPIS • Measurements: what, when, how, who • Metric characteristic: purpose, useful, focus, measured, reflect true status of project. • Types: business/ financial, success, project and project management	Project management	Book chapter
	(Prentice, Frakt, & Pizer, 2016)	• Performance metrics are used to measure healthcare • Health goals should be defined then metrics to measure these goals	JGIM	Journal article
Information security metrics				
	(Chew et al., 2008)	• Measure IT security performance • Metric development and implementation • P.vii "metrics are tools designed to facilitate decision making and improve performance and accountability through collection, analysis and reporting of relevant performance-related data" • IT security metrics monitor the accomplishment of the goals and objectives • Metrics must be quantifiable • Repeatable processes to be measured • Data for metrics needs to be readily available • Metrics must be useful for tracking performance • Metrics identify causes for poor performance. • Implementation, 2. Effectiveness and 3. Impact metrics • Metrics can be obtained for different levels of the organisations • P. 15 has metric development diagram	NIST	Technical document
	(Savola, 2007)	• Systematic approaches for measuring security are suggested • Survey emerging security metrics approaches from government, academia and industry • Security metrics offers quantitative and objective basis for security assurance • Assessment and prediction • Mathematical models and algorithms are applied to collected data. • Measurement: provide discrete factors • Metrics: compare measurements • Taxonomy: technical, operational and organizational • Taxonomy p. 29	VTT research centre	Journal article
	(Wang, 2005)	• Analytical modelling and metrics-based assessment will overcome problems with experimental analysis and qualitative metrics • Security metric focused	Southern polytehcnical state uni	Journal article

		• Qualitative metrics can lead to ambiguous confusion, mathematical formula based from qualitative metrics is presented • Metrics are important to security, policy, mechanisms, implemented as they need to be measured • Metrics are often subjective instead of objective. • Measurement involves 1. Data collection. 2. Data validation. 3. Data processing • Data collection: what and how to collect • Data validation: analysing the data for: correctness, consistency and completeness. • Data processing: statistical analysis to identify trends and evaluate qualitative measures • Security metrics: how well a system meets security requirements • There is a formula • Good diagram on info states: storage, transmission, processing CIA technology, policy, education		
	(Tariq, 2012)	• Metrics for cloud computing • Information security metrics to measure efficiency. Performance, effectiveness and impact of security constraints. • Purpose of paper is to discuss cloud security issues and propose an information security metric framework • Framework helps users to create metrics, analyse threats and mitigate them • Cloud issues: data location, theft, loss, integrity, privacy, regulatory, BCP • Security metric framework • Framework: 1. Metrics preparation. 2. Threat ID and analysis 3. Threat processing. 4. Application	IAES	Journal article
Information metrics				
	(Yang, Ke, & Wanlei, 2011)	• Information metric can quantify the differences of network traffic • This paper proposes 1. Generalised entropy metric 2. Information distance metric • 1. Generalized entropic metric GEM: information entropy is a measure of the uncertainty associated with a random variable, forming the basis for distance and divergence measurements between provability densities (part of information theory).	IEEE	Journal article
	(Galas, Dewey, Kunert-Graf, & Sakhanenko, 2017)	• Central function of information theory	Axioms	Journal article
Information flow taxonomy				
	(Bielova & Rezk, 2016)	• Taxonomy of information flow monitors • Soundness and transparency • Soundness: observes outputs that comply with the policy • Web applications focused	HAL	Journal article

Information flow metrics				
	(Pickard & Carter, 1995)	• Software metrics • Looked at a field study of the relationship of information flow to the maintainability of cobol modules in a data processing environment	Information and software technology	Journal article
	(Jabbar & Sarala, 2012)	• Software metrics • Metric analysis in object orientated programming and metrics validation process by RAA algorithm	Elsevier	Journal article
	(Clarkson, Myers, & Schneider, 2009)	• Software metrics • Information flow model to show how attackers beliefs change • Model supports a quantitative metric that measures accuracy of attacker's belief	Journal of computer security	Journal article
	(Carney & Shea, 2017)	• Information metrics and measures for smart public health • Lists measures and capabilities as p. 6 • Knowledge discovery rate, aberrant detection analysis, cognitive mapping, agent, understand factors (environment).	Hindwai Publishing group	Review article
	(S. Henry & Kafura, 1981)	• Software metrics from information flow • Metrics: procedure complexity, module complexity module coupling • Validated with unix system	IEEE	Journal article
Developing metrics				
	(Freundlich & Ehrenfeld, 2017)	• Hard to develop and validate metrics	British journal of anaesthesia	Journal article
	(Klubeck, 2015)	• Develop metrics: what, why, when where who how • Common language for metrics	Google books	Ebook
Communication metrics				
	(Dutoit & Bruegge, 1998)	• Communication software metrics	IEEE	Journal article
Information flow measurements				
	(Bossomaier, 2016)	• transfer entropy • information theory and complex systems	Flinders library	Ebook
	(Badenhorst-Weiss, Maurer, & Brevis-Landsberg, 2013)	• Information flow, business process and decisions • Information flow efficiency metrics	University of South Africa	PhD Thesis
Metric development				
	(Holman, 2009)	• Developing metrics and KPIs • Performance measurement is a comparison of actual returns against a specified benchmark • Performance metric is a type of measurement used to quantify the performance of some component of an organisation • 3 types of measures • Key result indicators • Performance indicator • Key performance indicator • A kpi is a metric and reflects value drivers	Linkedin	Presentation

		• Business strategy – goals and objectives – key business objectives – kpi – metrics • Measure what is important, measure problems measure objectives • SMART (specific, measurable, actionable, relevant, timely) • Characteristics – accuracy, completeness, reliability, timeliness, consistency		
	(Climate Research et al., 2005)	• Principles for developing metrics • “metrics are tools for supporting actions that allow programs to evolve toward successful outcomes” • Focus is on climate change science program, but concepts can be used elsewhere • Prerequisites – good leader ship and good strategic plan • Characteristics – accuracy, specific, frequent reporting, large numbers. • advance progress and improve • Easily understood and accepted • Quality • Access progress and process • Many metrics are needed • Application challenges • challenges should be expected • Metrics must evolve with objectives • - meaningful metrics requires human, financial and computational resources	Flinders library	ebook
	(Mustafa & Khan, 2005)	• Validity, utility and reliability of metrics • Metrics must be developed from a framework • Study developed MDF aka Metric Development Framework • Quality metrics • Characteristics: compliance, orthogonality, formality, minimality, usability/ implementation, accuracy, validity, reliability, interpretability. • P. 440 for MDF • Conceptualize – plan – design – validate – test – review – packaging	Journal of computer science	Journal article
	(Rombach2)	• Goal – Question – Metric approach • Focus on software development • Feedback and evaluation • Focused • Applied to all products, processes and resources • Interpreted based on characteristics and org context, goals • Measurement should be top down • Approach was initially developed for NASA project defects • Conceptual – goal, objects to measure: projects, processes, resources • Operational – question: characterise the object of measurement • Qualitative (metric): objective and subjective • P. 3 has diagram of GQM	University of Maryland	Review article
Metric characteristics				
	(blog)	• Strategic • Simple • Owned • Actionable • Timely • Referenceable • Accurate • Correlated • Game-proof	TDWU	Online article

		• Aligned • Standardized • relevant		
Information flow characteristics				
	(Westrum, 2014)	• IF is vital to the organisations "nervous system" • IF shows quality of organisations functionality • Organisations function on information • IF is like water moving through a pipeline • Good information has following characteristics • Provides answers to questions, timely, presented so it can be efficiently used, • Information as an indicator • Cooperation and information	Elsevier	Journal article
	(Glauser, 1984)	• Upward communication and information flow in organisations • Effective organisations functioning = accurate information transmission • Organisations should be information processing systems • Upward information flow • Characteristics = needs, personality, situation in the organisation. • information load, mobility aspirations, security, laws of control, job satisfaction, performance, power/ upward influence, consideration/ employee orientation, information load, attitude toward interaction episodes, performance.	Human relations	Journal article
	(Крутіна І. А.)	• Characteristics: Direction, amount, time, cost, intensity, information, structure, integration	Oles Honcher University	Review article
	(Tribelsky1 &)	• Info flow in civil engineering • Action rate • Package size • Work in progress batch size • Development velocity • Bottlenecks • rework	Research gateway	Conference paper
Information flow metrics characteristics				
	(Sherif, Ng, & Steinbacher, 1985)	• software metric • "quality metrics involve a set of measures that can describe the attributes of a system" • Accuracy and reliabilities • Attributes include • Availability • Reliability – correctness, consistency, completeness, traceability • Maintainability – reparability, serviceability, accessibility, modularity • Testability – understandability – simplicity, structuredness, self- descriptiveness, conciseness • Measurability – accessibility, sensitivity, quantifiability, modulates • Flexibility – generalizability – adaptability, compatibility portability usability, input/ output rate/ volume, tolerance, (input variations), operability • Performance – effectiveness – operational reliability, system readiness, design adequacy • Performance – effectiveness – operational reliability, system readiness, design adequacy – efficiency – execution, storage transformation • Automated/ manual • Quality/ cost	Microelectron reliab	Journal article

		• Product • Process • Subjective / objective		
	(Petkova, Sander, & Brombacher, 2000)	• Quality metrics in service centres • Functionality, time to market, quality and reliability, profitability • Feedback control loop (good diagram, p. 28) • Information flow from service desk centres to development and production • “maturity index on reliability” • Metrics – quality, reliability concepts, product reliability, hazard function, cost, classical field call rate	Elsevier	Journal article
	(Ciurea, 2009)	• Metrics for collaborative systems • Collaborative system – works for people and other systems to get jobs done faster • Quality characteristics of collaborative systems – complexity, reliability, maintainability, usability, portability, anywhere – anytime, sociability, the tele proximity, automation, management, group composition, task features, communication media, techniques for validation, indicators.	Informatica economica	Journal article
	(Cook & Roesch, 1994)	• Software metrics	Cute Seer	Journal article
	(Laguë & April, 2020)	• Software metrics	Research gateway	Journal article
	(Shepperd, 1990)	• Design metrics to software development • *local and global information flows	Software engineering journal	Journal article
	(Kitchenham, Pickard, & Linkman, 1990)	• Evaluate software design metrics using data from a communication system • Based on information metrics by henry and kafura • Practical use of information flow metrics • Measure “links among procedures in terms of the flow of information” • Relevant to any system • Henry and jaura is software metrics	Software engineering journal	Journal article
	(Oman & Hagemeister, 1992)	• Software metrics	IEEE	Journal article
	(Alshammari, Fidge, & Corney, 2009)	• Security software metrics	IEEE	Conference paper
	(Zonouz, Berthier, Khurana, Sanders, & Yardley, 2015)	• System security metric based on information flow • Intrusion detection systems	IEEE	Journal article
	(Parraguez, Eppinger, & Maier, 2015)	• Dynamic modelling, • Temporal dynamics of information transfer between activities • Project management • Info flow: organisational, process, intersection of org and process • “function of information exchanges’ • Network metrics • Topology for information network	IEEE	Journal article

		• Proposes model to analyse actual info flow between stages of complex engineering design projects		
	(Singh, Singh, & Singh, 2011)	• Software metrics – process and product metrics	IJCEM	Journal article
	(Abdul, Wei, Muketha, & Wen, 2008)	• Complexity metrics • GQM metrics • Software metrics • Business process model • Comparison of GAM< BSC and GQM • GAM – goal, attribute, measure • BSC – goal, driver, indicator • GQM – goal, question, metric • Understandability and maintainability	IJCSNS	Journal article
	(Sallie Henry, 1979)	Information flow metrics for the evaluation of operating system structure *earliest Software metrics	Iowa state university	Thesis
Information flow measures				
	(Alvim et al., 2019)Alum,	Quantitative info flow – assess and control leakage of sensitive information by computer systems Many measures with different properties	Elsevier	Journal article
	(Jumarie, 1990)	Information theory	Flinders library	ebook
	(Yeung, 2008)	Diagram for point to print communication systems	Springer link	ebook
	(Sarala & Abdul Jabbar, 2010)	Software metrics	Research gate	Conference paper
Information metrics				
	(Brath, 1997)	Metrics for information visualisation No. of data points and data density No. of dimensions and cognitive overhead Occlusion % Reference context and percentage of identifiable points Metrics will and the development of effective 3D information visualizations	Research gate	Journal article
	(Yang et al., 2011)	Information metric can quantify the differences of network traffic with various probability distributions Software metric DDOS attack metrics	IEEE	Journal article
	(Wang, 2005)	Information security models and metrics Metrics are quantitative and are important for assessing the effectives of proposed improvements in security environments	ACM digital	Journal article

	(Swanson, Bartol, Sabato, Hash, & Graffo, 2003)	How organisations through the use of metrics, identifies the adequacy of in-place security controls, policies and procedures	NIST	Journal article
	(Tang, Musolesi, Mascolo, Latora, & Nicosia, 2010)	Information flows and key mediators through temporal centrality metrics Temporal metrics to analyse human networks	ACM digital	Conference paper
Metric framework				
	(Eswaran, Shur, & Samtani, 2011)	Mcs (mean cognition score) Network metric	Elsevier	Journal article
	(Review, 2016)	can’t move what you can’t measure build a metrics framework CSF, KPIS from ITIL Choose your own metrics Start with the business Know the vision Document goals Align CSG with business Create KPIS that target CSFs Create dashboard Develop scored cards	ITSM website	Online article
	(Smith, 2008)	Metrics framework for value and CSI purpose, goal, destination Plan based on goal Measurement framework: learn, implement, manage, improve Aligned with ITIL, COBIT, supports ISO/IEC20000 Metrics define what is to be measured Implementing metrics Measure process and service effectiveness Measure function/ technologies	Think hdi webpage	Book chapter
	(Berander & Jönsson, 2006)	GWM approach for measurement framework definition Software metrics Software engineering: measurements can be used to monitor, understand, improve software processes as well as products and resource utilisation GQM aligns with organisational direction and goals	ACM	Conference paper

		Measurement tree 1. Conceptual level (goal Operational level (question) Quantitative (metric) Objective/ subjective metrics Goals, questions and metrics are related		
	(Hussain & Kutar, 2009)	Measuring usability to ensure the application is accurate Quality characteristics, goal, guidelines	Research gateway	Conference paper
Metric model				
	(EDRM, 2020)	Metrics model provides a framework for planning, preparation, execution and follow up of e- discovery matters	EDRM	Technical document
	(Eiffel, 2018)	Metrics tools Quantitative information	Eifel	Online article
Types of metrics				
	(Spacey, 2017)	7 types of metrics Metrics are meaningful measurements and calculations that are used to direct and control an organisation KIP Qualitative Quantitative Actionable Informational	Simplicale website	Online article
	(Bose, 2004)	Knowledge management metrics	Emerald	Journal article
	(Melnyk, Stewart, & Swink, 2004)	Metrics and performance measurement in operations management Metrics provide links between strategy, execution and value creation Metric is a verifiable measure, stated in either quantitative or qualitative terms Metrics provide three basic functions: control, communication, improvement Metric typology: metrics flows, metric tense	Emerald	Journal article
	(Frakes & Terry, 1996)	Software metrics and models	ACM	Journal article

Metric Characteristics found in the Scoping Review

Metric	Reference
Metrics must be quantifiable Repeatable processes to be measured Data for metrics needs to be readily available Metrics must be useful for tracking performance Metrics identify causes for poor performance.	(Chew et al., 2008)
correctness, consistency and completeness.	(Wang, 2005)
Soundness and transparency	(Bielova & Rezk, 2016)
accuracy, specific, frequent reporting, large numbers. advance progress and improve Easily understood and accepted Quality Access progress and process	(Climate Research et al., 2005)
Characteristics: compliance, orthogonaity, formality, minimality, usability/ implementatabiltiy, accuracy, validity, reliability, interpretability	(Mustafa & Khan, 2005)
Strategic Simple Owned Actionable Timely Referencable Accurate Correlated Game-proof Aligned Standardized Relevant	(blog)
Characteristics = needs, personality, situation in the organisation. information load, mobility aspirations, security, laws of control, job satisfaction, performance, power/ upward influence, consideration/ employee orientation, information load, attitude toward interaction episodes, performance.	(Glauser, 1984)
1) direction of the information flow; 2) amount of the information flow; 3) time of the information flow;	(Крутіна І. А.)

4) cost of the information flow; 5) intensity of the information flow; 6) adequacy of the information flow; 7) informativity of the information flow [2]; 8) structure of information flow; 9) integration of information flows of different departments [3]	
Accuracy and reliabilities Attributes include Availability Reliability – correctness, consistency, completeness, traceability Maintainability – reparability, serviceability, accessibility, modularity Testability – understandability – simplicity, structuresness, self- descriptiovesness, conciness Measuresability – accessibility, sensitivity, quantifability, modulants Flexibility – generability – adapatability, compatablitym portability 0 usability,, input/ output rate/ volumne, tolerance, (input variations), operability Performance – effectiveness – operational reliability, system readiness, design adequacy Performance – effectiveness – operational reliability, system readiness, design adequacy – effeciciency – execution, storage transformation Automated/ manual Quality/ cost Product Process Subjective / objective	(Sherif et al., 1985)
quality, reliability concepts, product reliability, hazard function, cost, classical field call rate	(Petkova et al., 2000)
Quality characteristics of collaborative systems – complexity, reliability, maintainability, usability, portability, anywhere – anytime, sociability, the teleproximity, automation, management, roup composition, task feastures, communication media, techniques for validation, indicators.	(Ciurea, 2009)

Appendix B: Case Study Artefacts

Case Study 1 Summary

Hayden, L. (2010). *IT Security Metrics: A Practical Framework for Measuring Security and Protecting Data*.

Summary Notes:

- The book is about the process of measurement and in particular measuring IT security with metrics, which can be used to support the decision making process.
- In chapter 1 it defines metrics and measurement. Haydon suggests you measure security to understand security. The researcher identified in the same way you can measure information-flow to understand information-flow.
- Metrics provide a standard for information collection and is a result. The point is to collect data that can be understood.
- Measurement is an activity that collects data in order to result in understanding.
- P. 8 “empirical measurement that helps an organization reduce uncertainty is a good metric”.

- Risk: is hard to measure consistently in security.
- Security metric lesson 1: improve data collection, analysis and understanding will improve metrics and management decisions. The Researcher identified lessons could also be applied to information-flow processes.
- Lesson 2: security is a business process. if you are not measuring and controlling the process, you are not measuring and controlling security.
- Lesson 3: security is the result of human activity. Effective measurement programs attempt to understand people as well as technology.
- Summary of chapter 1: metrics are the result of a measurement process built on human and organizational activities and are not an end in and of themselves p. 23. The researcher identified the justification for using this text to develop information-flow metrics as Haydens method could be applied to any metric and measurement.
- Security metrics used today include: risk matrices, security and vulnerability and incident statistics, annual loss expectancy (ALE), return on investment (ROI) and total cost of ownership (TCO).
- Chapter 2: choosing and developing metrics from the GQM or Goal-Question-Metric
- Metric has been defined to mean “some standard of measurement” p. 27
- Metric definition but be alongside the definition of measurement p. 27 “the act of judging or estimating the qualities of something including both physical and nonphysical qualities, through comparison to something else”.
- What is being measured is compared to the standard.
- Metrics are standards of measurement, and measurement the comparison of things, usually against standards p. 28
- Measurement can be qualitative and quantitative.
- Metrics need to be developed based on your requirements. Don’t focus on good or bad metric thinking.
- What makes a metric good: how you measure it.
- Is the metric good: 1. Do you understand the metric? 2. Do you use the metric? 3. Do you gain insight or value from the metric?
- Metrics need to suit about what you want to know.
- The 5 W: who, what, when, where, why and how?
- GQM for security metrics:
- GQM is a simple, three-step process for developing security metrics p. 36
- The Goal are the goals for what the measurement will achieve. These goals are then translated into specific questions. The questions are answered through metrics and collecting data that is measured.
- Example diagram is listed on p. 37
- GQM is from software engineering from the 1970s. it was developed to test software defects from qualitative and subjective states. GQM is intuitive and functional.

- GQM provides three benefits: 1. Metrics are top down. 2. Measurement has boundaries. 3. Metrics are customised to the requirements. The researcher identified information-flow metrics need to be subjective and tailored to each environment.
- Goals are specific and limited and meaningful (attainable and verifiable), have context and are documented.
- P. 46 offers a GQM project definition template. The goal of this project is to understand information-flow and reduce points of information-flow failure that result in medication variances.
- Good metrics: are understood, used and provide value and insight.
- Chapter 3: IT metrics are about collecting and analysing data based on observations you make.
- Metrics are a means of organising and classifying that data.
- What is data? P. 57 data is a form of information and is represented by the facts, quantities, figures, statements, symbols, and observations that we use for inquiry, reference or analysis.
- P. 58 has the DIKQ hierarchy diagram
- Data types: quantitative :nominal, ordinal, interval ratio, and qualitative: observations, responses, records and artifacts,
- Analyzing qualitative data: interpretation and meaning is first. Coding of data such as ATLAS, Nvivo software tools. TAMS analyser. The Researcher identified Could use TAMS to code data. Create information-flow metrics for a specific organisation. However, develop a framework for metrics for use in information-flow.
- Data sources: system data, process data, documentary data, people data,
- Information asset concerns: compliance, data loss, uptime, malware, development
- Information behaviour concerns: confidentiality, integrity, availability, flexibility, agility, autonomy.

Researcher comments:

- Can you measure information-flow to understand information-flow?
- Security metric lesson 1 can also apply to information flow processes.
- Definition of Haydons metrics show this can be applied to any metric and measurement.
- Are information flow metrics subjective and tailored to each environment?
- GQM is useful for developing metrics.
- The goal of this project is to understand information-flow and reduce points of information-flow failure that result in medication variances.
- Could use TAMS be used to code data and create information-flow metrics for a specific organisation, and to develop a framework for metrics for use in information-flow.

Case Study 2 Summary

Klubeck, M. (2015). *Planning and Designing Effective Metrics*: Berkeley, CA : Apress : Imprint: Apress.

Summary Notes:

- Metrics definition requires What, Why, When, Where, Who, and How.
- Improving something

- Tools for improvement
- Use different levels of information to tell a story
- Metrics show what was wrong, how implementations have worked and what the change like.
- Improve, change, understanding
- Measures time, money, effort = baseline metric
- Metrics provide insight
- Collect data and measures
- Common language needed
- Guidelines for developing metrics
- Measures of success and goals.
- SMART goals = specific, measurable, attainable, realistic, time- bond.
- Metrics tell stories and valuable insights.
- Metrics = use data, measures, information to improve organisation
- Data, info, metrics are distinct but connect, they build upon each other.
- Metrics are = metrics and information
- Information = measures
- Measures – data
- Data definition p. 12 “individual facts, statistics, or items of information”
- Data needs meaning “simplest form of information. Number/ value”.
- Measures – bring clarity to data
- Data, measures, information and metrics: each different but related.
- Data by itself is useless
- Data is within measures
- Measures make data meaningful
- Metric – made of information, measures, data
- Metrics can include other metrics
- Metrics tell the full correct story
- Different interpretations of metrics
- Your metrics – one way to view the meaning
- Metrics need root questions
- Root question – provides focus and direction with foals first
- A metrics is a complete story, told through representation of information, information is a compilation of measures used to convey meaning.
- Measures are results built from data
- Goal – to develop metrics – answers to questions
    - metrics are tools to answer the questions
- Data the easiest to get started should be the last to focus on. When developing metrics
- Start at the most complex
- Question, metrics, information, measures, data development
- Vague questions = complex

- Clarity is simple
- Designing the metrics
- The root questions
- The 5 whys
- Develop goals
- Define terms
- Test the root question (5 tests)
- Draw
- Identify the info, measures and data needed
- Collecting measures and data
- Automated data, software and hardware, surveys, people, document metrics
- Purpose statement
- How it will be used
- How it wont be used
- Schedules
- Analysis
- Pictures
- Narrative
- How metrics will and wont be used
- Only show metrics to customers * define customers
- Repeat, need, repeatability for a process
- Metrics as indicators
- Metrics can be misinterpreted as facts
- Reponses to metrics – investigation
- Metrics can be wrong
- Accurate metrics are just indicators
- Qualitative vs quantities data
- Metrics require interpretation
- Answer key to answer the root questions
- 5 framework tier
- Return of investment
- State of the union
- Produce / service health – effectiveness and efficiency
- Organisational health
- Do things for the right reason
- Triangulation of measures
- Delivery is objective
- Usage is objective
- Customer satisfaction is subjective
- benchmarks

Researcher Comments:

- interoperability supposedly makes info-flow and decision faster but does that equal quality?

Case Study 3 Summary

Maurer, C. (2013). *The measurement of information flow efficiency in supply chain management.* University of South Africa, Pretoria. Retrieved from http://hdl.handle.net/10500/8772

Summary Notes:

- measurement of information flow efficiency in supply chain management
- thesis
- charcteristics: speed of reaction, order accuracy, operational flexibility, sustained quality
- characteristsic fo successful business
- efficieny communiticaion and IT is key
- “communication between supply chain members requires that relevant information is transferred from its pint of inception to the next point(s) of use”
- “the transfer of information entails an efficient flow of information between systmes, between systems and humans and humans between humans,
- Interoperability = faster info flow and effective decision making
- Indicators and metrics posed for the assessment of info-flow efficiency in supply chain
- Existing info flow measurement and weaknesses
- Definition of info flow efficiency
- Provides definition of a metrics
- Categories of information
- Characteristics of info flow efficiency framework
- Used exploratory research
- Measures info flow efficiency
- p/ 327 for characteristisc
- identify metrics of info flow efficiency
- p. 325 Measreuemnt framework

Researcher comments

- does fast mean quality?

Appendix C: Information-flow Maturity Framework Development Artefacts

Information-flow characteristics developed for all capability maturity model levels.

Characteristic	Level 0: None	Level 1: Initial	Level 2: Managed	Level 3: Defined	Level 4: Quantitatively Managed	Level 5: Optimising
Acceptability - Information	Information is not accepted	Information-flow failure is consistent. Certain information-flow processes are accepted. Acceptability is reactive.	Acceptability characteristic is measured. Goals for reaching acceptability have been decided. Information-flow failure improvement.	Acceptability is actively a goal and sought. There are information standards.	Acceptability measurements and surveys or users are used to implement activities to build user trust. Interventions for building information reliability are in place.	Information is accepted. Information-flow errors are least likely as information is reliable and trusted.
Acceptability – Information-flow process	Information-flow processes are not accepted	Information is not accepted. Users are suspicious of information. Information-flow processes are present with the highest amount of errors.	Information-flow process acceptability is measured.	Acceptability in information-flow processes have a standard	Acceptability information-flow is improved through interventions.	Information acceptability management
Accessibility - Information	Information is not accessible	Processes that involve accessing particular information is a repeatable process.	Accessibility is measured. Accessibility errors are reduced.	Access for information aligns with organisational standards.	Accessibility as a metric is used to predict future accessibility errors.	Information is accessible.
Accessibility – Information-flow Process	No accessibility in information-flow process	Information is not accessible and not in the correct locations.	Accessibility in information-flow processes is measured	Accessibility in information-flow has standards.	Accessibility in information-flow processes are improved through interventions.	Information Accessibility Management

		Accessibility is not measured.				
Accuracy - Information	Information is not accurate	Accuracy measurements are unpredictable, inefficient and accuracy is not controlled.	Accuracy in information-flow processes are repeatable and measurable.	Standards for accuracy are implemented. Reduced information-flow errors due to accuracy errors.	Interventions to prevent information-flow accuracy errors are implemented. Accuracy of information-flow can be predicted.	Information is accurate. Accuracy in information-flow is effective, efficient and consistent.
Accuracy – Information-flow Process	Information-flow process is not accurate	Information is not accurate. High rates of inaccurate information within information-flow.	Accuracy in information-flow process are managed	Accuracy in information-flow processes are defined	Accuracy in information-flow processes are quantitatively managed	Accuracy information-flow process management. Accuracy in information-flow management is focused on process improvement.
Adaptability - Information	Information is not adaptable	Information is inefficient at adapting. Information-flow errors are a result of information failing to be adaptable.	Adaptability is measured, controlled.	Adaptability is proactive and has standards	Adaptability reduces information-flow failures	The focus is improving adaptability in information-flow
Adaptability – Information-flow processes	Information-flow process is not adaptable	Information is not adaptable or measured.	Information-flow processes are adaptable	Information-flow processes follow organisational standards	Information-flow process failure is reduced	Information-flow process adaptability management
Addressability - information	Information is not addressable	Information addressability is planned, measured.	Information can be defined through addressability	Information addressability reduced information-flow failures	Addressability is measured and controlled.	Addressability in information is optimised

Addressability – information-flow processes	Information-flow process is not addressable	Addressability is uncontrolled and inefficient	Information-flow processes can be measured through addressability	Information-flow addressability is defined	Interventions to prevent information-flow failures. Addressability is predicted.	Addressability Information-flow process management
Aligned – information	Information is not aligned	Information alignment is inefficient and uncontrolled	Information alignment is planned, measured and controlled. Reduced information-flow failures associated with alignment.	Reduced information-flow failures	Interventions to prevent information-flow failures. Aligned is predicted.	Information alignment is optimised
Aligned – information-flow processes	Information-flow process is not aligned	Information-flow processes have alignment. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Aligned – information-flow processes is predicted.	Information-flow process alignment management
Automatility - information	Information does not have automatility	Automatility in information is inefficient and uncontrolled.	Information Automatility is planned, measured and controlled. Reduced information-flow failures associated with Automatility.	Reduced information-flow failures	Interventions to prevent information-flow failures. Automatility is predicted.	Information automatility optimisation
Automatility – information-flow processes	Information-flow processes do not have automatility	Information-flow processes have basic automatility. However, these processes are	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Automatility – information-flow process is predicted.	Information-flow automatility process management

		inefficient and uncontrolled.				
Availability - information	Information is not available	Information is available to a degree. However, the information availability is not controlled or efficient	Information Availability is planned, measured and controlled. Reduced information-flow failures associated with Availability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Availability is predicted.	Information availability optimisation
Availability – information-flow process	Information-flow process is not available	Information-flow processes have availability. However, they are uncontrolled and inefficient processes.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Availability – information-flow is predicted.	Information-flow availability process management
Capacity – information	Information does not have capacity	Information has inefficient and uncontrolled capacity.	Information Capacity is planned, measured and controlled. Reduced information-flow failures associated with Capacity.	Reduced information-flow failures	Interventions to prevent information-flow failures. Capacity is predicted.	Information capacity optimisation
Capacity – information-flow process	Information-flow does not have capacity	Information-flow processes have capacity. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Capacity – information-flow process is predicted.	Information-flow capacity process management

Compatibility – information	Information is not compatible	Information has compatibility. However, it is uncontrolled and inefficient.	Information Compatibility is planned, measured and controlled. Reduced information-flow failures associated with Compatibility.	Reduced information-flow failures	Interventions to prevent information-flow failures. Compatibility is predicted.	Compatibility information optimisation
Compatibility – information-flow process	Information-flow process is not compatible	Information-flow processes have compatibility. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Compatibility – information-flow process is predicted.	compatibility information-flow process management
Completeness – information	Information is not complete	Information has completeness. However, this is unpredictable and inefficient.	Information Completeness is planned, measured and controlled. Reduced information-flow failures associated with Completeness.	Reduced information-flow failures	Interventions to prevent information-flow failures. Completeness is predicted.	Completeness information optimisation
Completeness – information-flow processes	Information-flow process is not complete	Information-flow processes have completeness. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Completeness – information-flow process is predicted.	Completeness information-flow process management

Complexity - information	Information does not have complexity	Information has complexity. However, the complexity is uncontrolled and inefficient.	Information Complexity is planned, measured and controlled. Reduced information-flow failures associated with Complexity.	Reduced information-flow failures	Interventions to prevent information-flow failures. Complexity is predicted.	Complexity information optimisation
Complexity – information-flow process	Information-flow process does not have complexity	Information-flow processes have complexity. However, the processes are uncontrolled and inefficient.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Complexity – information-flow process is predicted.	Complexity information-flow process management
Confidentiality-information	Information is not confidential	Information has confidentiality. However, the confidentiality is uncontrolled and inefficient.	Information Confidentiality is planned, measured and controlled. Reduced information-flow failures associated with Confidentiality.	Reduced information-flow failures	Interventions to prevent information-flow failures. Confidentiality is predicted.	Information confidentiality optimisation
Confidentiality – information-flow process	Information-flow process is not confidential	Information-flow processes have confidentiality. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Confidentiality – information-flow process is predicted.	Information-flow confidentiality process management

Concise – information	Information is not concise	Information is concise. However, it is uncontrolled and inefficient.	Information Concise is planned, measured and controlled. Reduced information-flow failures associated with Concise.	Reduced information-flow failures	Interventions to prevent information-flow failures. Concise is predicted.	Information concise management
Concise – information-flow process	Information-flow process is not concise	Information-flow process are concise. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Concise – information-flow process is predicted.	Information-flow concise process management
Consistency - information	Information is not consistent	Information is consistent. However, it is uncontrolled and inefficient.	Information Consistency is planned, measured and controlled. Reduced information-flow failures associated with Consistency.	Reduced information-flow failures	Interventions to prevent information-flow failures. Consistency is predicted.	Information consistency optimisation
Consistency – information-flow process	Information-flow process is not consistent	Information-flow processes are consistent. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Consistency – information-flow process is predicted.	Information-flow consistency process management
Correlated - information	Information is not correlated	Information has correlation. However, the correlation is	Information Correlated is planned, measured and controlled. Reduced information-flow failures	Reduced information-flow failures	Interventions to prevent information-flow failures. Correlated is predicted.	Information correlation optimisation

		unpredictable and uncontrolled.	associated with Correlated.			
Correlated – information-flow process	Information-flow process is not correlated	Information-flow processes are correlated. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Correlated – information-flow process is predicted.	Information-flow correlation management
Effectiveness - information	Information is not effective	Information is effective. However, the effectiveness is not controlled or predicted.	Information Effectiveness is planned, measured and controlled. Reduced information-flow failures associated with Effectiveness.	Reduced information-flow failures	Interventions to prevent information-flow failures. Effectiveness is predicted.	Information effectiveness optimisation
Effectiveness – information-flow process	Information-flow process is not effective	Information-flow processes have effectiveness. However, they are not controlled or predicted.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Effectiveness – information-flow process is predicted.	Information-flow effectiveness process management
Efficiency - information	Information is not efficient	Information has efficiency. However, it is not controlled or predicted.	Information Efficiency is planned, measured and controlled. Reduced information-flow failures associated with Efficiency.	Reduced information-flow failures	Interventions to prevent information-flow failures. Efficiency is predicted.	Information efficieny optimisation

Efficiency – information-flow process	Information-flow process is not efficient	Information-flow processes are efficient. However, these processes are not controlled or predictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Efficiency – information-flow process is predicted.	Information-flow efficiency process management
Evidence - information	Information does not have evidence	Information has evidence. However, the evidence is uncontrolled or predictable.	Information Evidence is planned, measured and controlled. Reduced information-flow failures associated with Evidence.	Reduced information-flow failures	Interventions to prevent information-flow failures. Evidence is predicted.	Information evidence optimisation
Evidence – information-flow process	Information-flow process does not have evidence	Information-flow processes have evidence. However, these processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Evidence – information-flow process is predicted.	Information-flow evidence process management
Flexibility-information	Information is not flexible	Information is flexible. However, it is uncontrolled and unpredictable.	Information Flexibility is planned, measured and controlled. Reduced information-flow failures associated with Flexibility.	Reduced information-flow failures	Interventions to prevent information-flow failures. Flexibility is predicted.	Information flexibility optimisation
Flexibility – information-flow process	Information-flow process is not flexible	Information-flow processes are flexible. However, these processes are	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Flexibility – information-flow process is predicted.	Information-flow flexibility process management

		uncontrolled and unpredictable.				
Formality-information	Information does not have formality	Information has formality. However, it is uncontrolled and unpredictable.	Information Formality is planned, measured and controlled. Reduced information-flow failures associated with Formality.	Reduced information-flow failures	Interventions to prevent information-flow failures. Formality is predicted.	Information formality optimisation
Formality – information-flow process	Information-flow process does not have formality	Information-flow processes have formality. However, these processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Formality – information-flow process is predicted.	Information-flow formality process management
Generality - information	Information does not have generality	Information has generality. However, the information is still inefficient and the generality is uncontrolled and unpredictable.	Information Generality is planned, measured and controlled. Reduced information-flow failures associated with Generality.	Reduced information-flow failures	Interventions to prevent information-flow failures. Generality is predicted.	Information generality optimisation
Generality – information-flow process	Information-flow process does not have generality	Information-flow processes have generality. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Generality – information-flow process is predicted.	Information-flow generality process management

Implantability-information	Information does not have implantability	Information has implantability. However, the information is still inefficient and the implantability is uncontrolled.	Information Implantability is planned, measured and controlled. Reduced information-flow failures associated with Implantability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Implantability is predicted.	Information implantability optimisation
Implantability - information-flow process	Information-flow process do not have implantability	Information-flow processes have implantability. However, these processes are inefficient and unconrtrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Implantability -information-flow process is predicted.	Information-flow implantability process management
Improvability-information	Information does not have improvability	Information has improvability. However, it is uncontrolled.	Information Improvability is planned, measured and controlled. Reduced information-flow failures associated with Improvability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Improvability is predicted.	Information improvablity optimisation
Improvability – information-flow process	Information-flow process does not have improvability	Information-flow processes have improvability. However, these processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Improvability – information-flow process is predicted.	Information-flow improvability process management

Interoperability-information	Information is not interoperable	Information has interoperability. However, the information is still inefficient and interoperability is uncontrolled.	Information Interoperability is planned, measured and controlled. Reduced information-flow failures associated with Interoperability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Interoperability is predicted.	Information interoperability optimisation
Interoperability-information-flow process	Information-flow process is not interoperable.	Information-flow processes have interoperability. However, these processes are still inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Interoperability-information-flow process is predicted.	Information-flow interoperability process management
Interpretability-information	Information is not interpretable	Information is interpretable. However, it is still inefficient and uncontrolled.	Information Interpretability is planned, measured and controlled. Reduced information-flow failures associated with Interpretability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Interpretability is predicted.	Information interpretability optimisation
Interpretability – information-flow process	Information-flow process is not interpretable.	Information-flow processes are interpretable. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Interpretability – information-flow process is predicted.	Information-flow interpretability process management

Latency - information	Information has no latency	Information has latency. However, the information is inefficient and uncontrolled.	Information Latency is planned, measured and controlled. Reduced information-flow failures associated with Latency.	Reduced information-flow failures	Interventions to prevent information-flow failures. Latency is predicted.	Information latency optimisation
Latency- information-flow process	Information-flow process has no latency	Information-flow processes have latency. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Latency- information-flow process is predicted.	Information-flow latency process management
Longevity – information	Information does not have longevity	Information has longevity. However, it is uncontrolled and unpredictable.	Information Longevity is planned, measured and controlled. Reduced information-flow failures associated with Longevity.	Reduced information-flow failures	Interventions to prevent information-flow failures. Longevity is predicted.	Information longevity optimisation
Longevity – information-flow process	Information-flow process does not have longevity	Information-flow processes have longevity. However, these processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Longevity – information-flow process is predicted.	Information-flow longevity process management
Maintainability-information	Information does not have maintainability	Information has maintainability. However, it is	Information Maintainability is planned, measured and controlled. Reduced information-flow failures	Reduced information-flow failures	Interventions to prevent information-flow failures. Maintainability is predicted.	Maintainability information optimisation

		uncontrolled and inefficient.	associated with Maintainability.			
Maintainability – information-flow process	Information-flow process does not have maintainability	Information-flow processes have maintainability. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Maintainability – information-flow process is predicted.	Information-flow maintainability process management
Measurability-information	Information does not have measurability	Information has measurability. However, it is inefficient.	Information Measurability is planned, measured and controlled. Reduced information-flow failures associated with Measurability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Measurability is predicted.	Information measurability optimisation
Measurability-information-flow process	Information-flow process does not have measurability	Information-flow process has measurability. However, it is inefficient and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Measurability-information-flow process is predicted.	Information-flow measurability process management
Mobility-information	Information does not have mobility	Information has mobility. However, it is uncontrolled and inefficient.	Information Mobility is planned, measured and controlled. Reduced information-flow failures associated with Mobility.	Reduced information-flow failures	Interventions to prevent information-flow failures. Mobility is predicted.	Information mobility optimisation

Mobility- information-flow process	Information-flow process does not have mobility	Information-flow processes have mobility. However, these processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Mobility- information-flow process is predicted.	Information-flow mobility process management
Modularity-information	Information does not have modularity	Information has modularity. Information is not efficient. Modularity is not controlled.	Information Modularity is planned, measured and controlled. Reduced information-flow failures associated with Modularity.	Reduced information-flow failures	Interventions to prevent information-flow failures. Modularity is predicted.	Information modularity optimisation
Modularity-information-flow process	Information-flow process does not have modularity	Information-flow processes have modularity. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Modularity-information-flow process is predicted.	Information-flow modularity process management
Mutability-information	Information does not have mutability	Information has mutability. The mutability is not controlled.	Information Mutability is planned, measured and controlled. Reduced information-flow failures associated with Mutability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Mutability is predicted.	Information mutability optimisation
Mutability-information-flow process	Information-flow process does not have mutability	Information-flow processes have mutability. However, these processes are inefficient.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Mutability-information-flow process is predicted.	Information-flow mutability process management

Operability-information	Information does not have operability	Information has operability. Operability is not controlled.	Information Operability is planned, measured and controlled. Reduced information-flow failures associated with Operability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Operability is predicted.	Information operability optimisation
Operability-information-flow process	Information-flow process does not have operability	Information-flow processes have operability. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Operability-information-flow process is predicted.	Information-flow operability process management
Orthogonality-information						
Orthogonality-information-flow process						
Ownable-information	Information is not ownable	Information is ownable. Information is not controlled or predictable.	Information Ownable is planned, measured and controlled. Reduced information-flow failures associated with Ownable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Ownable is predicted.	Information ownable optimisation
Ownable-information-flow process	Information-flow process is not ownable	Information-flow processes are ownable. However, these processes are	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Ownable-information-flow process is predicted.	Information-flow ownable process managment

		inefficient and uncontrolled.				
Performance-information	Information does not have performance	Information has performance. Performance is not controlled or predictable.	Information Performance is planned, measured and controlled. Reduced information-flow failures associated with Performance.	Reduced information-flow failures	Interventions to prevent information-flow failures. Performance is predicted.	Information performance optimisation
Performance - information-flow process	Information-flow process does not have performance	Information-flow processes have performance. These processes are not efficient or predictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Performance -information-flow process is predicted.	Information-flow performance process management
Portability - information	Information does not have portability	Information is portable. Portability is not controlled or efficient.	Information Portability is planned, measured and controlled. Reduced information-flow failures associated with Portability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Portability is predicted.	Portability information optimisation
Portability - information-flow process	Information-flow process does not have portability	Information-flow processes have portability. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Portability -information-flow process is predicted.	Information-flow portability process management

Progress ability – information	Information does not have progress ability	Information has progressability. Progressability is not controlled or predictable.	Information Progress ability is planned, measured and controlled. Reduced information-flow failures associated with Progress ability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Progress ability is predicted.	Information progressability optimisation
Progress ability – information-flow process	Information-flow process does not have progress ability	Information-flow processes have progress ability. These process are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Progress ability – information-flow process is predicted.	Information-flow process progress ability management
Quality – information	Information does not have quality	Information has quality. The quality is not predictable.	Information Quality is planned, measured and controlled. Reduced information-flow failures associated with Quality.	Reduced information-flow failures	Interventions to prevent information-flow failures. Quality is predicted.	Information quality optimisation
Quality – information-flow process	Information-flow process does not have quality	Information-flow processes have quality. These processes are not predictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Quality – information-flow process is predicted.	Information-flow quality process management
Quantifiability - information	Information is not quantifiable	Information is quantifiable. Quantifiable information not predictable.	Information Quantifiability is planned, measured and controlled. Reduced information-flow failures	Reduced information-flow failures	Interventions to prevent information-flow failures. Quantifiability is predicted.	Information Quantifiability optimisation

			associated with Quantifiability.			
Quantifiability – information-flow process	Information-flow process is not quantifiable	Information-flow processes are quantifiable. These processes are not predictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Quantifiability – information-flow process is predicted.	Information-flow Quantifiability process management
Redundancy – information	Information does not have redundancy	Information has redundancy. Redundancy is not controlled or efficient.	Information Redundancy is planned, measured and controlled. Reduced information-flow failures associated with Redundancy.	Reduced information-flow failures	Interventions to prevent information-flow failures. Redundancy is predicted.	Information redundancy optimisation
Redundancy – information-flow process	Information-flow process does not have redundancy	Information-flow processes have redundancy. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Redundancy – information-flow process is predicted.	Information-flow redundancy process management
Relevance – information	Information does not have relevance	Information has relevance. Relevance is not controlled or predictable.	Information Relevance is planned, measured and controlled. Reduced information-flow failures associated with Relevance.	Reduced information-flow failures	Interventions to prevent information-flow failures. Relevance is predicted.	Information relevance optimisation

Relevance – information-flow process	Information-flow process does not have relevance	Information-flow processes have relevance. Relevance is inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Relevance – information-flow process is predicted.	Information-flow relevance process management
Reliability – information	Information does not have reliability	Information has reliability. Reliability is not controlled and unpredictable.	Information Reliability is planned, measured and controlled. Reduced information-flow failures associated with Reliability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Reliability is predicted.	Information reliability optimisation
Reliability – information-flow process	Information-flow process does not have reliability	Information-flow processes have reliability. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Reliability – information-flow process is predicted.	Information-flow reliability process management
Repairability – information	Information does not have repairability	Information have repairability. Repairability is not controlled.	Information Repairability is planned, measured and controlled. Reduced information-flow failures associated with Repairability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Repairability is predicted.	Information repairability optimisation
Repairability – information-flow process	Information-flow process does not have repairability	Information-flow processes have repairability. These processes are	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Repairability – information-flow process is predicted.	Information-flow reparability process management

		inefficient and uncontrolled.				
Repeatability - information	Information does not have repeatability	Information has repeatability. Repeatability is unpredictable.	Information Repeatability is planned, measured and controlled. Reduced information-flow failures associated with Repeatability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Repeatability is predicted.	Information repeatability optimisation
Repeatability – information-flow process	Information-flow process does not have repeatability	Information-flow processes have repeatability. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Repeatability – information-flow process is predicted.	Information-flow repeatability process management
Safety – information	Information does not have safety	Information has safety. Safety is not controlled and is inefficient.	Information Safety is planned, measured and controlled. Reduced information-flow failures associated with Safety.	Reduced information-flow failures	Interventions to prevent information-flow failures. Safety is predicted.	Information safety optimisation
Safety – information-flow process	Information-flow process does not have safety	Information-flow processes have safety. These processes are uncontrolled and inefficient.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Safety – information-flow process is predicted.	Information-flow safety process management

Security – information	Information does not have security	Information has security. Security is not controlled or predictable.	Information Security is planned, measured and controlled. Reduced information-flow failures associated with Security.	Reduced information-flow failures	Interventions to prevent information-flow failures. Security is predicted.	Information security optimisation
Security – information-flow process	Information-flow process does not have security	Information-flow processes have security. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Security – information-flow process is predicted.	Information-flow security process management
Self-descriptiveness - information	Information does not have self-descriptiveness	Information has self-descriptiveness. Self-descriptiveness is not controlled or predictable.	Information Self-descriptiveness is planned, measured and controlled. Reduced information-flow failures associated with Self-descriptiveness.	Reduced information-flow failures	Interventions to prevent information-flow failures. Self-descriptiveness is predicted.	Information self-descriptiveness optimisation
Self-descriptiveness – information-flow process	Information-flow process does not have self-descriptiveness	Information-flow processes have self descriptiveness. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Self-descriptiveness – information-flow process is predicted.	Information-flow Self-descriptiveness process management
Sensitivity - information	Information does not have sensitivity	Information has sensitivity. Sensitivity	Information Sensitivity is planned, measured and controlled. Reduced information-flow failures	Reduced information-flow failures	Interventions to prevent information-flow failures. Sensitivity is predicted.	Information sensitivity optimisation

		is uncontrolled and unpredictable.	associated with Sensitivity.			
Sensitivity – information-flow process	Information-flow process does not have sensitivity	Information-flow processes have sensitivity. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Sensitivity – information-flow process is predicted.	Information-flow sensitivity process management
Serviceability - information	Information does not have serviceability	Information has serviceability. Serviceability is not controlled or efficient.	Information Serviceability is planned, measured and controlled. Reduced information-flow failures associated with Serviceability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Serviceability is predicted.	Information serviceability optimisation
Serviceability – information-flow process	Information-flow process does not have serviceability	Information-flow processes have serviceability. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Serviceability – information-flow process is predicted.	Information-flow serviceability process management
Simplicity – information	Information does not have simplicity	Information has simplicity. Simplicity is not controlled or efficient.	Information Simplicity is planned, measured and controlled. Reduced information-flow failures associated with Simplicity.	Reduced information-flow failures	Interventions to prevent information-flow failures. Simplicity is predicted.	Information simplicity optimisation

Simplicity-information-flow process	Information-flow process does not have simplicity	Information-flow processes have simplicity. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Simplicity-information-flow process is predicted.	Information-flow simplicity process management
Sociability- information	Information does not have sociability	Information has sociability. Sociability is not controlled.	Information Sociability is planned, measured and controlled. Reduced information-flow failures associated with Sociability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Sociability is predicted.	Information sociability optimisation
Sociability-information-flow process	Information-flow process does not have sociability	Information-flow processes have sociability. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Sociability-information-flow process is predicted.	Information-flow sociability process management
Soundness-information	Information does not have soundness	Information has soundness. Soundness is not predictable.	Information Soundness is planned, measured and controlled. Reduced information-flow failures associated with Soundness.	Reduced information-flow failures	Interventions to prevent information-flow failures. Soundness is predicted.	Information soundness optimisation
Soundness-information-flow process	Information-flow process does not have soundness	Information-flow processes have soundness. These processes are	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Soundness-information-flow process is predicted.	Information-flow soundness process management

		inefficient and uncontrolled.				
Structuredness-information	Information does not have structuredness	Information has structuredness. However, it is unpredictable.	Information Structuredness is planned, measured and controlled. Reduced information-flow failures associated with Structuredness.	Reduced information-flow failures	Interventions to prevent information-flow failures. Structuredness is predicted.	Information Structuredness optimisation
Structuredness-information-flow process	Information-flow process does not have structuredness	Information-flow processes have structuredness. These processes are unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Structuredness-information-flow process is predicted.	Information-flow Structuredness process management
Teleproximity-information						
Teleproximity-information-flow process						
Testability- information	Information does not have testability	Information has testability. Testability is not efficient.	Information Testability is planned, measured and controlled. Reduced information-flow failures associated with Testability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Testability is predicted.	Information testability optimisation

Testability-information-flow process	Information-flow process does not have testability	Information-flow processes have testability. These processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Testability-information-flow process is predicted.	Information testability process management
Timely- information	Information is not timely	Information is timely. Information is unpredictable.	Information Timely is planned, measured and controlled. Reduced information-flow failures associated with Timely.	Reduced information-flow failures	Interventions to prevent information-flow failures. Timely is predicted.	Information timely optimisation
Timely-information-flow process	Information-flow process does is not timely	Information-flow processes have timeliness. These processes are unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Timely-information-flow process is predicted.	Information-flow timely process management
Tolerance- information	Information does not have tolerance	Information has tolerance. Tolerance is not controlled.	Information Tolerance is planned, measured and controlled. Reduced information-flow failures associated with Tolerance.	Reduced information-flow failures	Interventions to prevent information-flow failures. Tolerance is predicted.	Information tolerance optimisation
Tolerance-information-flow process	Information-flow process does not have tolerance	Information-flow processes have tolerance. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Tolerance-information-flow process is predicted.	Information-flow tolerance process management

Traceability-information	Information does not have traceability	Information has traceability. Traceability is not controlled or predictable.	Information Traceability is planned, measured and controlled. Reduced information-flow failures associated with Traceability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Traceability is predicted.	Information traceability optimisation
Traceability-information-flow process	Information-flow process does not have traceability	Information-flow processes have traceability. These processes are uncontrolled and unpredictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Traceability-information-flow process is predicted.	Information-flow traceability process management
Transparency-information	Information does not have transparency	Information has transparency. Transparency is inefficient.	Information Transparency is planned, measured and controlled. Reduced information-flow failures associated with Transparency.	Reduced information-flow failures	Interventions to prevent information-flow failures. Transparency is predicted.	Information transparency optimisation
Transparency-information-flow process	Information-flow process does not have transparency	Information-flow processes have transparency. These processes are inefficient and uncontrolled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Transparency-information-flow process is predicted.	Information-flow transparency process management

Understandability- information	Information does not have understandability	Information has understandability. Information is uncontrolled and unpredictable.	Information Understandability is planned, measured and controlled. Reduced information-flow failures associated with Understandability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Understandability is predicted.	Understandability information optimisation
Understandability- information-flow process	Information-flow process does not have understandability	Information-flow processes have understandability. These processes are not efficient or controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Understandability- information-flow process is predicted.	Understandability information-flow process management
Usability- information	Information does not have usability	Information has usability. Usability is not controlled or predictable.	Information Usability is planned, measured and controlled. Reduced information-flow failures associated with Usability.	Reduced information-flow failures	Interventions to prevent information-flow failures. Usability is predicted.	Information usability optimisation
Usability-information-flow process	Information-flow process does not have usability	Information-flow processes have usability.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Usability-information-flow process is predicted.	Information-flow usability process management
Validity- information	Information does not have validity	Information has validity. Validity is not controlled or predictable.	Information Validity is planned, measured and controlled. Reduced	Reduced information-flow failures	Interventions to prevent information-flow failures. Validity is predicted.	Information validy optimsiation

			information-flow failures associated with Validity.			
Validity-information-flow process	Information-flow process does not have validity	Information-flow processes have validity. These processes are not controlled or predictable.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Validity-information-flow process is predicted.	Information-flow validity optimisation
Value- information	Information does not have value	Information has value. The value is not controlled.	Information Value is planned, measured and controlled. Reduced information-flow failures associated with Value.	Reduced information-flow failures	Interventions to prevent information-flow failures. Value is predicted.	Information value optimisation
Value-information-flow process	Information-flow process does not have value	Information-flow process have value. These processes are not controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Value-information-flow process is predicted.	Information-flow value process management
Volatility- information	Information does not have volatility	Information has volatility. Volatility is not controlled.	Information Volatility is planned, measured and controlled. Reduced information-flow failures associated with Volatility.	Reduced information-flow failures	Interventions to prevent information-flow failures. Volatility is predicted.	Information volatility optimisation

Volatility-information-flow process	Information-flow process does not have volatility	Information-flow process have volatility. These processes are not controlled.	Information-flow processes are repeatable.	Reduced information-flow failures	Interventions to prevent information-flow failures. Volatility-information-flow process is predicted.	Information-flow volatility process management

Appendix D: Desk Study 1 Artefacts

TAPS Case study Results

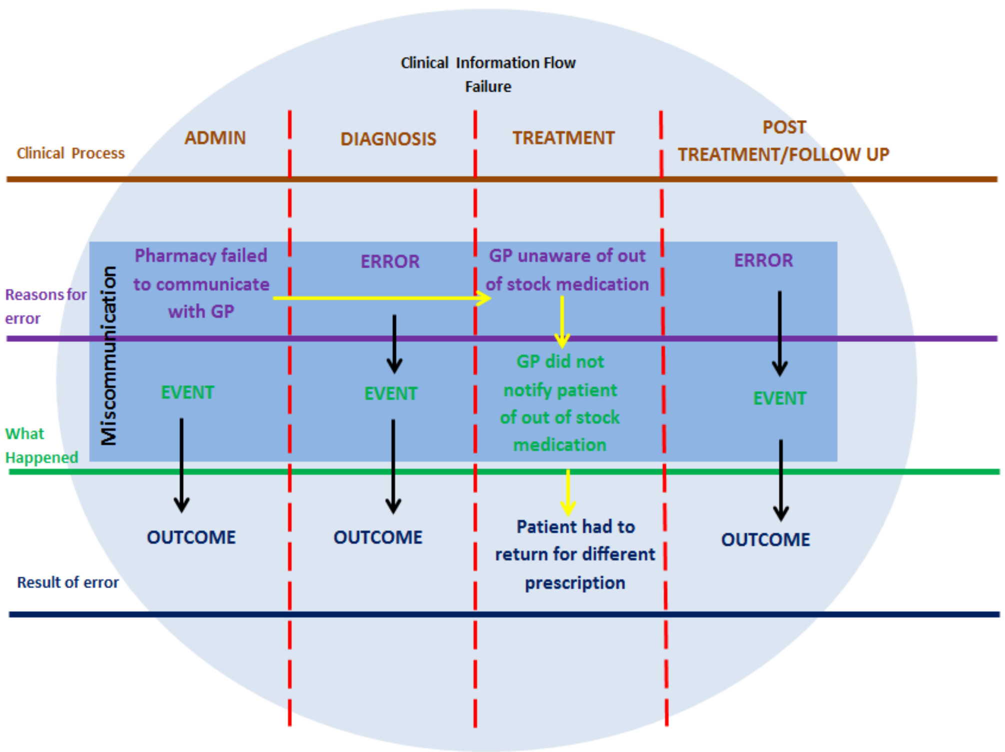
<u>TAPS Case study 1</u>

Admin - "good"

Case study # 1

Report No. 75: Topical steroid prescription item out of stock with pharmacy, GP not made aware resulting in patient having to return for different prescription.

Error Category: Admin failure



Overall Maturity Ratings:

Coverage: Level 2

Relevancy: Level 1

Usability: Level 1

Availability: Level 1

Reliability: Level 1

Security: Level 1

Quality Assurance: Level 1

Detailed Maturity Ratings:

Metric Characteristic		**Level Rating**	**Why it was given that Level Rating**
Coverage	Capacity	1	Within this information-flow there is some information present. Therefore, it has not been listed as a 0. However, more data could have been used within the information-flow to prevent the error. The pharmacy failing to communicate with the GP, and the GP not communicating with the patient are data that is missing from this information-flow. If that data was available in this information-flow the error could have been prevented. The CMM level 1 for Initial includes information-flow that is inefficient. Information-flow in Case Study #1 is inefficient; therefore, the maturity level was categorised as 1.
	Completeness	1	This is categorised as a 1, as there is some information. However, information is missing from the information-flow. Information being whole within the context and not missing, is a significant aspect and definition of the completeness quality.
	Quality	1	This information was not fit for purpose or fit for use as impacted patients' medication. The information within the information=flow was not of quality because there was missing information and lack of communication.
	Self-Descriptive	2	A retrospective view of the information-flow events depicts the information-flow failure clearly. Therefore, this has been categorised as a 2, which is Managed.
	Simplicity	2	The information-flow events were easily understood; in particular, the information-flow failure was a simple failure and not complex. Hence, Simplicity is categorised as a 2.
	Soundness	1	The information condition and robustness are present at minimum. This is because information failed to be communicated twice in this information-flow failure.
	Structured	Not enough Information	Listed as a 0 because there is not enough information in the information-flow, to suggest if the structure of the information could improve understanding and utility. Rather, the Researcher believes, there are several interventions that could be in place to prevent this error.
	Overall Coverage Level	2	Overall a level 2 for managed Coverage. Although the information was available, the failure occurred when communication between the Pharmacist to GP and GP to Patient did not occur. At current a Level 2, this information-flow case has several levels of potential improvement.
Relevancy	Aligned	0	The information-flow failure did not support the organisational goals, which is Patient care. Therefore, this is listed as a 0.

	Flexible	1	The information was able to change; however, there were some errors present.
	Generalisability	1	This information-flow failure of miscommunication and not communicating can be applied to general information-flow situations.
	Maintainability	Not enough information	There is not enough evidence in the case to suggest the information could over a time improve and meet tasks. There is a possibility for interventions to be included. However, this was not stated in the information-flow.
	Overall Relevancy level	1	Relevancy is listed as a 1, as the information was not correct, timely, current or sufficient; which is the opposite of Relevancy.
Usability	Adaptability	Not enough information	There is not sufficient information in the information-flow to suggest this information could be used in different contexts.
	Addressability	1	Although there was information-flow failure, the patient was still able to seek treatment through a different prescription.
	Compatible	Not enough information	This has been placed as a 0 as insufficient information is available. What information is required to adhere to quality frameworks and which specific frameworks.
	Complexity	1	The information was relevant to the context. However, categorised as a 1 because of lack of communication to the GP and to the Patient.
	Effectiveness	1	There is some effectiveness as the Patient was able to seek treatment in the end. This is categorised as some effectiveness qualities available.
	Efficient	0	Based on the information-flow there is no efficiency present as there was failure to communicate and to achieve desired outcomes.
	Interoperable	Not applicable	Not relevant to the current case.
	Interpretability	Not enough information	Insufficient information available to decide if the information presented to the pharmacy, GP or Patient has an interpretability quality.
	Mobility	0	Same as the efficient quality. However, in mobility, both capability and efficiency were not present.
	Modularity	Not enough information	This information-flow failure case does not show if the information could be separated.
	Operability	1	The information was not functional, reliable or fit for use. However, the Patient was able to get treatment. Therefore, some operability quality is present.
	Performance	1	As the result was the Patient being treated and the focus is Patient care, Performance has been categorised as a 1.

	Safety	1	The result was benefit to the Patient as they were treated. However, the information-flow processes were not intentionally leading to benefit as there was information-flow failure.
	Serviceable	1	Although there was information-flow failure through lack of communication, the information was useable and resulted in Patient treatment.
	Sociability	Not enough information	Insufficient information available to decide if this information could be used in other instances or contexts.
	Understandable	1	The information was understandable. The issue in this information-flow was the lack of information and lack of communication.
	Value	1	The patient was able to be treated. However, if the patient could not be treated and this impacted their care and safety, this would significantly impact the organisational goals.
	Volatility	1	The information itself did not provide value as information was missing. However, the context of the information-flow that relates to the Patient has value.
	Fit for Use	1	Some of the information was fit for use as the Patient was able to get a different type of medication.
	Functionality	1	The result was the patient receiving treatment. Therefore, a 1 was categorised.
	Overall Usability Level	1	Overall Usability level is a 1. This indicates there are some basic qualities of usability found in the information-flow case. Additionally, the clinical outcome resulted in the Patient being treated. However, the information-flow points to treatment were lacking information and had contained miscommunication. Therefore, this usability is uncontrolled, unpredictable and inefficient.
Availability	Accessibility	1	Information was present. However, it is missing.
	Latency	Not enough information	Information providing the response time of the information-flow points are not available.
	Overall Availability Level	1	Some qualities of information availability were present. However, these were at a minimum, with the qualities being uncontrolled, unpredictable and inefficient.
Reliability	Accuracy	1	The information was not 100% free from errors. There were some accurate qualities available as the lack of medication available was rectified through use of a different medication.
	Consistency	0	The information quality was not consistent within the information-flow.
	Portability	Not enough information	Not enough information is available.
	Redundancy	0	No interventions were listed.

	Repairability	Not enough information	Insufficient information stating what could have been done to prevent this error.
	Repeatability	Not enough information	The information-flow contained errors. There is insufficient information to show this same outcome would occur without impacting patient care or safety.
	Sensitivity	1	Miscommunication and lack of communication resulted in information-flow failure.
	Timely	Not enough information	Insufficient information to state the information was provided in a timely manner.
	Tolerance	Not enough information	Not enough information present to measure the limit to which the information-flow points fail.
	Validity	1	The result was for the patient to get a different prescription. It appears that the patient accepted this information as they received a different prescription.
	Trust	1	The information was not reliable or at a satisfactory/ acceptable level. However, there are measures of trust through the GP trusted the Pharmacy information and Patient trusted the GPs information. However, this information was incorrect; therefore, Trust is measured at Level 1.
	Longevity	Not enough information	Difficult to measure. Not enough information.
	Overall Reliability Level	1	Some reliability qualities are present. However, it is at a minimum, with information-flow unpredictable and inefficient.
Security	Confidentiality	1	Information was available to individuals with correct access. This was at a minimum.
	Formality	Not enough information	Not information such as which standards and quality frameworks. Therefore, difficult to measure.
	Overall Security level	1	Some security qualities were present at a minimum.
Quality Assurance	Automobility	Not enough information	No evidence to show the information is automated.
	Implantability	Not enough information	No evidence to show interventions were placed.
	Improvability	Not enough information	No evidence to show any improvement.
	Mutability	Not relevant	Not relevant to this information-flow case.
	Progress	Not enough information	No evidence to show that progress was being made in the information-flow.

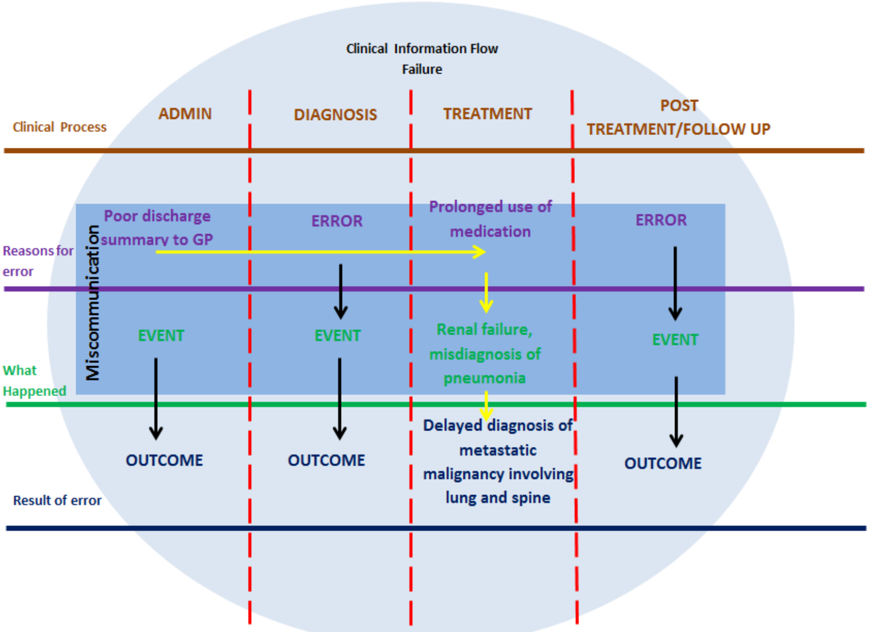
	Testable	Not enough information	No evidence to show that information points were being tested for failure.
	Correlated	1	The information is depended on one another. The lack of communication impacted the information-flow points.
	Evidence	Not enough information	Insufficient information available to show statistics.
	Measurability	1	Some qualities can be given a capability maturity level rating. This is a quantifiable measurement. However, the way the level is measured is subjective and qualitative.
	Ownable	Not enough information	Insufficient information regarding if the information was ownable or the information-flow was accountable.
	Quantifiable	1	Similar to Measurability. Some qualities could be given a capability maturity rating level. However, from the information-flow case, there is insufficient information to measure certain qualities.
	Traceability	2	The information-flow points could be mapped within the context.
	Transparency	1	Information from a information-flow mapping perspective was transparent.
	Consistency	1	The information quality was not consistent within the information-flow.
	Audit Capability	1	From the information-flow case, the qualities can be measured and then tracked to asses performance.
	Coverage Quality	1	The information at a minimum was fit for purpose and resulted in Patient treatment.
	Overall Quality Assurance Level	1	Some Quality Assurance qualities present at a minimum.

TAPS Case Study 2

Admin "bad"

Case Study # 10

Repot no. 100 Poor discharge summary information to GP resulting in prolonged use of A drug which contributed to renal failure. Misdiagnosis of pneumonia. Delayed diagnosis of metastatic malignancy involving lung and spine, primary unknown.



Overall Maturity Rating:

Coverage: Level 1

Relevancy: Level 0

Usability: Level 1

Availability: Level 0

Reliability: Level 0

Security: Level 1

Quality Assurance: Level 1

Detailed Maturity Rating:

Metric Characteristic	Level Rating	Why it was given that Level Rating

Coverage	Capacity	1	Some information capacity quality is identifiable within the information-flow. However, information is missing such as the primary is unknown.
	Completeness	1	A lot of information is incomplete. As there is some information, this is rated a 1.
	Quality	0	Rating as a 0 as there is no evidence that the poor discharge summary was fit for purpose of use. In fact, the poor discharge summary resulted in prolonged medication use and renal failure for the patient.
	Self-Descriptive	1	Some of information is self-descriptive. However, there is missing information such as the primary unknown and what exactly about the discharge summary was poor. These are not self-descriptive statements and suggest there is not enough information within this information-flow context.
	Simplicity	0	As with quality, the information within this information-flow did not contain the quality simplicity. This justification is because the summary was poor; therefore, the GP could not understand it.
	Soundness	Not enough information	Not enough information available to suggest the information was robust or sound.
	Structured	0	No evidence within the information-flow to suggest that the information had a structured quality to improve understanding and utility.
	Overall Coverage Level	1	Rated a Level 1, as there are some information qualities for coverage. However, a lot of the qualities of coverage could not be found within this information-flow context because of the lack of evidence, which can be possibility linked to the information-flow failure.
Relevancy	Aligned	0	No evidence to suggest the information was correct and supported organisational goals.
	Flexible	0	The information-flow context had several errors. Therefore, this is marked as a 0.
	Generalisability	Not enough information	Not enough information to suggest this could be applied anywhere.
	Maintainability	0	No evidence to show the information could improve over time. The information-flow showed repeat failures which resulted in harm for the patient.
	Overall Relevancy level	0	No evidence to support any Relevancy qualities in the information-flow.
Usability	Adaptability	Not enough information	No evidence to suggest the information has adaptability.
	Addressability	Not enough information	The information was unable to respond to external or internal factors.

	Compatible	0	As this error caused prolonged medication use, I can assume it did not adhere to quality frameworks.
	Complexity	1	Some of the information was relevant to the context.
	Effectiveness	0	No evidence of effectiveness within the context.
	Efficient	0	No evidence of the information being efficient.
	Interoperable	0	No evidence of the information being interoperable.
	Interpretability	0	The discharge summary was poor. Therefore, it could not be understood.
	Mobility	0	No evidence of Mobility.
	Modularity	0	No evidence of Modularity.
	Operability	0	No evidence of the information being functional, reliable, or fit for use.
	Performance	0	Marking performance as a 0 as through the information-flow there were errors or patient harm.
	Safety	0	Marking performance as a 0 as the patient did not experience any benefit.
	Serviceable	0	The information within the discharge summary was not usable.
	Sociability	Not enough information	Not enough information available.
	Understandable	0	The discharge summary was poor and not understandable.
	Value	0	Marking as a 0 as it did not provide Value to the patient or the organisational goals. However, the information involved within the information-flow is highly valuable as it impacted patient safety.
	Volatility	0	Similar to Value, this information-flow did not result in value to organisational goals.
	Fit for Use	0	No evidence to suggest fit for use.
	Functionality	0	The information was not fit for use and did not server organisational goals.
	Overall Usability Level	1	There were several qualities that were listed as a 0 for non-existent. However, as there were some usability qualities present in the information-flow, this has resulted in a 1 rating and shows Usability as uncontrolled, unpredictable, and inefficient.
Availability	Accessibility	Not enough information	Not enough information to suggest it was available in the correct locations and accessible.

	Latency	Not enough information	No evidence to suggest the information-flow response time was adequate.
	Overall Availability Level	Not enough information	No evidence to suggest availability as a quality.
Reliability	Accuracy	0	The information was not accurate or free from errors.
	Consistency	0	No information consistency evident.
	Portability	0	Information flow failure was present throughout the context.
	Redundancy	Not enough information	No evidence of interventions.
	Repairability	0	Not enough information to suggest with a different context or with different individuals would this same error occur.
	Repeatability	0	There were several errors present.
	Sensitivity	0	The information caused errors. Therefore, the sensitivity was non-existent.
	Timely	Not enough information	Not enough information to suggest the information was timely.
	Tolerance	0	The information-flow points failed. No Tolerance present.
	Validity	Not enough information	Not enough information to suggest there was validity.
	Trust	0	No trust quality present. The information was not reliable, satisfactory, or acceptable.
	Longevity	Not enough information	Not enough information available.
	Overall Reliability Level	0	No reliability qualities were found within the information-flow. Therefore, this is marked as a 0.
Security	Confidentiality	Not enough information	No information to suggest the information was available to individuals who should not have it.
	Formality	1	If this is about information security frameworks, then there is no evidence to suggest it did not. Therefore, marking as a 1.
	Overall Security level	1	Rated a level 1, because there is no information to suggest no security qualities or any violation of confidentiality.
Quality Assurance	Automobility	0	The information was not automated.
	Implantability	0	No interventions present.

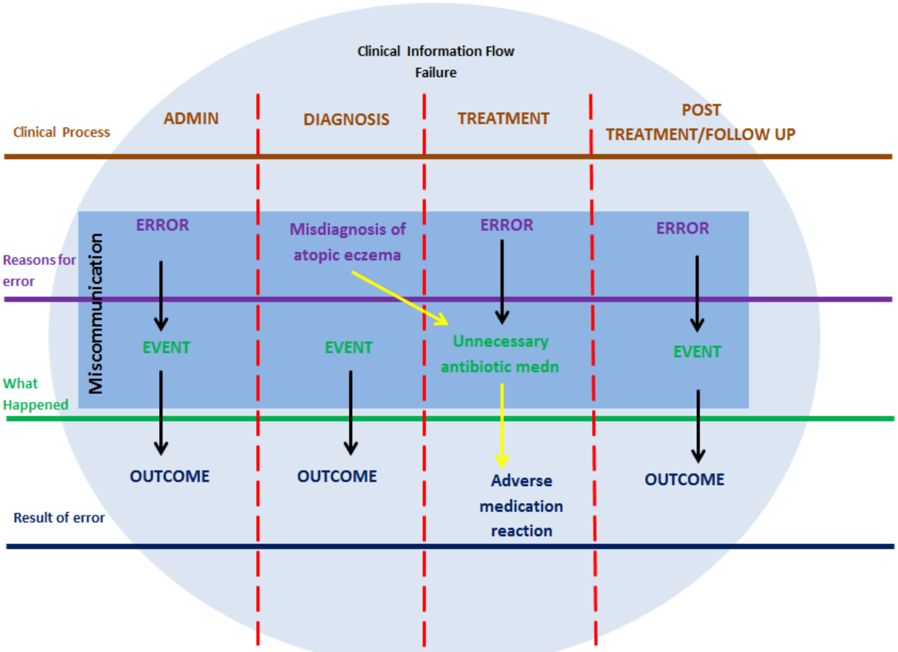
	Improvability	0	The information did not improve any artefact.
	Mutability	0	The information did not change structure.
	Progress	Not enough information	No evidence to suggest anything was improved or matured.
	Testable	Not enough information	Not enough information available.
	Correlated	1	The information was dependent on one another. However, because it was dependent, it resulted in patient harm.
	Evidence	Not enough information	Not enough information available.
	Measurability	Not enough information	Not enough information available.
	Ownable	Not enough information	Not enough information available.
	Quantifiable	1	The information can be measured though the capability maturity model.
	Traceability	1	The information-flow could be traced and mapped.
	Transparency	1	The information could be mapped as it was transparent.
	Consistency	0	No information quality consistency.
	Audit Capability	1	Information was able to be reported on.
	Coverage Quality	0	The information was not fit for purpose.
	Overall Quality Assurance Level	1	Some Quality Assurance qualities were present. However, the majority of the Quality Assurance qualities could not be measured as there was insufficient information available in the information-flow context.

TAPS Case Study 3

Diagnosis “good”

Case Study # 72

Report no 274 Misdiagnosis of atopic eczema resulting in patient experiencing adverse effects of unnecessary antibiotic medication



Metric Characteristic		Level rating	Why it was given that rating
Coverage	Capacity	1	Rated as a 1 it does not specify what caused the misdiagnosis. Was it poor information? Incorrect or missing information? Could be more data in this context that could have potentially prevented the error?
	Completeness	1	Rated as a 1 as more information could be included to complete the context. Based on the error, it was a diagnosis error rather than a information-flow failure. However, there is insufficient information to state whether this was caused by information.
	Quality	0	The information quality was not fit for purpose or use because an adverse reaction occurred because of the misdiagnosis.
	Self-Descriptive	1	The information is self-explanatory to an extent. However, it could cover more. Eg. What adverse reaction.
	Simplicity	1	From what we know in that information-flow, the information can be understood. However, looking further, I do question, did the clinician have simplicity when looking at patient

			records or communicating to the patient. I think these are factors that may need to be considered as influencing.
	Soundness	1	Marking as 1 as the information condition was basic.
	Structured	Not enough information	Not enough information to state the information within the context could improve unstanding and utility.
	Overall Coverage Level	1	Overall a level 1. Not surprisingly as it was a misdiagnosis and resulted in an adverse reaction of the patient. As reflected in the capability maturity model, some coverage characteristics are present. Overall uncontrolled and inefficient information-flow because of the misdiagnosis and patient impact.
Relevancy	Aligned	0	A misdiagnosis and adverse reaction to a patient do not support the goals of the GP system.
	Flexible	Insufficient information	Insufficient information to state that this information in the information-flow could change with limited errors.
	Generalisability	Insufficient information	In theory misdiagnosis and adverse reactions could be applied to a variety of scenarios. However, there is insufficient information to state it could do so.
	Maintainability	Not relevant	This quality is not relevant as it cannot be measured in this information-flow case.
	Overall Relevancy level	0	Rated as 0 for no relevancy qualities measurable in the information-flow case.
Usability	Adaptability	Insufficient information	Similar to generalisability
	Addressability	Not relevant	Not relevant to the situation
	Compatible	0	Misdiagnosis does not adhere to quality frameworks.
	Complexity	Not relevant	Structure is not relevant to this information-flow case.
	Effectiveness	1	The failure was misdiagnosis and not the information within the information-flow.
	Efficient	1	Misdiagnosis was the failure. Not applicable to the efficiency of the information within the information-flow.
	Interoperable	Not relevant.	Not relevant to the information-flow case
	Interpretability	Insufficient information	Not enough information available to suggest the misdiagnosis was caused by interpretability of information.

	Mobility	1	This information would have been efficient if the diagnosis was correct.
	Modularity	0	The information cannot be separated in this information-flow case.
	Operability	0	If the diagnosis was correct, the information-flow could have been functional, reliable and fit for use. As it was not, marking as 0.
	Performance	1	Overall performance is a 1 because of the misdiagnosis.
	Safety	0	There was no benefit to the patient as an adverse reaction occurred.
	Serviceable	0	The information was not usable because of the misdiagnosis.
	Sociability	Not relevant	Not relevant to the information-flow case.
	Understandable	Insufficient information	Not enough information to state that the information that lead to diagnosis was comprehensible.
	Value	0	Marked as a 0 as this information-flow resulted in a patient adverse reaction. Therefore, the information had no value.
	Volatility	0	Similar to Value.
	Fit for Use	1	The information appears to be available, to the right person at the right time and right format. However, this overall was not fit for use as it was a misdiagnosis.
	Functionality	0	This situation did not server the organismal goals.
	Overall Usability Level	Level 1	Resulting in a level 1, as many of the qualities were a 0 or had insufficient information or were not relevant to the case.
Availability	Accessibility	1	The information-flow does not state it was incorrect.
	Latency	Insufficient information	Marked with insufficient information as it cannot be measured.
	Overall Availability Level	Level 1	Some availability qualities present.
Reliability	Accuracy	0	The misdiagnosis resulted in the wrong information for treatment.
	Consistency	0	The information quality was not consistent.
	Portability	0	Information could not be used in treatment.

	Redundancy	0	None mentioned
	Repairability	0	Not measurable in the information-flow
	Repeatability	Insufficient information	Insufficient information available to state if this could happen again.
	Sensitivity	Not relevant	The failure was misdiagnosis.
	Timely	0	The diagnosis was not relevant to the patient
	Tolerance	1	Rated as a 1 as if the diagnosis was correct, the information flow points would not fail.
	Validity	0	The source is supposed to be valid. However, this did not result in quality of acceptability.
	Trust	0	The information was not reliable or at a satisfactory level.
	Longevity	Not relevant.	
	Overall Reliability Level	Level 1	Many of the qualities were listed as a 0 for not present. Therefore, a level 1 has been calculated.
Security	Confidentiality	Not relevant	Not relevant to the information-flow case.
	Formality	Not relevant	Not relevant to the information flow case.
	Overall Security level	Not relevant	This measurement was not relevant to the information-flow case
Quality Assurance	Automobility	Insufficient information	Not enough information available
	Implantability	Insufficient information	Not enough information available
	Improvability	Insufficient information	Not enough information available
	Mutability	Insufficient information	Not enough information available
	Progress	Insufficient information	Not enough information available
	Testable	Insufficient information	Not enough information available
	Correlated	1	The information was dependent on one another. However, as this resulted in a failure, it is categorised as 1.

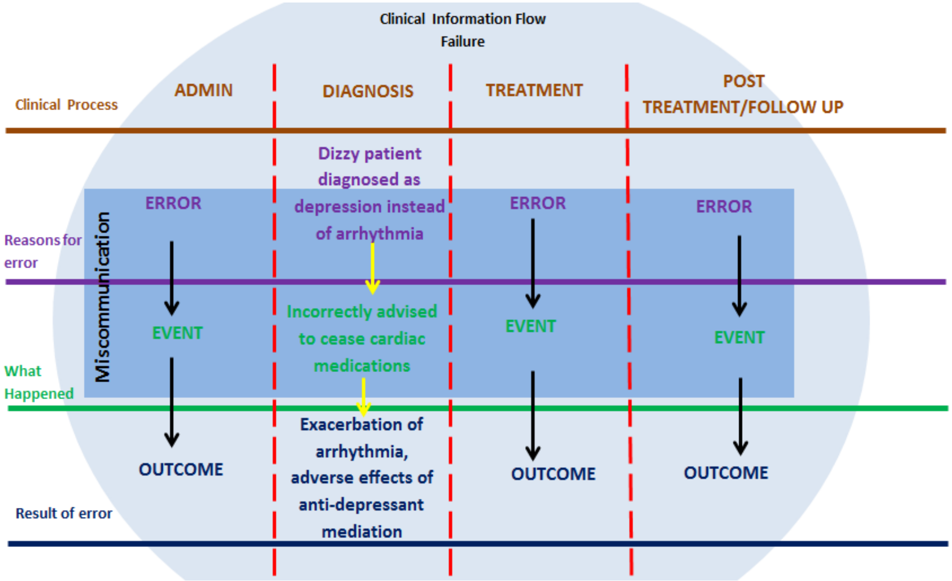
	Evidence	1	Information regarding this information-flow case is available.
	Measurability	1	To some extent this information-flow case data qualities can be measured.
	Ownable	Insufficient information	Not enough information available
	Quantifiable	1	To some extent this information-flow case data qualities can be quantifiable.
	Traceability	1	The information-flow could be mapped.
	Transparency	1	The information-flow was transparent.
	Consistency	0	The information quality was not consistent.
	Audit Capability	1	The information performance can be tracked and reported on.
	Coverage Quality	0	The information was incorrect because of the misdiagnosis.
	Overall Quality Assurance Level	Level 1	Some qualities are available for quality assurance.

TAPS Case Study 4

Diagnosis “bad”

Case Study # 148

Report no 249 Dizzy patient incorrectly diagnosed as depression rather than arrhythia patient incorrectly advised to cease cardiac medications causing hypertension and exacerbation of arrhythmia, adverse effects of antidepressant medication .



Metric Characteristic		Level Rating	Why it was given that Level Rating
Coverage	Capacity	1	Incorrect diagnosis. Not enough information to state what caused the incorrect diagnosis.
	Completeness	1	Information is missing from the information-flow case
	Quality	0	The information was not fit for purpose or use as the diagnosis was incorrect, incorrect medication prescribed and adverse medication effects impacted the patient.
	Self-Descriptive	Not relevant	Not relevant to the information-flow
	Simplicity	1	The information-flow events are understandable. However, there is insufficient information regarding if the information relating to diagnosis was understandable.
	Soundness	0	Information was not sound as it was incorrect.
	Structured	Insufficient information	Not enough information to state if the information could improve understanding and utility.
	Overall Coverage Level	Level 1	Information is unpredictable, uncontrolled and results in errors.
Relevancy	Aligned	0	Does not support organisational goals, as resulted in misdiagnosis and patient impacted.
	Flexible	0	The information could not change with limited errors.
	Generalisability	Insufficient information	Not enough information to state the same result would occur.

	Maintainability	Not relevant	Not relevant to this information-flow case.
	Overall Relevancy level	Level 0	No relevancy qualities found in this information-flow case.
Usability	Adaptability	Insufficient information	Insufficient information
	Addressability	0	The information could not respond to patient medication information.
	Compatible	0	Did not adhere to quality frameworks
	Complexity	Not relevant	Not relevant to the context
	Effectiveness	0	Not effective as there were several errors.
	Efficient	0	Not efficient as there were several errors
	Interoperable	Not relevant	Not relevant to the context
	Interpretability	0	Several errors resulting in adverse error
	Mobility	0	The information was not efficient
	Modularity	0	The information could not be separated
	Operability	0	Information was not fit for use.
	Performance	0	Performance was a 0 as patient experienced adverse impact.
	Safety	0	Did not promote patient safety.
	Serviceable	0	The information was not useable as it was incorrect.
	Sociability	0	The information was not useable
	Understandable	0	The information was not understandable
	Value	0	The information did not provide value
	Volatility	0	The information did not provide value
	Fit for Use	0	The information was not fit for use
	Functionality	0	There was no evidence of it serving the organisational goals.
	Overall Usability Level	Level 0	Level 0 as no qualities for usability were found. This was because there were several diagnosis error, which led to medication errors and resulted in adverse medication errors.

Availability	Accessibility	Insufficient information	Insufficient information stating if the information for diagnosis was available.
	Latency	Not relevant	Not relevant to the information-flow case.
	Overall Availability Level	Not available	Quality not available as it was unmeasurable.
Reliability	Accuracy	0	Information was not free from errors.
	Consistency	0	Quality was not consistent
	Portability	0	Information could not be transferred into diagnosis stage.
	Redundancy	0	No interventions in place.
	Repairability	0	Information failure was not prevented.
	Repeatability	Insufficient information	Not enough information to state this would occur again,
	Sensitivity	0	Information had several errors
	Timely	Insufficient information	Insufficient information
	Tolerance	0	Information had several points of failure
	Validity	0	Information was not valid
	Trust	Not relevant	Not relevant
	Longevity	Not relevant	Not relevant
	Overall Reliability Level	Level 0	No reliability data qualities were found in the information-flow case.
Security	Confidentiality	Not relevant	Not relevant
	Formality	Not relevant	Not relevant
	Overall Security level	Not relevant	Not relevant
Quality Assurance	Automobility	Insufficient information	Insufficient information
	Implantability	Insufficient information	Insufficient information
	Improvability	Insufficient information	Insufficient information
	Mutability	Insufficient information	Insufficient information

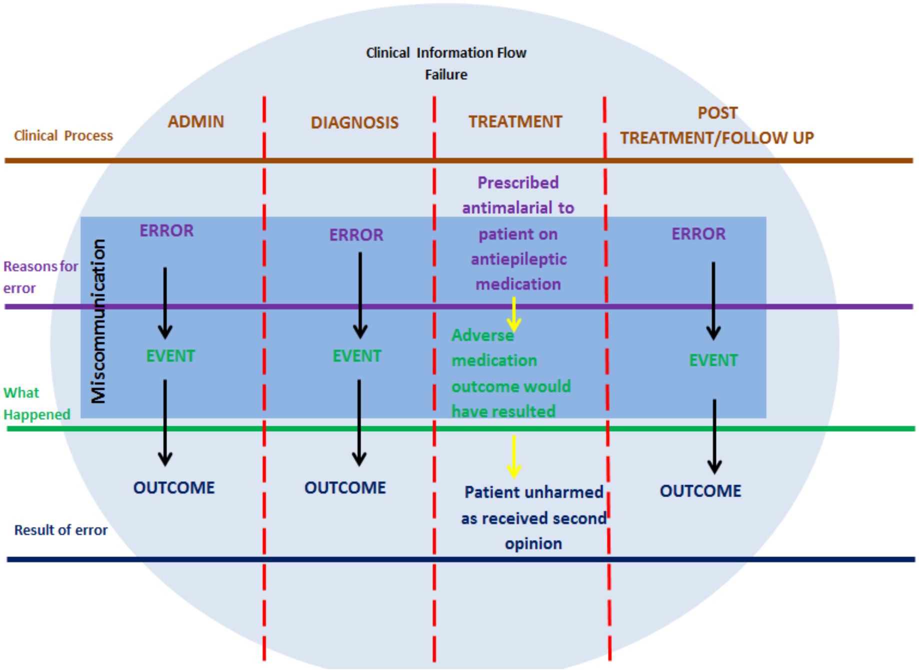
	Progress	Insufficient information	Insufficient information
	Testable	Insufficient information	Insufficient information
	Correlated	1	Information was correlated
	Evidence	1	Information was available for reporting
	Measurability	1	Some information measurements were available
	Ownable	Insufficient information	Insufficient information
	Quantifiable	1	Some information measurements were available
	Traceability	1	The information was traceable
	Transparency	1	Information was transparent
	Consistency	0	Information was not consistent
	Audit Capability	1	Information has audit capability
	Coverage Quality	0	Not fit for purpose
	Overall Quality Assurance Level	Level 1	Some quality assurance data qualities available

TAPS Case Study 5

Treatment "good"

Case Study # 11

Report no 101: Prescribed antimalarial to a patient on antiepileptic medication which could have resulted in serious interaction if patient had not gotten a second opinion.



Metric Characteristic		Level Rating	Why it was given that Level Rating
Coverage	Capacity	1	Listed as a 1 as incorrect medication was prescribed.
	Completeness	1	Information does not appear to be missing.
	Quality	1	The original prescription would have been fit for use if the patient was not on another medication.
	Self-Descriptive	1	Information was self-explanatory
	Simplicity	1	Information could be understood
	Soundness	1	Information to some extent was sound
	Structured	1	Some structured qualities listed.
	Overall Coverage Level	1	Listed as a 1 as some coverage characteristics were present at a minimum.
Relevancy	Aligned	1	The result was that the patient was not harmed.

	Flexible	1	The patient was able to seek a second opinion which resulted in no errors.
	Generalisability	1	The patient information could be applied in several contexts.
	Maintainability	Insufficient information	Insufficient information to measure this.
	Overall Relevancy level	1	Level 1 as some relevancy qualities were present.
Usability	Adaptability	1	The information was used by different GPS which resulted in a different outcome.
	Addressability	Not relevant	Not relevant to the case
	Compatible	1	The second GP adhered to quality frameworks.
	Complexity	Not relevant	Not relevant to the case.
	Effectiveness	1	Marked as a 1 because of the second GP. However, because the first mis prescribed it is no higher than a 1.
	Efficient	1	Marked as a 1 because of the second GP. However, because the first mis prescribed it is no higher than a 1.
	Interoperable	Not relevant	Not relevant to the case
	Interpretability	1	Marked as a 1 because of the second GP. However, because the first mis prescribed it is no higher than a 1.
	Mobility	1	Marked as a 1 because of the second GP. However, because the first mis prescribed it is no higher than a 1.
	Modularity	Insufficient information	Insufficient information to measure.
	Operability	1	1 as the second GP was able to prevent a medication error.
	Performance	2	2 because the second GP did not result in any failure.
	Safety	1	Marked as a 1 because of the second GP. However, because the first mis prescribed it is no higher than a 1.
	Serviceable	1	The information was usable
	Sociability	1	The information could be used in other contexts.
	Understandable	1	The information was understandable
	Value	1	The information provided value
	Volatility	1	The result of the 2nd GP assisted with organisational goals.

	Fit for Use	1	The information was fit for use.
	Functionality	1	The information was functional.
	Overall Usability Level	Level 1	The information flow shows characteristics of usability as the patient did not have any harm. This was because the patient sought a second opinion. There is insufficient information as to why the first GP prescribed incorrect medication.
Availability	Accessibility	1	As the second GP was able to make an accurate diagnosis and treatment for the patient, it is assumed the information had the correct accessibility.
	Latency	1	The information-flow response time is appropriate as no one was harmed.
	Overall Availability Level	2	As both measurements for availability are a 1, this has been measured as a level 2. All characteristics are evident and measurable which resulted in no errors or information-flow failures.
Reliability	Accuracy	1	1 as the 1st GP made a prescription error.
	Consistency	0	Not consistent as two GPs had two different outcomes.
	Portability	1	Information could be transferred to another GP.
	Redundancy	1	The intervention which prevented the error was seeking another opinion.
	Repairability	1	The failure could only be prevented because of the second opinion.
	Repeatability	Insufficient information	Insufficient information. Unknown why the 1st GP prescribed incorrect medication. Unknown why the patient decided to seek a second opinion. Unknown why the 2nd GP could diagnosis and prescribe correct medication.
	Sensitivity	1	Listed as a 1 because if the patient did not seek another opinion, there would have been patient harm.
	Timely	1	The information was used in a relevant context.
	Tolerance	1	Evident the information point which failed was at treatment with the first GP.
	Validity	1	Listed as a 1 because of second GP.
	Trust	1	Listed as a 1 because of second GP.
	Longevity	1	Listed as a 1 because of second GP.

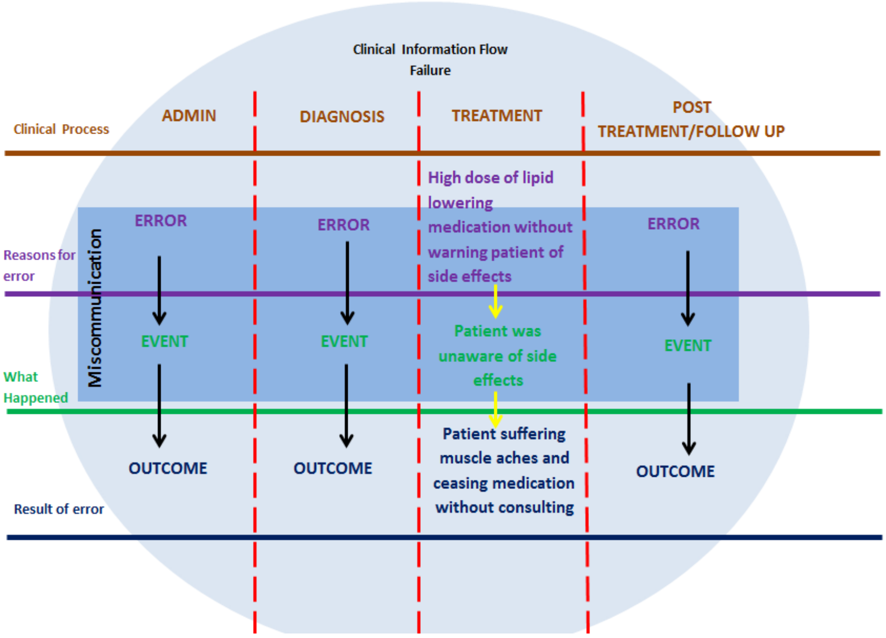
	Overall Reliability Level	1	Some qualities for reliability are evident in the case.
Security	Confidentiality	Not relevant	Not relevant to this case.
	Formality	Insufficient information	Insufficient information to state they adhered to frameworks.
	Overall Security level	Not applicable to case.	Not applicable to case.
Quality Assurance	Automobility	Insufficient information	Insufficient information
	Implantability	1	The second GP was a change that resulted in no harm
	Improvability	Insufficient information	Insufficient information
	Mutability	1	The second GP was a change that resulted in no harm
	Progress	Insufficient information	Insufficient information
	Testable	1	The information flow point where the first GP resulted in failure.
	Correlated	1	Information was depended on one another.
	Evidence	1	Information was available.
	Measurability	1	Qualities could be measured.
	Ownable	Insufficient information	Insufficient information
	Quantifiable	1	Information could be measured
	Traceability	1	Information could be tracked
	Transparency	1	Information was transparent
	Consistency	0	Information quality was not consistent as two GPs would have given two different outcomes.
	Audit Capability	1	Performance can be tracked
	Coverage Quality	1	Information was fit for purpose.
	Overall Quality Assurance Level	1	Quality Assurance qualities were evident in the case

TAPS Case Study 6

Treatment “bad”

Case Study # 3

Report No. 82: Lipid lowering medication commenced at too high a dose and without warning patient of potential side effects or arranging review, resulting in patient suffering muscle aches and ceasing medication without consulting.



Metric Characteristic		**Level rating**	**Why it was given that rating**
Coverage	Capacity	1	Patient was not warned about side effects. Patient suffered side effects and stopped medication without consultation. Some information was listed in the context. However, clearly more information could have been presented.
	Completeness	0	Information is missing from the context.
	Quality	1	To some degree quality was present and fit for use. However, because the patient was not provided all the information it resulted in not being fit for use.
	Self-Descriptive	0	Information was not self-explanatory
	Simplicity	0	There was miscommunication in the information-flow.

	Soundness	0	No soundness present
	Structured	0	No structure present.
	Overall Coverage Level	1	Only 2 qualities were present.
Relevancy	Aligned	0	There was miscommunication between the clinician and patient. This resulted in organisational goals not supported.
	Flexible	0	Flexibility not present
	Generalisability	Insufficient information	Insufficient information
	Maintainability	Insufficient information	Insufficient information
	Overall Relevancy level	0	Relevancy not present
Usability	Adaptability	Insufficient information	Insufficient information
	Addressability	0	The information responded poorly to miscommunication and no communication.
	Compatible	0	Information did not adhere to frameworks.
	Complexity	Insufficient information	Insufficient information
	Effectiveness	0	Lack of communication resulted in ineffective information flow
	Efficient	0	Lack of communication resulted in inefficient information flow
	Interoperable	Insufficient information	Insufficient information. Unknown how to measure.
	Interpretability	0	Lack of communication resulted in failures.
	Mobility	0	Lack of communication resulted in failures.
	Modularity	0	Information could not be separated.
	Operability	0	Lack of communication resulted in failures.
	Performance	0	Lack of communication resulted in failures.
	Safety	0	Lack of communication resulted in failures.
	Serviceable	0	Lack of communication resulted in failures.

	Sociability	Insufficient information	Insufficient information
	Understandable	0	Lack of communication resulted in failures.
	Value	0	Lack of communication resulted in failures.
	Volatility	0	Lack of communication resulted in failures.
	Fit for Use	0	Lack of communication resulted in failures.
	Functionality	0	Lack of communication resulted in failures.
	Overall Usability Level	0	No usability present because of the lack of communication.
Availability	Accessibility	Insufficient information	Insufficient information
	Latency	Insufficient information	Insufficient information
	Overall Availability Level	Insufficient information	Insufficient information
Reliability	Accuracy	0	Information was not free from errors as lack of information resulted in an error.
	Consistency	0	Information was not consistent
	Portability	Insufficient information	Insufficient information
	Redundancy	0	No interventions in place
	Repairability	0	No prevention in place
	Repeatability	Insufficient information	Insufficient information
	Sensitivity	Insufficient information	Insufficient information
	Timely	Insufficient information	Insufficient information
	Tolerance	Insufficient information	Insufficient information

	Validity	0	Patient did not accept side affects as they were not informed.
	Trust	0	Patient did not trust medication as it resulted in side affects
	Longevity	0	Information was only relevant for when the patient required it
	Overall Reliability Level	0	Reliability not present
Security	Confidentiality	Insufficient information	Insufficient information
	Formality	Insufficient information	Insufficient information
	Overall Security level	Insufficient information	Insufficient information
Quality Assurance	Automobility	Insufficient information	Insufficient information
	Implantability	Insufficient information	Insufficient information
	Improvability	Insufficient information	Insufficient information
	Mutability	Insufficient information	Insufficient information
	Progress	Insufficient information	Insufficient information
	Testable	0	Points were not tested prior to the prescription.
	Correlated	1	Information was correlated
	Evidence	1	Evidence available
	Measurability	1	Information measurements available
	Ownable	Insufficient information	Insufficient information
	Quantifiable	1	Information quantifiable
	Traceability	1	Information traceable
	Transparency	1	Information transparent post review. However, lack of information for the patient resulted in no transparency.

	Consistency	0	No consistency.
	Audit Capability	1	Information could be tracked
	Coverage Quality	0	Not fit for purpose.
	Overall Quality Assurance Level	1	1 quality assurance characteristic present.

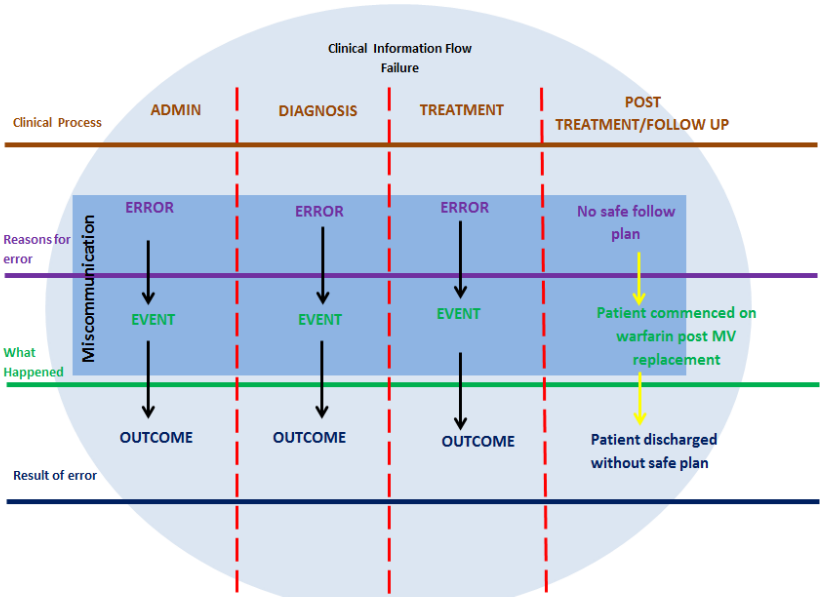
TAPS Case Study 7

Post treatment "good"

Case Study # 75

Report no 282

Warfarin mismanagement; hospital discharged patient commenced on warfarin post MV replacement with no safe follow up plan in place.



Metric Characteristic		**Level rating**	**Why it was given that rating**
Coverage	Capacity	1	Rated as a 1 because a safe plan could have been implemented

	Completeness	1	Rated as a 1 as only the safe plan was missing. The case does not state if patient harm occurred.
	Quality	0	It was not fit for purpose because there was no discharge safe plan.
	Self-Descriptive	0	The information was no self-descriptive for the patient as a safe plan was required.
	Simplicity	0	The information was not easily understood as a safe plan was required.
	Soundness	Not relevant	Not relevant to case
	Structured	Insufficient information	Insufficient information
	Overall Coverage Level	1	Level 1 for Coverage. Some coverage qualities were present. However, as there was no safe plan for the patient this was an information-flow failure. Failure to provide information to the patient.
Relevancy	Aligned	0	Warfarin mismanagement does not support the organisational goals.
	Flexible	0	Information was not provided and resulted in warfarin mismanagement.
	Generalisability	Insufficient information	Insufficient information
	Maintainability	Insufficient information	Insufficient information
	Overall Relevancy level	0	Level 0 as no relevancy qualities were present because warfarin was mismanaged.
Usability	Adaptability	Insufficient information	Insufficient information
	Addressability	0	The safe plan was required to prevent mismanagement.
	Compatible	0	Without the warfarin safe plan, quality frameworks were not adhered to.
	Complexity	Insufficient information	Insufficient information
	Effectiveness	0	Not effective because of warfarin mismanagement.
	Efficient	0	Not efficient because of warfarin mismanagement.

	Interoperable	Insufficient information	Insufficient information
	Interpretability	0	No safe plan
	Mobility	0	No safe plan resulted in mismanagement of warfarin
	Modularity	Insufficient information	Insufficient information
	Operability	0	Mismanagement resulted in not fit for use.
	Performance	0	Mismanagement resulted in low performance
	Safety	0	Mismanagement can result in patient harm
	Serviceable	0	Not useable without a safe plan
	Sociability	Not relevant	Not relevant
	Understandable	0	Safe plan was missing.
	Value	0	At current level, did not provide value
	Volatility	0	At current level, did not provide value
	Fit for Use	0	Not fit for use without proper management.
	Functionality	0	Not fit for use without proper management.
	Overall Usability Level	0	Without proper management of warfarin after patient discharge, this usability has been rated a level 0.
Availability	Accessibility	Insufficient information	Insufficient information
	Latency	Insufficient information	Insufficient information
	Overall Availability Level	Insufficient information	Insufficient information
Reliability	Accuracy	0	No safe plan was a failure during post treatment.
	Consistency	0	No consistency of quality after post treatment.
	Portability	Insufficient information	Insufficient information

	Redundancy	0	No interventions listed
	Repairability	0	Not mentioned
	Repeatability	Insufficient information	Insufficient information
	Sensitivity	0	Failure was in post treatment safe plan
	Timely	0	The appropriate timing was for a safe plan to be in place for post treatment.
	Tolerance	0	The post treatment is an information-flow point which failed.
	Validity	0	Not at a satisfactory or acceptable level
	Trust	0	Not at a satisfactory level.
	Longevity	0	Only relevant for post treatment.
	Overall Reliability Level	0	Level 0 as no qualities were present without a safe plan post treatment.
Security	Confidentiality	Not relevant	Not relevant to case
	Formality	Not relevant	Not relevant to case
	Overall Security level	Not relevant to case	Not relevant in terms of patient safety for this case.
Quality Assurance	Automobility	Insufficient information	Insufficient information
	Implantability	Insufficient information	Insufficient information
	Improvability	Insufficient information	Insufficient information
	Mutability	Insufficient information	Insufficient information
	Progress	Insufficient information	Insufficient information
	Testable	0	Post treatment point failed
	Correlated	1	Information was correlated
	Evidence	1	There is information and statistics available
	Measurability	1	Qualities can be measured

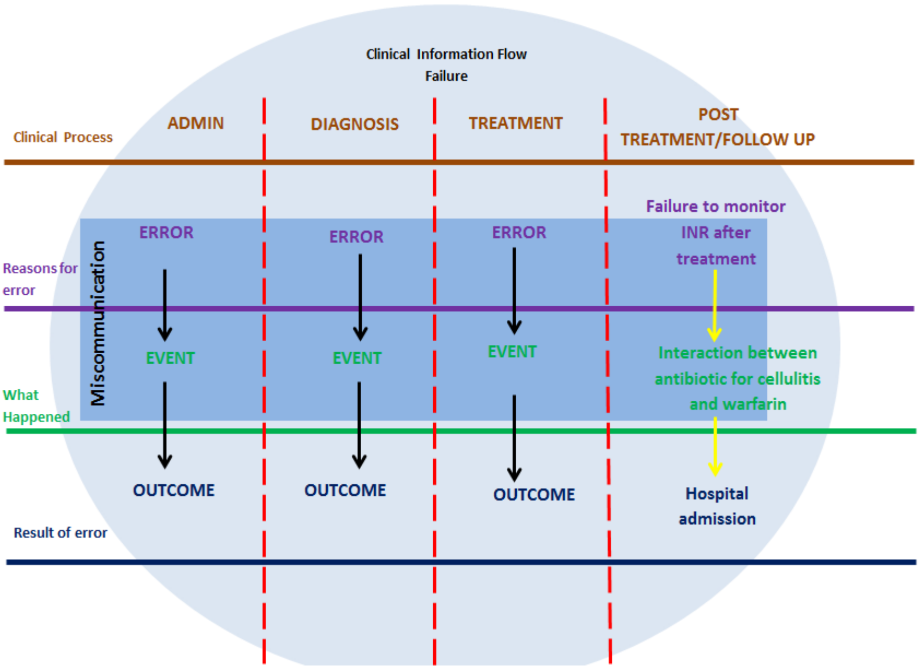
	Ownable	Insufficient information	Insufficient information
	Quantifiable	1	Qualities can be measured
	Traceability	1	Information-flow is traceable
	Transparency	1	Post review information points were transparent
	Consistency	0	No consistency
	Audit Capability	1	Audit capability present through information-flow mapping
	Coverage Quality	0	Not fit for scope
	Overall Quality Assurance Level	1	Some quality assurance qualities present which makes it an overall level 1.

TAPS Case Study 8

Post Treatment "bad"

Case Study # 53

Report no 243 Interaction between antibiotic for cellulitis and warfarin, and failure to appropriately monitor INR over weekend resulting in hospital admission.



Metric Characteristic		**Level rating**	**Why it was given that rating**
Coverage	Capacity	0	Rated a 0 because there was failure to monitor INR after treatment.
	Completeness	0	Rated a 0 because there was failure to monitor INR after treatment.
	Quality	0	Rated a 0 because there was failure to monitor INR after treatment. This resulted in an interaction and hospital admission.
	Self-Descriptive	Not relevant	Not relevant
	Simplicity	Not relevant	Not relevant
	Soundness	0	Not sound as failure to monitor resulted in an interaction post treatment.
	Structured	Not relevant	Not relevant
	Overall Coverage Level	0	Overall level 0 because of failure to monitor during post treatment, which resulted in medication interaction and hospital admission.
Relevancy	Aligned	0	This case did not support organisational goals.
	Flexible	0	Information could not change in the information-flow without failure.
	Generalisability	Insufficient information	Not enough information to state this could be applied anywhere.

	Maintainability	Insufficient information	Insufficient information
	Overall Relevancy level	0	No relevancy qualities listed.
Usability	Adaptability	Insufficient information	Insufficient information
	Addressability	Insufficient information	Insufficient information
	Compatible	0	Did not adhere to frameworks
	Complexity	Not relevant	Not relevant
	Effectiveness	0	Not effective because of interaction and hospital admission
	Efficient	0	Not efficient because of interaction and hospital admission
	Interoperable	Not relevant	Not relevant
	Interpretability	Not relevant	Not relevant
	Mobility	0	Not capable or efficient
	Modularity	0	Could not have post treatment without monitoring of INR
	Operability	0	Was not fit for use without monitoring post treatment
	Performance	0	Patient experience interaction and hospital admission.
	Safety	0	Not safe for the patient
	Serviceable	0	Not useable
	Sociability	Insufficient information	Insufficient information
	Understandable	Insufficient information	Insufficient information
	Value	0	Did not provide value
	Volatility	0	Did not provide value
	Fit for Use	0	Not fit for use
	Functionality	0	Not functional

	Overall Usability Level	0	Level 0 as no qualities for usability were present.
Availability	Accessibility	Insufficient information	Insufficient information
	Latency	Insufficient information	Insufficient information
	Overall Availability Level	Insufficient information	Insufficient information
Reliability	Accuracy	0	Failure to monitor resulted in patient hospital admission
	Consistency	0	Not consistent after post treatment
	Portability	0	Information flow could not be transferred during post treatment
	Redundancy	0	No interventions listed
	Repairability	Insufficient information	Insufficient information
	Repeatability	Insufficient information	Insufficient information
	Sensitivity	0	Failure during post treatment
	Timely	0	Not timely as needed to monitor post treatment
	Tolerance	0	Post treatment point failed
	Validity	0	Not acceptable
	Trust	0	Not at a satisfactory level
	Longevity	0	Only relevant for post treatment monitoring.
	Overall Reliability Level	0	No reliability qualities listed.
Security	Confidentiality	Not relevant	Not relevant
	Formality	Not relevant	Not relevant
	Overall Security level	Not relevant	Not relevant
Quality Assurance	Automobility	Insufficient information	Insufficient information
	Implantability	Insufficient information	Insufficient information

	Improvability	Insufficient information	Insufficient information
	Mutability	Insufficient information	Insufficient information
	Progress	Insufficient information	Insufficient information
	Testable	0	Failed at post treatment point
	Correlated	1	Point of information-flow are correlated
	Evidence	1	Evidence available for review
	Measurability	1	Measurements available
	Ownable	Insufficient information	Insufficient information
	Quantifiable	1	Information is measurable
	Traceability	1	Information was traceable
	Transparency	1	Post review points are transparent for mapping
	Consistency	0	Not consistent
	Audit Capability	1	Audit capability available
	Coverage Quality	0	Not fit for use
	Overall Quality Assurance Level	0	Level 0 as some Quality assurance available

Appendix E: Semi-Structured Interview Artefacts

Interview Guide

Activity	Comments/Questions	Approximate Time
Introduction	Brief the participant. Introduce self. Explain goals of interview. Explain interview process.	3 min
Structured Topics	Topic 1: Background Questions.	5 min
	Topic 2: Information-flow metric definitions.	15
	Topic 3: Worked example Case.	15
	Topic 4: Worked example questions.	10
	Topic 4: Post worked questions.	10
Closing comments		2 min
Total Interview Time		60 minutes

Interview Questions

Interviewer: Rebecca Hermon

Participant: _________________

Date: __________________

The purpose of the interviews are to get answers for refining the framework and to develop a guide on improving information-flow maturity. The participant will be asked background questions to determine their background experience with information-flow and to understand how they define concepts such as information-flow. The participant will be asked to review information-flow metric definitions. The participant will then be shown a completed worked example. The participant will be asked questions about the worked example and then will be asked to complete the worked example against the information-flow metrics framework. Questions will then be asked to determine how easy or difficult the framework was to use, what metrics could be measured and how they determined the levels. This is to identify how similar/ different answers are when using a assessment tool to identify information-flow maturity and to identify saturation. Additionally, questions to assist developing the guide to improve maturity will be asked.

Background Questions:

- Participants Experience -
- Please describe your experience -
- How do you define information-flow?
- How would you define information-flow metric/s?

- Do you currently use information-flow metrics? If so what?
- Have you had prior exposure to Capability Maturity Models?
- Do you currently use any methods to prevent errors in information-flow be prevented?
- Do you currently use any methods to enhance information-flow?
- How can information-flow be improved in your organisation?

Data definitions: The participant will now review the information-flow metric definitions.

- How important is standard terminology in information-flow?
- Please comment on the definitions presented.
- Are there any information-flow metrics missing?
- Are there information-flow metrics that are unnecessary?

Worked Example Questions: The participant will now review a worked example and complete the framework.

- Did you clearly understand the worked example present? If not, what would make this clearer?
- How easy or difficult was it to complete the worked example against the framework?
- What changes to the framework would you recommend to allow further understandability?
- Using the framework were you able to identify a Maturity Level for this worked example?
- Were there any metrics you could not measure? Why?
- Were there metrics that were not applicable to the scenario?
- Do you think using metrics and assigning maturity would improve information-flow?
- Do you think this type of framework would be useful in your organisation?

Post Worked Example Questions:

I. How can metrics be used to improve information-flow?

II. How can capability maturity models be used to improve information-flow?

Appendix F: Desk Study 2 Case Artefacts

Desk Study 2 Results

Case Study 1

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 2	
	Completeness	Level 1	
	Quality	Level 3	
	Self-Descriptive	Level 3	
	Simplicity	Level 2	
	Soundness	Not Measurable	Not Relevant
	Structured	Level 4	
Overall Coverage Maturity Level		Level 3	
Relevancy	Aligned	Level 0	
	Flexible	Level 1	
	Generalisability	Level 2	
	Maintainability	Not Measurable	Not Relevant
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 3	
	Adressability	Level 1	
	Compatible	Level 1	
	Complexity	Not Measurable	Insufficient Information
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 2	
	Interpretability	Level 2	
	Mobility	Level 0	
	Modularity	Level 1	
	Operability	Level 2	
	Performance	Level 1	
	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 2	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 2	
	Latency	Level 3	
Overall Availability Maturity Level		Level 2	
Reliability	Accuracy	Level 2	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 0	

	Repeatability	Not Measurable	Insufficient Information
	Sensitivity	Level 1	
	Timely	Level 1	
	Tolerance	Level 0	
	Validity	Level 2	
	Trust	Level 1	
	Longevity	Level 1	
	Bias	Level 1	
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 2	
	Formality	Level 2	
Overall Security Maturity Level		Level 2	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 2	
	Correlated	Level 1	
	Evidence	Level 3	
	Measurability	Level 3	
	Custodian	Level 3	
	Quantifable	Level 3	
	Traceability	Level 4	
	Transparency	Level 5	
	Consistency	Level 1	
	Audit Capability	Level 5	
	Coverage Quality	Level 3	
	Data Lineage	Level 5	
Overall Quality Assurance (QA) Maturity Level		Level 3	

Case Study 2

Metric Category	**Metric Characteristic**	**Metric Level**	**Justification**
Coverage	Capacity	Level 2	
	Completeness	Level 2	
	Quality	Level 2	
	Self-Descriptive	Level 3	
	Simplicity	Level 3	
	Soundness	Level 2	
	Structured	Level 2	
Overall Coverage Maturity Level		Level 2	
Relevancy	Aligned	Level 1	
	Flexible	Level 1	
	Generalisability	Level 1	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	

Usability	Adaptability	Level 1	
	Adressability	Level 1	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Not Measurable	Insufficient Information
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 1	
	Performance	Level 0	
	Safety	Level 0	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	
Overall Usability Maturity Level		Level 0	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 0	
	Redundancy	Level 1	
	Repairability	Level 1	
	Repeatability	Not Measurable	Insufficient Information
	Sensitivity	Level 1	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 2	
	Trust	Level 1	
	Longevity	Level 1	
	Bias	Not Measurable	Influencing factor
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 0	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 0	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Not Measurable	Insufficient Information
	Progress	Level 2	
	Testable	Level 1	
	Correlated	Level 1	
	Evidence	Level 3	

	Measurability	Level 3	
	Custodian	Level 3	
	Quantifable	Level 3	
	Traceability	Level 4	
	Transparency	Level 4	
	Consistency	Level 1	
	Audit Capability	Level 4	
	Coverage Quality	Level 3	
	Data Lineage	Level 4	
Overall Quality Assurance (QA) Maturity Level		Level 3	

Case Study 3

Metric Category	**Metric Characteristic**	**Metric Level**	**Justification**
Coverage	Capacity	Level 1	
	Completeness	Level 2	
	Quality	Level 1	
	Self-Descriptive	Level 2	
	Simplicity	Level 2	
	Soundness	Level 2	
	Structured	Level 2	
Overall Coverage Maturity Level		Level 2	
Relevancy	Aligned	Level 1	
	Flexible	Level 1	
	Generalisability	Not Measurable	Insufficient Information
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 1	
	Adressability	Level 2	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 1	
	Efficient	Level 1	
	Interoperable	Level 0	
	Interpretability	Level 0	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 0	
	Performance	Level 1	
	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	

Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 1	
	Repeatability	Level 1	
	Sensitivity	Level 1	
	Timely	Level 1	
	Tolerance	Level 1	
	Validity	Level 1	
	Trust	Level 1	
	Longevity	Level 1	
	Bias	Not Measurable	Influencing factor
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 0	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Level 2	
	Progress	Level 2	
	Testable	Level 2	
	Correlated	Not Measurable	Insufficient Information
	Evidence	Level 2	
	Measurability	Level 2	
	Custodian	Level 3	
	Quantifable	Level 2	
	Traceability	Level 2	
	Transparency	Level 3	
	Consistency	Level 2	
	Audit Capability	Level 3	
	Coverage Quality	Level 3	
	Data Lineage	Level 3	
Overall Quality Assurance (QA) Maturity Level		Level 2	

Case Study 4

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 1	
	Quality	Level 1	
	Self-Descriptive	Level 2	

	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 1	
	Flexible	Level 1	
	Generalisability	Level 1	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 1	
	Adressability	Level 1	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 1	
	Efficient	Level 1	
	Interoperable	Level 1	
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 1	
	Performance	Level 1	
	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 1	
	Votality	Level 1	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 1	
	Repeatability	Level 1	
	Sensitivity	Level 1	
	Timely	Level 1	
	Tolerance	Level 1	
	Validity	Level 1	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Level 0	
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 1	

Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 2	
	Improvability	Level 3	
	Mutability	Level 2	
	Progress	Level 2	
	Testable	Level 2	
	Correlated	Level 3	
	Evidence	Level 3	
	Measurability	Level 2	
	Custodian	Level 2	
	Quantifable	Level 2	
	Traceability	Level 2	
	Transparency	Level 2	
	Consistency	Level 2	
	Audit Capability	Level 2	
	Coverage Quality	Level 2	
	Data Lineage	Level 2	
Overall Quality Assurance (QA) Maturity Level		Level 2	

Case Study 5

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 0	
	Completeness	Level 0	
	Quality	Level 0	
	Self-Descriptive	Level 1	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 0	
	Flexible	Level 0	
	Generalisability	Level 0	
	Maintainability	Level 0	
Overall Relevancy Maturity Level		Level 0	
Usability	Adaptability	Level 0	
	Adressability	Level 1	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 0	
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 0	
	Operability	Level 1	

	Performance	Level 0	
	Safety	Level 0	
	Serviceable	Level 0	
	Sociability	Level 0	
	Understandable	Level 1	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	
Overall Usability Maturity Level		Level 0	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 0	
	Portability	Level 1	
	Redundancy	Level 0	
	Repairability	Level 0	
	Repeatability	Level 0	
	Sensitivity	Level 0	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 0	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Level 0	
Overall Reliability Maturity Level		Level 0	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 0	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 0	
	Correlated	Level 1	
	Evidence	Level 1	
	Measurability	Level 2	
	Custodian	Level 1	
	Quantifable	Level 1	
	Traceability	Level 2	
	Transparency	Level 1	
	Consistency	Level 1	
	Audit Capability	Level 2	
	Coverage Quality	Level 2	
	Data Lineage	Level 1	
Overall Quality Assurance (QA) Maturity Level		Level 1	

Case Study 6

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 1	
	Quality	Level 2	
	Self-Descriptive	Level 3	
	Simplicity	Level 2	
	Soundness	Level 2	
	Structured	Level 2	
Overall Coverage Maturity Level		Level 2	
Relevancy	Aligned	Level 0	
	Flexible	Level 0	
	Generalisability	Level 1	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 1	
	Adressability	Level 2	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 1	
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 1	
	Performance	Level 0	
	Safety	Level 0	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 2	
	Latency	Level 2	
Overall Availability Maturity Level		Level 2	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 0	
	Repairability	Level 0	
	Repeatability	Level 1	

	Sensitivity	Level 1	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 1	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Not Measurable	Influencing factor
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 0	
	Improvability	Level 1	
	Mutability	Level 1	
	Progress	Level 2	
	Testable	Level 1	
	Correlated	Level 2	
	Evidence	Level 2	
	Measurability	Level 2	
	Custodian	Level 2	
	Quantifable	Level 2	
	Traceability	Level 2	
	Transparency	Level 2	
	Consistency	Level 2	
	Audit Capability	Level 2	
	Coverage Quality	Level 2	
	Data Lineage	Level 2	
Overall Quality Assurance (QA) Maturity Level		Level 2	

Case Study 7

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 0	
	Quality	Level 0	
	Self-Descriptive	Level 3	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 1	
	Flexible	Level 1	
	Generalisability	Level 2	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 1	

	Adressability	Level 0	
	Compatible	Level 1	
	Complexity	Level 0	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 1	
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 1	
	Performance	Level 1	
	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 0	
	Understandable	Level 0	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 0	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 0	
	Repeatability	Level 1	
	Sensitivity	Level 1	
	Timely	Level 1	
	Tolerance	Level 1	
	Validity	Level 1	
	Trust	Level 0	
	Longevity	Level 1	
	Bias	Level 1	
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 0	
Overall Security Maturity Level		Level 0	
Quality Assurance (QA)	Automobility	Level 0	
	Implantability	Level 1	
	Improvability	Level 1	
	Mutability	Level 0	
	Progress	Level 1	
	Testable	Level 1	
	Correlated	Level 0	
	Evidence	Level 1	
	Measurability	Level 1	

	Custodian	Level 2	
	Quantifable	Level 1	
	Traceability	Level 3	
	Transparency	Level 3	
	Consistency	Level 1	
	Audit Capability	Level 2	
	Coverage Quality	Level 1	
	Data Lineage	Level 3	
Overall Quality Assurance (QA) Maturity Level		Level 2	

Case Study 8

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 1	
	Quality	Level 1	
	Self-Descriptive	Level 2	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 0	
	Flexible	Level 0	
	Generalisability	Level 1	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 0	
Usability	Adaptability	Level 1	
	Adressability	Level 1	
	Compatible	Level 0	
	Complexity	Level 1	
	Effectiveness	Level 1	
	Efficient	Level 1	
	Interoperable	Level 1	
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 0	
	Operability	Level 1	
	Performance	Level 1	
	Safety	Level 0	
	Serviceable	Level 1	
	Sociability	Level 0	
	Understandable	Level 2	
	Value	Level 1	
	Votality	Level 1	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	

Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 0	
	Redundancy	Level 0	
	Repairability	Level 1	
	Repeatability	Level 1	
	Sensitivity	Level 1	
	Timely	Level 0	
	Tolerance	Level 1	
	Validity	Level 1	
	Trust	Level 1	
	Longevity	Level 1	
	Bias	Level 1	
Overall Reliability Maturity Level		Level 1	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 1	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 1	
	Correlated	Level 1	
	Evidence	Level 1	
	Measurability	Level 1	
	Custodian	Level 1	
	Quantifable	Level 1	
	Traceability	Level 1	
	Transparency	Level 1	
	Consistency	Level 1	
	Audit Capability	Level 1	
	Coverage Quality	Level 1	
	Data Lineage	Level 1	
Overall Quality Assurance (QA) Maturity Level		Level 1	

Case Study 9

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 0	
	Quality	Level 0	
	Self-Descriptive	Level 1	
	Simplicity	Level 1	

	Soundness	Level 0	
	Structured	Level 0	
Overall Coverage Maturity Level		Level 0	
Relevancy	Aligned	Level 0	
	Flexible	Level 0	
	Generalisability	Level 0	
	Maintainability	Level 0	
Overall Relevancy Maturity Level		Level 0	
Usability	Adaptability	Level 0	
	Adressability	Level 0	
	Compatible	Level 0	
	Complexity	Level 0	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Level 0	
	Interpretability	Level 0	
	Mobility	Level 0	
	Modularity	Level 0	
	Operability	Level 0	
	Performance	Level 0	
	Safety	Level 0	
	Serviceable	Level 0	
	Sociability	Level 0	
	Understandable	Level 0	
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	
Overall Usability Maturity Level		Level 0	
Availability	Accessibility	Level 0	
	Latency	Level 0	
Overall Availability Maturity Level		Level 0	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 0	
	Repeatability	Level 1	
	Sensitivity	Level 1	
	Timely	Level 0	
	Tolerance	Level 1	
	Validity	Level 0	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Level 0	
Overall Reliability Maturity Level		Level 0	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	

Quality Assurance (QA)	Automobility	Level 0	
	Implantability	Level 1	
	Improvability	Level 0	
	Mutability	Level 1	
	Progress	Level 0	
	Testable	Level 1	
	Correlated	Level 1	
	Evidence	Level 1	
	Measurability	Level 1	
	Custodian	Level 1	
	Quantifable	Level 1	
	Traceability	Level 1	
	Transparency	Level 1	
	Consistency	Level 1	
	Audit Capability	Level 1	
	Coverage Quality	Level 1	
	Data Lineage	Level 1	
Overall Quality Assurance (QA) Maturity Level		Level 1	

Case Study 10

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 1	
	Quality	Level 1	
	Self-Descriptive	Level 2	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 1	
	Flexible	Level 0	
	Generalisability	Level 0	
	Maintainability	Level 1	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 1	
	Adressability	Level 1	
	Compatible	Level 0	
	Complexity	Level 1	
	Effectiveness	Level 1	
	Efficient	Level 0	
	Interoperable	Level 0	
	Interpretability	Level 0	
	Mobility	Level 0	
	Modularity	Level 1	
	Operability	Level 0	
	Performance	Level 0	

	Safety	Level 1	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 1	
	Votality	Level 0	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 0	
	Latency	Level 0	
Overall Availability Maturity Level		Level 0	
Reliability	Accuracy	Level 1	
	Consistency	Level 0	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 1	
	Repeatability	Level 0	
	Sensitivity	Level 0	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 0	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Level 0	
Overall Reliability Maturity Level		Level 0	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 2	
	Mutability	Level 1	
	Progress	Level 2	
	Testable	Level 2	
	Correlated	Level 2	
	Evidence	Level 2	
	Measurability	Level 2	
	Custodian	Level 2	
	Quantifable	Level 2	
	Traceability	Level 2	
	Transparency	Level 2	
	Consistency	Level 2	
	Audit Capability	Level 2	
	Coverage Quality	Level 2	
	Data Lineage	Level 2	
Overall Quality Assurance (QA) Maturity Level		Level 2	

Case Study 11

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 0	
	Quality	Level 0	
	Self-Descriptive	Level 0	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 1	
Overall Coverage Maturity Level		Level 0	
Relevancy	Aligned	Level 1	
	Flexible	Level 0	
	Generalisability	Not Measurable	Insufficient Information
	Maintainability	Level 0	
Overall Relevancy Maturity Level		Level 0	
Usability	Adaptability	Level 1	
	Adressability	Level 0	
	Compatible	Level 0	
	Complexity	Level 1	
	Effectiveness	Level 0	
	Efficient	Level 0	
	Interoperable	Not Measurable	Not Relevant
	Interpretability	Level 1	
	Mobility	Level 1	
	Modularity	Level 1	
	Operability	Level 1	
	Performance	Level 0	
	Safety	Level 0	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Not Measurable	Influencing factor
	Value	Level 0	
	Votality	Level 0	
	Fit for Use	Level 0	
	Functionality	Level 0	
Overall Usability Maturity Level		Level 0	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 1	
	Consistency	Level 1	
	Portability	Level 1	
	Redundancy	Level 1	
	Repairability	Level 0	
	Repeatability	Not Measurable	Insufficient Information

	Sensitivity	Level 1	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 0	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Not Measurable	Influencing factor
Overall Reliability Maturity Level		Level 0	
Security	Confidentiality	Level 0	
	Formality	Level 1	
Overall Security Maturity Level		Level 0	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 1	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 1	
	Correlated	Level 1	
	Evidence	Level 1	
	Measurability	Level 1	
	Custodian	Level 1	
	Quantifable	Level 1	
	Traceability	Level 1	
	Transparency	Level 1	
	Consistency	Level 1	
	Audit Capability	Level 1	
	Coverage Quality	Level 1	
	Data Lineage	Level 1	
Overall Quality Assurance (QA) Maturity Level		Level 1	

Case Study 12

Metric Category	Metric Characteristic	Metric Level	Justification
Coverage	Capacity	Level 1	
	Completeness	Level 0	
	Quality	Level 0	
	Self-Descriptive	Level 0	
	Simplicity	Level 1	
	Soundness	Level 1	
	Structured	Level 0	
Overall Coverage Maturity Level		Level 1	
Relevancy	Aligned	Level 0	
	Flexible	Level 0	
	Generalisability	Level 1	
	Maintainability	Level 0	
Overall Relevancy Maturity Level		Level 1	
Usability	Adaptability	Level 0	

	Adressability	Level 1	
	Compatible	Level 1	
	Complexity	Level 1	
	Effectiveness	Level 1	
	Efficient	Level 0	
	Interoperable	Level 1	
	Interpretability	Level 0	
	Mobility	Level 0	
	Modularity	Level 0	
	Operability	Level 1	
	Performance	Level 1	
	Safety	Level 0	
	Serviceable	Level 1	
	Sociability	Level 1	
	Understandable	Level 1	
	Value	Level 1	
	Votality	Level 1	
	Fit for Use	Level 1	
	Functionality	Level 1	
Overall Usability Maturity Level		Level 1	
Availability	Accessibility	Level 1	
	Latency	Level 1	
Overall Availability Maturity Level		Level 1	
Reliability	Accuracy	Level 0	
	Consistency	Level 0	
	Portability	Level 0	
	Redundancy	Level 0	
	Repairability	Level 0	
	Repeatability	Level 0	
	Sensitivity	Level 0	
	Timely	Level 0	
	Tolerance	Level 0	
	Validity	Level 0	
	Trust	Level 0	
	Longevity	Level 0	
	Bias	Level 0	
Overall Reliability Maturity Level		Level 0	
Security	Confidentiality	Level 1	
	Formality	Level 1	
Overall Security Maturity Level		Level 1	
Quality Assurance (QA)	Automobility	Level 1	
	Implantability	Level 1	
	Improvability	Level 1	
	Mutability	Level 1	
	Progress	Level 1	
	Testable	Level 1	
	Correlated	Level 1	
	Evidence	Level 1	
	Measurability	Level 1	

	Custodian	Level 1	
	Quantifable	Level 1	
	Traceability	Level 1	
	Transparency	Level 1	
	Consistency	Level 1	
	Audit Capability	Level 1	
	Coverage Quality	Level 1	
	Data Lineage	Level 1	
Overall Quality Assurance (QA) Maturity Level		Level 1	

Appendix G: Final Artefacts

Artefact 1: Instructions for using the Healthcare Information-flow Maturity Framework

A capability maturity model assessment guide for measuring and improving information-flow

Summary

Information-flow is how information is communicated from one place to another. This could be from system to system, system to person or person to person. Information-flow requires an understanding of information-flow dimensions and social, technology, security, governance, IT business alignment and operational context, and understanding of information-flow metric characteristics (coverage, relevancy, usability, availability, reliability, security, and quality assurance).

Introduction

Purpose of framework

The healthcare information-flow maturity framework has the purpose of being an information-flow metric capability maturity model assessment framework. This framework is designed to measure individual information-flow maturity levels and identify recommendations for improving individual information-flow. Although this framework was originally designed for use in healthcare, it has application across multiple information-flow environments.

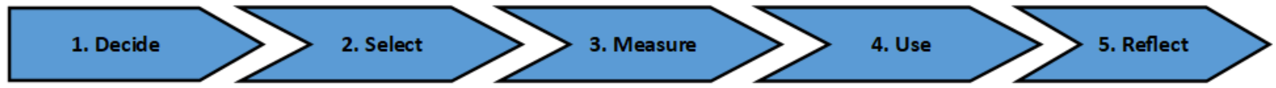
Why measure information-flow?

Information-flow is important as information-flow failure results in errors. Measuring information-low can result in identifying information-flow maturity and identify areas individual-information flow areas that require improvement.

Application to your organisation

This information-flow maturity framework is a subjective metric assessment framework and is not prescriptive. To get the full benefits of this framework, this framework will need to be adapted to your organization's context, and individual information-flows.

Figure 1: Healthcare Information-flow Maturity Framework Process



#	Process Stage	Description
1	**Decide**	Decide what information-flow (or process) is of concern.
2	**Select**	Select the characteristics that should be measured.
3	**Measure**	Measure selected characteristics against the Capability Maturity Matrix.
4	**Use**	Use the Calculator Tool to obtain an overall score.
5	**Reflect**	Reflect on what could be improved and how using the suggestions table can be used to capture and track an action plan.

How to use the framework

1. Information-flow Capability Maturity Model

The Information-flow Capability Maturity Model depicts 5 maturity levels. The levels range from Level 0 to Level 5, with Level 0 referring to no information-flow characteristics present and Level 5 referring to Information-flow characteristics optimised.

- Level 0: None
- Level 1: Initial
- Level 2: Managed
- Level 3: Defined
- Level 4: Quantitatively Managed
- Level 5: Optimising

The Information-flow Capability Maturity Model can be used to identify your organizations current information-flow maturity and where the information-flow maturity should be.

2. Information-flow Metric Characteristics

Within each Information-flow Metric category are information characteristics which form to create the metrics category. You will need to decide what metrics and what characteristics you wish to measure and select metrics which are relevant to your information-flow context. The information-flow characteristics have examples of what constitutes ‘desirable or ‘undesirable information-flow and also recommendations on how to measure the characteristics.

3. Information-flow Capability Maturity Model Calculator

Use this calculator with your organisations individual information-flow in order to identify a maturity level rating for the metric characteristics you have chosen to measure.

4. Guide to Improving Maturity

Once you have identified the maturity level rating, use the guide to identify potential information-flow improvement recommendations.

Artefact 2: Information-flow Capability Maturity Matrix

Metric	Level 0: None	Level 1: Initial	Level 2: Managed	Level 3: Defined	Level 4: Quantitatively Managed	Level 5: Optimising
Coverage	Coverage is not present.	Some Coverage characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Coverage characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Coverage characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Coverage is optimised. Coverage data characteristics are fully evident in the information-flow.
Relevancy	Relevancy is not present.	Some Relevancy characteristics are present at a minimum. The information-flow is uncontrolled,	Majority of Relevancy characteristics are evident, measurable, and repeatable. Naturally results in reduced	Organisation starts to actively engage Relevancy characteristics into information-flow. Continued reduction in	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent	Relevancy is optimised. Relevancy data characteristics are fully evident in the information-flow.

		unpredictable, and inefficient.	Information-flow failures.	information-flow failures.	information-flow failures.	
Usability (Clinical Outcomes)	Usability is not present.	Some Usability characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Usability characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Usability characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Usability is optimised. Usability data characteristics are fully evident in the information-flow.
Availability	Availability is not present.	Some Availability characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Availability characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Availability characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Availability is optimised. Availability data characteristics are fully evident in the information-flow.

Reliability	Reliability is not present.	Some Reliability characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Reliability characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Reliability characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Reliability is optimised. Reliability data characteristics are fully evident in the information-flow.
Security	Security is not present.	Some Security characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Security characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Security characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Security is optimised. Security data characteristics are fully evident in the information-flow.

Quality Assurance	Quality Assurance is not present.	Some Quality characteristics are present at a minimum. The information-flow is uncontrolled, unpredictable, and inefficient.	Majority of Quality characteristics are evident, measurable, and repeatable. Naturally results in reduced Information-flow failures.	Organisation starts to actively engage Quality characteristics into information-flow. Continued reduction in information-flow failures.	Metrics and measurements are used to predict information-flow failures. Proactive intervention is used to prevent information-flow failures.	Quality Assurance is optimised. Quality Assurance data characteristics are fully evident in the information-flow.

Artefact 3: Supporting Information-flow Characteristics explanation

Based on your organisations information-flow context, decide what metrics and their characteristics to measure.

<u>Terms:</u>

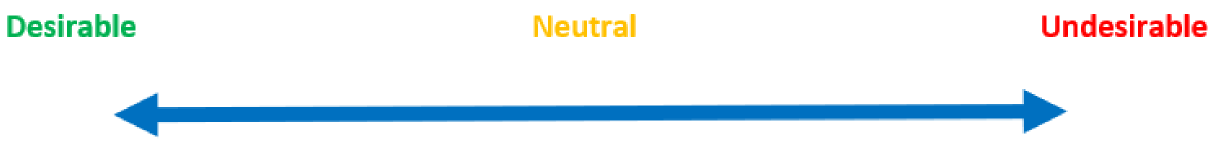
Information-flow Characteristic: Attribute of information-flow

How to Measure: Examples of how you can measure the characteristic. This is not prescriptive.

Taxonomy: Whether the characteristic can be measured in terms of desirable, neutral (not applicable) and undesirable. The taxonomy is based on a scale and is information-flow contextual. The below taxonomy are examples to assist in measuring the information-flow characteristic.

Taxonomy Scale:

The taxonomy scale represents the extremes of desirable and undesirable information-flow characteristics. However, within a real-life information-flow context the characteristic can be measured anywhere on the scale.



Coverage:

The data is sufficient, not missing and is whole. The data covers the whole domain and "contains all the context required for decision making" (Williams et al, 2019, p. 3).

Information-flow Characteristic	Definition	How to Measure	Taxonomy: Desirable/Neutral/ Undesirable
Capacity	The maximum amount of data that can be	Reporting tools/ functionality within	Neutral

	processed in the context.	information systems.	
Completeness	Information is not missing and is whole within the context.	The rate in which there is missing or incomplete data. Quality Checking.	**Desirable -** Information is not missing within the context. If information is missing, it does not impact the information-flow outcomes. **Undesirable -** information is missing within the context.
Quality	Quality refers to the information quality and includes fit for purpose and use.	Quality/ error checking	**Desirable -** Information meets organisations quality standards. **Undesirable -** information does not meet organisations quality standards.
Self-Descriptive	Information is self-explanatory.	The percentage of information that is general and operable.	**Neutral**
Simplicity	The ability for information to be understood. Incorporates ease of use.	Determined by general ability and self-descriptiveness.	**Desirable -** Information can be understood without miscommunication.

			Undesirable - Information is not easily understood.
Soundness	The condition and robustness of the information.	Determined by measuring the quality subjectively.	**Desirable -** Information is robust and in working condition that meets organisaitonal information requirements. **Undesirable -** Information does not meet organizational information requirements and does not have robustness.
Structured	Organisation and state of the information to improve understanding and utility.	Determined by measuring the quality subjectively.	**Neutral**

Relevancy:

Relevancy refers to how appropriate the information is for the context. Interdependencies include "current, timely, correct, and sufficient" information (Williams et al, 2019, p. 3).

Information-flow Characteristic	Definition	How to Measure	Taxonomy: Desirable/Neutral/ Undesirable

Aligned	Correct contextual attributed and supports organisational goals.	Measurement is based on level of metric alignment with Organisational objectives	**Desirable -** Information supports organizational goals **Undesirable -** Information does not support organizational goals
Flexible	The ability for the information to change with limited/ reduced or no errors.	Measured by determining the veracity of the data that has been exposed to multiple information-flow points. Therefore, understanding the number of information-flow errors.	**Desirable -** The information can change with limited/ reduced or no errors. **Undesirable -**The information changes with substantial errors.
Generalisability	Information that can be applied anywhere.	Measured by assessing if information is transferrable or interoperable.	**Neutral**
Maintainability	Resource requirement over time to improve and meet tasks.	The rate at which information-flow processes must be reviewed for improvement and prevention of errors.	**Neutral**

Usability:

Usability refers to the degree for information to be fit for use. Usability also refers to how the information impacts clinical outcome in terms of benefit or/and harm.

Information-flow Characteristic	**Definition**	**How to Measure**	**Taxonomy: Desirable/Neutral/ Undesirable**
Adaptability	The ability for the information to be used in different contexts.	Measured through organizational metrics.	**Neutral**
Addressability	The ability for information to respond to internal and external factors.	Measurement through organizational metrics.	**Neutral**
Compatible	Ability for information to be adhere to quality frameworks.	Evidence of quality framework practices in use within the context.	**Desirable -** The information to an extent adheres to quality frameworks **Undesirable -** The information does not adhere to quality frameworks
Complexity	Relevant structure and appropriate to the context.	Observation if the information is relevant to the information-flow context.	**Desirable -** The information is appropriate to the information-flow context. **Undesirable -** The information is not appropriate to the information-flow context.

Effectiveness	The effectiveness of the information within the context.	KPIs can be used to measure the effectiveness	**Desirable -** The information is effective within the context. **Undesirable -** The information is not effective within the context.
Efficient	The degree to which the information is efficient.	KPI which incorporates an aspect of timeliness	**Desirable -** The information is efficient. **Undesirable -** The information is not efficient.
Interoperable	Information is interoperable. Common or mappable ontology.	Subjective assessment to identify if information has a common ontology.	**Neutral**
Interpretability	The ease of how information can be translated and read.	Subjective approach to understand if the information is easily understood.	**Desirable -** Information is easily translates and read. **Undesirable -** Information is not easily translated or read.
Mobility	The capability and efficiency of information.	A mixture of capability and efficiency KPIs.	**Desirable -** Information has capacity and efficiency. **Undesirable –** Information does not

			have capacity or efficiency.
Modularity	The ability to which information can be separated.	Assessment to identify if information can be separated.	**Neutral**
Operability	The ability of information to be functional, reliable, and fit for use.	Subjective assessment on information operability.	**Desirable** – The information is functional, reliable and fit for use. **Undesirable –** The information is not functional, reliable and fit for use.
Performance	Overall performance of information within the context.	Identification on how the information functions within the context.	**Desirable** – Information meets performance levels within the context. **Undesirable –** Information does not meet performance within the context.
Safety	The degree that information-flow processes that lead to benefit	Identification of errors or impact to patient safety.	**Desirable -** The information=flow processes lead to benefit. **Undesirable –** The information-flow processes do not lead to benefit.

Serviceable	The ability for information to useable.	Subjective assessment on if the information could be used or was relevant to the context.	**Desirable** – The information is useable. **Undesirable – T**he information is not useable.
Sociability	The ability of information to be used in other instances or contexts.	Subjective assessment to understand if the information could have been used in other contexts without error.	**Desirable** – The information can be used in other contexts. **Undesirable – T**he information cannot be used in other contexts.
Understandable	The quality of information being comprehensible.	Subjective assessment to identify if information could be understood.	**Desirable** – The information is comprehensible. **Undesirable –** The information is not comprehensible.
Value	The worth of the information to the organisation and in relation to the organisational goals.	KPIs/ obvious observation that information achieved organizational goals.	**Desirable -** The information is of value to the organization. **Undesirable -** The information is not of value to the organisation**.**
Volatility	Information is unpredictable	How unpredictable information-flow is and the way in which it changes.	**Desirable –** The information-flow is predictable.

			Undesirable - The information is unpredictable.
Fit for Use	The right information is available to the right person, at the right place at the right time, in the right format. Includes organisational and individual fit for use.	Identification that information is fit for use.	**Desirable** The information is fit for use. **Undesirable -** The information is not fit for use.
Functionality	The ability for information to be fit for use and to serve the organisational goals.	Identification of information functionality and comparison to organisational goals.	**Desirable -** The information is fit for use and serves the organizational goals. **Undesirable –** The information is not fit for use and does not serve the organizational goals.

Availability:

Availability refers to information readily available and accessible when required. Availability includes accessibility and latency

Information-flow Characteristic	**Meaning**	**How to Measure**	**Taxonomy: Desirable/Neutral/ Undesirable**

Accessibility	The ease of accessing information and having information available in the correct location.	Confirmation that the information is accessible.	**Desirable -** Information is accessible and in the correct location. **Undesirable -** Information is not accessible and is not in the correct location.
Latency	Information-flow response time	Time measurement on the information-flow response time.	**Neutral**

Reliability:

Reliability refers to the degree to which information is trustworthy and accurate.

Information-flow Characteristic	Definition	How to Measure	Taxonomy: Desirable/Neutral/ Undesirable
Accuracy	The quality of information being correct and free from errors.	The amount of information free from error.	**Desirable -** The information is correct and free from errors. **Undesirable -** The information is not correct and contains errors.

Consistency	Information quality is consistent	The amount of information consistent.	**Desirable -** The information quality is consistently high. **Undesirable -**The information quality is not consistently high.
Portability	Ability for information to be transferrable from one context to another.	Observation of information portable ability	**Neutral**
Redundancy	Interventions to prevent information from errors or failure.	The number of interventions in place to prevent error/ failure.	**Desirable -** Interventions are in place to prevent information errors and failure. **Undesirable -** Interventions are not in place to prevent information errors and failure.
Repairability	Ability for information failure to be prevented.	The number of cases where information failure was prevented.	**Desirable -** Information failure can be prevented. **Undesirable -** Information failure cannot be prevented.
Repeatability	The degree to which information can be repeated with the same outcomes, without error.	The number of times the same information resulted in error.	**Desirable -** The information can be repeated with the same desirable outcomes without error.

			Undesirable - The information cannot be repeated with desirable outcomes and contains errors.
Sensitivity	The degree to which information causes errors.	The number of times and extent information causes error.	**Desirable -** Information does not cause error. **Undesirable -** Information causes error.
Timely	How useful information was at the appropriate time and context.	The number of times information was useful.	**Desirable -** Information was useful **Undesirable -** Information was not useful.
Tolerance	The limit to which information points can fail.	Review of information points as to when they fail.	**Desirable -** Information points do not fail **Undesirable -** Information points fail.
Validity	The quality of acceptability. Incorporates soundness.	The number of times information is acceptable.	**Desirable -** The information is acceptable. **Undesirable -** The information is not acceptable.
Trust	The information to be reliable and for it to be at	The number of times information is reliable.	**Desirable -** The information is reliable

	a satisfactory/ acceptable level.		**Undesirable -** The information is not reliable.
Longevity	The information lifecycle and the period for which information is relevant for.	The length of time information is relevant for.	**Desirable -** The information is relevant. **Undesirable -** The information is not relevant
Bias	The extent to which the information has disproportionate influence.	Subjective assessment on whether information has bias.	**Desirable -** The information is not bias. **Undesirable -** The information is bias.

Security:

Security refers to the state for the information to be secure, includes confidentiality and formality.

Information-flow Characteristic	**Definition**	**How to Measure**	**Taxonomy: Desirable/Neutral/ Undesirable**
Confidentiality	Information is available to those with correct access	The amount of information that is available to users with correct access.	**Desirable -** Information is available to those with correct access. **Undesirable –** Information is not available to those with correct access.

Formality	Information that adheres to standards and quality frameworks.	A review of how the quality frameworks and standards are adhered to.	**Desirable –** Information adheres to standards and quality frameworks. **Undesirable –** Information does not adhere to standards and quality frameworks.

Quality Assurance:

Quality Assurance refers to the continual improvement process for information-flow. Quality Assurance aims to improve information so that it is free from errors in coverage, relevancy, usability, availability, reliability, and security.

Information-flow Characteristic	Definition	How to Measure	Taxonomy: Desirable/Neutral/ Undesirable
Automobility	Information can be automated	The number of systems that automate information and reduce manual handle points.	**Neutral**
Implantability	The ability for interventions and changes to not harm information.	The amount of successful interventions with limited or no side effects.	**Desirable -** Interventions do not result in information errors.

			Undesirable - Interventions result in information errors.
Improvability	The extend the ability for information to improve.	The number of information-flow context that can be improved.	**Desirable -** Information can be improved. **Undesirable -** Information cannot be improved
Mutability	The ability for information to change structure.	The amount of information that can change structure.	**Neutral**
Progress	The ability for information to improve and mature.	The amount of information that can improve and mature.	**Desirable –** The information can mature. **Undesirable -** The information cannot mature.
Testable	The ability for information points to be tested for failure.	What information points can be tested.	**Desirable -** Information points can be tested. **Undesirable -** Information points cannot be tested.
Correlated	The state of information being connected and dependent on one another.	How the many information points are connected.	**Neutral**
Evidence	The availability of information and statistics.	KPIs, evidence and recordings.	**Desirable -** Information is available to provide

			measurement evidence. Undesirable - Information cannot provide measurement evidence.
Measurability	The ability for information measurements to be quantifiable.	The amount of information that can be measured.	Desirable - Information measurements are quantifiable. Undesirable - Information measurements are not quantifiable.
Custodian	Information is owned and held accountable within contexts.	The number of information that is owned.	Desirable - Information has ownership. Undesirable - Information does not have ownership.
Quantifiable	The ability of information measurements and qualities to be measured.	The number of information that is quantifiable.	Desirable - Information can be measured. Undesirable - Information cannot be measured.
Traceability	Ability to map or track information within the context.	How information is mapped.	Desirable - Information can be tracked. Undesirable - Information cannot be tracked.

Transparency	Ability for information to be transparent.	The number of information that is transparent.	**Desirable -** Information is transparent. **Undesirable -** Information is not transparent.
Consistency	Information quality is consistent	How much information quality is consistent.	**Desirable -** Information quality is consistent. **Undesirable -** Information quality is not consistent.
Audit Capability	Ability for information performance to be tracked and reported on.	The amount of information that has audit capability.	**Desirable -** Information can be tracked and reported on. **Undesirable -** Information cannot be tracked and reported on.
Coverage Quality	The information is fit for purpose. Suitable to a task and within the scope, and appropriate to the domain (context).	The amount of information has coverage quality.	**Desirable** - The information is fit for purpose. **Undesirable -** Information is not fit for purpose.
Data Lineage	The data origin and the changes that occur to information.	Traceability of a data's origin and changes.	**Neutral**

Artefact 4: Supporting Information-flow Characteristics explanation

How to Use the Capability Maturity Calculator:

- Use the Capability Maturity Calculator to Calculate the maturity level of your organisation's information-flow. Ensure you have information-flow data and information-flow context that can be used in the Calculator.
- The Maturity Calculator Tab, the 7 Information-flow metrics are present. Each Information-flow metric has information characteristics. To determine the Information-flow metric maturity level, the information characteristics maturity level needs to be subjectively determined, based on your organisations information-flow context.
- Using your organisation's information-flow context mark each information characteristic as: Level 0, Level 1, Level 2, Level 3, Level 4, Level 5 or Not Measurable. Use the Capability Maturity Model to identify the information characteristic measurement.
- If it is not Measurable, place the justification (Not Relevant, Insufficient Information, Influencing Factors).
- The Overall Totals are determined based on average Maturity Level. This will be determined by your organisation's information-flow maturity level characteristics and subjectively determined by your organisation.
- Refer to the Guide to Improving Maturity to improve the information-flow maturity level. There is a column in the calculator to enter potential improvement activities for information-flow.
- Once the improvements have been implemented to your organisation, remeasure the maturity levels with the Framework.

Artefact 4: Calculator Tool (Healthcare Information-flow Maturity Framework Calculator)

About the Calculator

This tool is the Health Information-flow Maturity Framework's Calculator.

This tool can be used to calculator information-flow maturity and to identify improvements to information-flow.

Ensure you have read the Healthcare Information-flow Maturity Framework. Further instructions for the Healthcare Information-flow Maturity Calculator can be found within the Healthcare Information-flow Maturity Framework.

Instructions:

1. There are 7 information-flow capability maturity metrics (Coverage, Relevancy, Usability, Availability, Reliability, Security). Refer to the Capability Maturity Model Tab

2. These 7 information-flow capability maturity metrics each have information characteristics. Refer to the Metric Definitions Tab.

3. To determine the Information-flow category maturity level, the information characteristic levels need to be subjectively and individually determined based on your organisational information-flow context.

4. For each information characteristic, use the drop-down box to mark as: Level 0, Level 1, Level 2, Level 3, Level 4, Level 5 or Not Measurable. (Level 0 being no characteristic present, while Level 5 being the characteristic optimised).

6. Then use the drop-down box to select the Overall Maturity Level based on the information characteristics maturity levels.

Note:

- If an Information characteristic or overall maturity level is Not Measurable, select the justification (Not Relevant, Insufficient Information, Influencing Factors). If you would like to type your justification, select “Type” and then type your comments.

- If you have ideas for improving the information characteristic, type the activities in the Improvements column.

Maturity Calculator

Metric Category	Metric Characteristic	Metric Level	Justification	Improvement Activities
Coverage	Capacity			
	Completeness			
	Quality			
	Self-Descriptive			
	Simplicity			
	Soundness			
	Structured			
Overall Coverage Maturity Level				
Relevancy	Aligned			
	Flexible			
	Generalisability			
	Maintainability			
Overall Relevancy Maturity Level				
Usability	Adaptability			
	Adressability			
	Compatible			
	Complexity			
	Effectiveness			
	Efficient			
	Interoperable			
	Interpretability			
	Mobility			
	Modularity			
	Operability			
	Performance			

	Safety			
	Serviceable			
	Sociability			
	Understandable			
	Value			
	Votality			
	Fit for Use			
	Functionality			
Overall Usability Maturity Level				
Availability	Accessibility			
	Latency			
Overall Availability Maturity Level				
Reliability	Accuracy			
	Consistency			
	Portability			
	Redundancy			
	Repairability			
	Repeatability			
	Sensitivity			
	Timely			
	Tolerance			
	Validity			
	Trust			
	Longevity			
	Bias			
Overall Reliability Maturity Level				
Security	Confidentiality			
	Formality			
Overall Security Maturity Level				
Quality Assurance (QA)	Automobility			
	Implantability			
	Improvability			

	Mutability			
	Progress			
	Testable			
	Correlated			
	Evidence			
	Measurability			
	Custodian			
	Quantifable			
	Traceability			
	Transparency			
	Consistency			
	Audit Capability			
	Coverage Quality			
	Data Lineage			
Overall Quality Assurance (QA) Maturity Level				

Artefact 5: Suggested Improvement Table

Once the information-flow maturity levels have been determined, your organisation will need to create objectives for improving the information-flow maturity levels. Using the Calculators improvement activities create an Improvement Activities Action Plan.

Appendix H: Research Ethics Approval

From: donotreply@infonetica.net <donotreply@infonetica.net>
Sent: 07 May 2021 13:31
To: Rebecca Hermon <rebecca.hermon@flinders.edu.au>
Subject: 4259- Low Risk Panel Approval

Dear Miss Rebecca Hermon,

The ethics application outlined below has been reviewed by the Human Research Low Risk Panel and has been Approved.

Project ID: 4259

Project Title: Health Information-flow Quality Determinacy

Chief Investigator: Miss Rebecca Hermon

Application Link: https://researchnow-ethics-forms.flinders.edu.au/Project/Index/4172

The full Approval Notice is attached to this email and you can access the application in the ResearchNow Ethics & Biosafety system via the Application Link above.

Please note: Due to the current COVID-19 situation, researchers are strongly advised to develop a research design that aligns with the University's COVID-19 research protocol involving human studies. Where possible, avoid face-to-face testing and consider rescheduling face-to-face testing or undertaking alternative distance/online data or interview collection means. For further information, please go to https://staff.flinders.edu.au/coronavirus-information/research-updates.

Please don't hesitate to contact the Human Ethics Executive Officers if you have any questions.

Regards,

Hendryk

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Information-flow Maturity Improvement Activities Action Plan

Metric to be improved						
Characteristic to be improved	**Current Maturity Level**	**Date of initial measurement**	**Actions to be taken**	**Goal Maturity Level**	**Date to be completed**	**Comments**