A Concept for Evaluating Value-oriented Frameworks in Software Engineering

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von **Till Johannes Winkler**

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A Concept for Evaluating Value-oriented Frameworks in Software Engineering

PhD Thesis

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Abstract

Considering that many of today's information systems have negative impacts on individuals, society, the economy, the environment, or the technology itself, one must conclude that software engineering is in crisis. Under the umbrella term "Values in Design," an entire field of research and over 18 different frameworks have emerged that attempt to bring value considerations and ethics into practice. Some of these frameworks even claim to facilitate the development of innovative and ethical systems. While these claims are highly desirable, proving that they can be met is anything but easy. So far, the same software has never been developed in parallel, which would allow comparison of results and a proper evaluation of frameworks. A typical approach is to conduct case studies to demonstrate effectiveness, but this has its limitations. Drawing from the literature on software engineering, mediation theory, and sustainability, this thesis proposes a concept to systematize and evaluate the theoretical foundations and methodology of such "Values in Design" frameworks. This concept can help to prevent the reintroduction of similar theories and methods, allow for mutual learning and improvement of frameworks, and facilitate further research in this area. In addition, a systematic examination could provide a starting point for practitioners to incorporate value considerations and ethical aspects into their current software engineering practice and facilitate the selection of framework aspects to use. The proposed concept is demonstrated for "Value Sensitive Design" and IEEE Std. 7000 "Standard Model Process for Addressing Ethical Concerns during System Design," both recognized in the field. In addition, quality metrics to measure the innovative and ethical potential of system requirements are proposed and demonstrated, which can help to substantiate the claims made without the need to develop a final software product.

Keywords:

Software Engineering, Requirements Engineering, Sustainability, Values in Design

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List of Abbreviations

Abbreviation	Meaning
AI	Artificial Intelligence
ConOps	Concept of Operations
DT	Design Thinking
EVRs	Ethical-Value Requirements
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GORE	Goal-oriented Requirement Engineering
HNs	Hygiene Necessities
IEEE	Institute of Electrical and Electronics Engineers
IEEE Std. 7000	IEEE Std. 7000 Standard Model Process for Addressing Ethical Concerns during System Design
IS	Information Systems
ISO	International Standardization Organization
MRI	Magnetic Resonance Imaging
MTNs	Mediation Theory Necessities
NFR	Non-functional Requirement Framework
OSS	Open Source Software
RE	Requirements Engineering
RED	Requirements Engineering Deliverable
SDGs	Sustainable Development Goals
SE	Software Engineering
SOI	System of Interest
SOS	System of Systems
TPM	Trusted Platform Module
VSD	Value Sensitive Design
VOF	Value-oriented Framework
VOF EvalCon	VOF Evaluation Concept

1. Introduction

The handling of information has a long and rich tradition in the history of mankind. With the advent of digital technology and the triumph of information systems (IS), the cost of processing and exchanging information has been drastically reduced (Hansen et al., 2019). Collecting, processing and transmitting information used to be a tedious and labor-intensive task, but today we are surrounded by opaque IS that automatically collect, process and transmit information. This often happens without our knowledge or consent (Hansen et al., 2019; Christl & Spiekerman, 2016). Such systems can be very complex, encompassing people, processes and—on the technical side—software, hardware and communications infrastructure (Hansen et al., 2019). To a large extent, it is software that makes IS versatile and useful by allowing people to interact with the system, solve problems, and share the results. Just five decades after the invention of microprocessors—an essential hardware component—and three decades after the Internet—the communication infrastructure—was made publicly available, over 6.3 billion people own a mobile, internet capable device (Statista, 2021). A myriad of different software runs on such devices every day. Today, every part of our daily lives, and even those aspects that make us human, are influenced or at least accompanied by software. While 10 years ago the Wall Street Journal concluded that "[i]n short, software is eating the world" (Andreessen, 2011, p.1), the enormous increase in the ubiquity of software could not have been foreseen even ten years ago. Considering that software affects individual, social, economic and environmental aspects of our lives, some even go so far as to predict that software could one day determine the future of our species and the planet (Naumann et al., 2011). At an individual level, software has an impact on the way we communicate (messenger apps), meet partners (dating apps), acquire knowledge (Wikipedia), and maintain our health for instance by artificial intelligence (AI) driven-diagnosis. On a social level, the ability to use software is crucial for active participation in society, whether through contributing to public opinion forming (social media) or cultural participation (buying online tickets). Furthermore, the economic success of individuals (AI recruiting) or the preservation of individual goods, time and money (online banking) are increasingly dependent on software. Finally, software has a profound but double-edged impact on our environment, by either promoting climate protection (climate monitoring) or by consuming a substantial amount of resources. Just twelve years after Andreessen (2011) realized that it eats the world, software is devouring the world with unimaginable ubiquity and speed.

Software—as an essential part of IS—is not only pervasive, but also can lead to various negative consequences and negatively influence values such as privacy, autonomy, or human well-being. Research has shown that IS can reduce human well-being by increasing stress (Barley et al., 2011), leading to symptoms of depression (Rosenthal et al., 2021) and even increasing suicide rates (Twenge et al., 2018). Some social media platforms, such as Instagram, are known to promote negative body image among teenagers, thereby reducing self-satisfaction and human well-being (Well et al., 2021). Other platforms and especially their software can reinforce political radicalization, which threatens to lead to social fragmentation (Törnberg et al., 2021). Blockchain-based systems are known to produce unnecessary carbon dioxide emissions and large amounts of toxic e-waste, posing a threat to our environment (de Vries & Stoll, 2021). These are only a few examples that show how existing systems can have negative consequences for us as individuals, our society and the environment. Considering such negative effects, we ask ourselves whether the triumph of IS can really be affirmed by a simple metric like decreasing cost, or whether the real costs are merely imposed on individuals, the society and the environment (cf. Hansen et al., 2019). Overall, this thesis revolves around exactly such negative consequences, where they come from, and what can be done about them. When I talk about IS in this thesis, I mainly refer to the software component of these systems.

1.1 A Need to Change Software Engineering

There are four widely held assumptions about the origin of harmful IS, which I will briefly introduce below and in more detail later. Understanding the causes of harmful IS can help determine a potential direction for solutions or mitigation strategies.

First, according to proponents of the value-neutrality thesis such as Joseph Pitt, technology is generally "... morally and politically neutral, neither good nor bad …" (Miller, 2021, p. 54). This assumption is still widespread in Software Engineering (SE) and implies that software is a purely functional and neutral tool or instrument that merely produces outputs according to inputs (cf. Hansen et al., 2019). Negative consequences in this view are therefore only the result of use—depending on the input—and misuse or malicious use can never be completely ruled out. In this view, a knife is just an instrument without moral significance that ".... can be used to murder an innocent person or peel an orange for a starving person ...". (Miller, 2021, p. 54). This logic is applied, for example, to software related to social media, which can be used either for communication and community building or for self-representation, leading to lower self-esteem among others (cf. Well et al., 2021). Adherence to this assumption is widely disputed and also problematic because engineers can do little to reduce the negative impacts of IS.

Second, countless scholars have overcome the myth that technology is amoral and neutral, and that its harmful effects cannot be prevented by engineers (cf. Friedman & Nissenbaum, 1996; Van Gorp & van de Poel, 2001; Verbeek, 2011; Johnson, 2015; Miller, 2021; Spiekermann, 2015). According to mediation theory, for instance, technology is not a neutral tool but value-laden with moral implications (Verbeek, 2011). In line with this theory, many scholars assume that the main cause of harm is a lack of value considerations during SE—the specification, design and development of software (Spiekermann, 2015). According to this assumption, the consideration of values such as privacy, autonomy, or human well-being in SE can help to prevent many negative consequences and ethical issues. Values are seen as essential for more responsible or even ethical engineering, as they provide a starting point for considering what should or ought to be done in a given context (Gogoll et al., 2021). In contrast to the value-neutrality thesis, this—if successfully put into practice—could enable a paradigm shift in the way software is developed.

The third common assumption is that the complexity of the system leads to unpredictable and sometimes negative consequences. Today’s IS can often be classified as a system of systems (SOS), which is a collection of multiple sub-systems with policies, processes, organizations, and people behind them (Sommerville, 2016). Many in the SE community believe that it is the complexity of current SOS that makes it impossible to prevent harmful effects since these types of systems are not deterministic (Sommerville, 2016). Taking, for instance, the complexity of an Artificial Intelligence (AI) system, some might even consider it “… unfair to blame humans for the behavior of machines that they cannot control…,” which could be termed a “responsibility gap” (Johnson, 2015, p. 709). However, also according to this assumption, something can be done, for instance, to either reduce complexity or adopt practices that allow us to deal with it (Schneberger & McLean, 2003). It is certainly necessary to take responsibility for the systems and associated software (Johnson, 2015).

Fourth, other scholars see the origin of the negative effects in the current conditions under which software systems are developed. It might especially be the market-driven development context that produces systems that challenge social norms (such as privacy) and even lead to the violation of rights and laws (Zuboff, 2015). According to this view, it is a combination of aspects, such as “… economic environment, regulatory decisions, historical events, public attitudes, media presentations…,” (Johnson, 2015, p. 712) that lead to the development of harmful systems. Something can be done in this regard as well, as the development conditions under which systems are created can be changed.

In summary, there are several perspectives on the origin of harmful IS, all of which have merit. Systems can be misused, values such as human well-being are typically not considered during SE, effects are hard to predict due to complexity, and the development context invites the violation of rights and laws (cf. Sommerville, 2016; Spiekermann, 2015; Zuboff, 2015). Against this background, many scholars point out that we need a paradigm shift in the way we practice SE if we want to live in a world with better IS that come with fewer harmful consequences (cf. Sommerville, 2016; Spiekermann, 2015; Friedman & Nissenbaum, 1996).

1.2 Research Question

Regardless of the perspective from which one views the origins of harmful IS, it seems clear that businesses, management, designers, and engineers need to pay more attention to the way SE is practiced, and thus to the way software is specified, designed, and developed. Fields such as “Computer Ethics” and “Social Informatics” have developed a good understanding of the relationships between technology, humans, and values, but these field have been criticized in the past for not achieving practical applicability (Friedman & Kahn, 2007). However, under umbrella terms such as "Values in Design" or "Design for Values," many frameworks have emerged that set out to include value considerations in SE to address the suspected causes of harmful IS (Grunwald, 2015). While Donia and Shaw (2021) alone consider 18 different value-oriented frameworks (VOFs), this number can be easily increased if technology-specific or non-academic frameworks are also included (cf. Aldewereld & Mioch, 2021; Gispen, 2017; Praca, 2018). Gregor and Jones (2007) suggest that due to a lack of theories and systematization, there is a general tendency in the IS sector to reinvent design artifacts, methods, or frameworks under new labels. This may partly explain why there are 18 different VOFs (Donia & Shaw, 2021) with varying levels of sophistication. In practice, this enormous number of VOFs can be burdensome for practitioners seeking to improve their SE practices with value considerations, as it is difficult to choose which one to use.

Of all frameworks proposed, I will hereafter mainly focus on Value Sensitive Design (VSD) and IEEE Std. 7000 “Standard Model Process for Addressing Ethical Concerns during System Design” (hereafter: IEEE Std. 7000) in this thesis (cf. IEEE, 2021; Friedmann & Hendry, 2019). I focus on these two in particular, since both are well established and either, in the case of VSD, have a long academic history or, in the case of IEEE Std. 7000, are well recognized by the standards community (Friedman & Nissenbaum, 1996; Friedmann & Hendry, 2019; IEEE, 2021; ISO, 2022a). The IEEE Std. 7000 framework’s stated purpose is that it helps to “address ethical concerns or risks”, supports “anticipating value implications and consequences” and helps in “avoiding or mitigating value harms or ethical pitfalls” (IEEE, 2021, p. 12f). In addition, there is an emphasis on innovation, for instance, by explicitly including stakeholders who are “driving the innovation effort” (IEEE, 2021, p. 37). Similarly, VSD states that it “… is distinctive for its design stance—envisioning, designing, and implementing technology in moral and ethical ways that enhance our futures” (Friedman & Hendry, 2019, p. 2). The basic idea behind these frameworks is the same: insufficient ethical and value considerations during SE lead to poor design decisions that in turn result in harmful systems (Mittelstadt, 2019). In short, both frameworks have the stated purpose, and thus claim to facilitate the development of innovative and ethical IS by putting ethical considerations into practice (cf. Friedmann & Hendry, 2019; IEEE, 2021). If these claims turn out to be true, it could drastically change the way we develop software, and thus IS, in the future.

That said, it is far from easy to prove that these frameworks can live up to their stated purposes. At this moment in time, the only convincing approach to evaluate them would be to develop the same software in parallel—each based on different frameworks—allowing a comparative impact assessment of the final product (Wright, 2011; Grunwald, 2015). Such an endeavor has never been undertaken because it would be too costly, and controlling external factors such as the motivation, skills and commitment of stakeholders and others is almost impossible to achieve. Another approach would be to compare the success of case studies, but such comparisons are also not without limitations.

In this thesis I want to offer an alternative comparative evaluation of VSD and IEEE Std. 7000 by systematizing their theoretical foundations and methodology. A particular focus is on whether the theoretical and methodological foundations of these VOFs do justice to their claims to facilitate the development of innovative and ethical IS. Therefore, this thesis aims to provide an answer:

- **Research Question:** “To what extend are VSD and IEEE Std. 7000 equipped with the necessary theoretical foundations and methodology to meet the claim of facilitating the development of innovative and ethical IS?”

To approach this question, one must first understand why a paradigm shift in the way IS are currently developed is needed, and what must be accomplished to develop the software part. There is also a need to understand why SE produces harmful software and what negative effects it has. Negative effects are defined here as negative consequences for individual, social, economic, environmental, and technical sustainability. To answer the research question, it is also important to gain an understanding of what a paradigm shift could ideally look like and what is needed to achieve it. Here, I refer to mediation theory as a philosophical perspective on the human-technology relationship that, in contrast to the state of practice in SE, sees the system as value-laden and with moral significance that co-shapes people, context, and itself (Verbeek, 2011). Partly unconsciously, VSD and IEEE Std. 7000 bring this philosophical perspective to practice and therefore should be able to meet the necessities of mediation theory with their own theory and methodology. Taken together, the findings on SE, sustainability, and meditation theory are brought together to formulate a concept to systematize and evaluate the theoretical underpinnings and methodology of VSD and IEEE Std. 7000. This concept allows to evaluate on a theoretical level whether they are able to fulfill the claim of enabling the development of innovative and ethical IS. To go beyond theoretical considerations, quality measures are proposed and tested—during a quantitative experiment—that could allow for measuring the ethical and innovative potential of the outcomes produced by VSD and IEEE Std. 7000. From a methodological point of view, the first part of this thesis—the formulation of the evaluation concept and its application—is a literature synthesis based on the snowballing method, using key documents as a starting point to search for further literature, while the second part is mainly a quantitative experiment.

Answering the research question and presenting and enabling a systematization of both frameworks—VSD and IEEE Std. 7000—can help not only to ease the agony of choice for practitioners who want to use VOFs, but also to improve them by finding and filling theoretical and methodological gaps.

1.3 Terms and Focus Area

While often used interchangeably there is a profound difference between the terms *"systems engineering,"* *"software engineering,"* *"requirements engineering,"* *"development,"* *"design,"* "*system design*," "*methodology*" and "*framework*." In the following, I will briefly explain the differences and relationships between these terms and narrow down the focus area of this thesis. The focus area and key relationships between these terms are illustrated in Figure 1.

Essentially, every engineering discipline is the application of processes—based on theories and frameworks—to find a solution for stakeholder expectations (ISO, 2015; Sommerville, 2016). The goal of both "*systems engineering*" and "*software engineering*" is to put processes into practice, which encompass all steps necessary to realize a successful system (Sommerville, 2016). Both the terms "*systems engineering*" and "*software engineering*" describe large disciplines that encompass several sub-fields. While *"systems engineering"* includes all aspects of IS, including organizational processes, hardware, software and infrastructure, "*software engineering*" focuses primarily on the realization of successful software systems (Sommerville, 2016). Therefore, "*software engineering*" (SE) is an important sub-field of "*systems engineering*". In this thesis I will mainly focus on software and thus on "*software engineering*" (SE) because I consider software to be the most consequential and also changeable part of a system. Compared to other aspects, such as hardware, software can "… be changed more easily —it is pure thought—stuff, indefinitely malleable" (Brooks & Bullet, 1987, p. 4). In the further course of this thesis, it will become clear how consequential software can be.

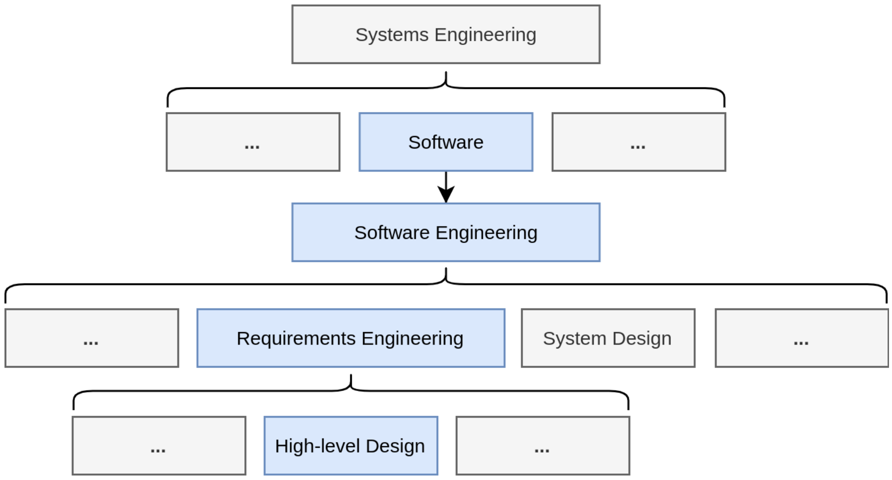


Figure 1: *Relationship between the terms and focus areas of this thesis*

The first step of SE is to specify software by defining requirements—called "*requirements engineering*" (RE)—that must be met in order to fully satisfy expectations stakeholders have towards a system (Sommerville, 2016). The conceptual work of requirements definition is generally considered the most challenging part of SE, and no other aspect is as debilitating and difficult to correct later if done incorrectly (Brooks & Bullet, 1987). Since many scholars consider this conceptual work to be the most impactful step that can lead to harmful or unethical software, special emphasis will be placed on RE in this thesis (Spiekermann, 2015; Van den Hoven, 2017; Van Gorp & van de Poel, 2001). Among other steps, RE involves "*design*," which is a highly individualized series of activities that help to understand stakeholder expectations and ideally propose a high-level concept to satisfy these (Hevner et al., 2004). Design activities within RE are often conducted by designers—non-engineers—and may include interviews, focus groups, workshops, prototyping, or any other activity that helps to understand and subsequently solve, on a relatively high-level, the expectations of the stakeholders (Sommerville, 2016; Sharma & Pandey, 2013). In this thesis, I will refer to such activities as "*high-level design*" in order to clearly delineate it from "*system design*," which is an SE activity that starts after RE. Once RE has delivered a collection of requirements, "*system design*" can begin, that is, finding a technical solution—orchestration and conception of subsystems, components, interfaces and software architecture—which fulfills these requirements (Sommerville, 2016). The development of a "*system design*" is then done by engineers, sometimes called "*systems engineers,*" while the subsequent implementation—turning a system into reality—is done by a developer or programmer during "*development.*" Since the distinction between designer, engineer, developer and programmer is often fluid, for readability reasons, I will refer only to "*engineers,*" which here encompasses all four practices.

From an SE perspective, VSD is mostly a "*high-level design*" framework, while IEEE Std. 7000 is a larger software engineering framework that among multiple RE activities also has a process with activities for "*system design*" (IEEE, 2021). It is this different range of included activities—of VSD and IEEE Std. 7000—that complicates the comparison and evaluation of these frameworks. In this thesis, I focus on RE. Although IEEE Std. 7000 and VSD are often referred to as "*methods,*" "*practices,*" "*approaches,*" or "*methodologies,*" in line with SE, I will use the term "*frameworks*" for these two. This is to avoid confusion with other methods, approaches, or methodologies that are a sub-part of these. Specifically, I will use the term "*value-oriented framework*" (VOF) to distinguish VSD and IEEE Std. 7000 from other frameworks such as Design Thinking (DT) or Goal-oriented Requirement Engineering (GORE) —without a focus on values—mentioned in this thesis. In general, a framework guides towards a purpose and is flexible, leaving room for the inclusion of other processes or methods, while a methodology is a rigorous set of principles, approaches, and practices for repeatedly solving a problem in the same systematic way (Draffin, 2010). Nevertheless, frameworks typically propose a methodology based on theoretical foundation; that is, they are a composition of methods. VSD is rightly viewed as a normative framework in that it encourages practitioners to consider specific aspects, theories, and methods, but does not prescribe solving a problem or situation in one systematic way (Hendry et al., 2021). Because there are many different types of software, this flexibility is essential from an SE perspective, which typically uses frameworks to guide the conception of software in a particular direction (Sommerville, 2016).

Although the wording may make it seem counterintuitive to some, standards (and their associated documents) such as IEEE Std. 7000, ISO 15288, and ISO 12207 also describe frameworks that are inherently flexible. ISO 12207, for instance, aims to “establish a common framework for software life cycle processes” (2017a, p. 1); similarly, ISO 15288 “establishes a common framework of process descriptions for describing the life cycle of systems created by humans” (2015, p. 1). Additionally, standards typically provide several conformance options that “allow flexibility in the application,” making them more of a framework than a methodology (IEEE, 2021, p. 24). Engineers applying a standard can, for instance, choose to “assert full conformance to the outcomes,” which enables the implementation of “… innovative process variants that achieve the results (i.e., the outcomes) of the declared set of processes without implementing all of the activities and tasks” (IEEE, 2021, p. 24). Such options provide the opportunity to be flexible and, for example, include processes or methodologies from other fields or frameworks that are deemed appropriate for achieving an outcome. Such an outcome can, for instance, be that “[s]takeholders involved with the envisaged system throughout its life cycle are identified and their representatives are chosen” (IEEE, 2021, p. 26), for which any methodology can be used to identify stakeholders and select their representatives.

Although it is much more rigorous than VSD, in this thesis, when I refer to IEEE Std. 7000, I will also use the term "*framework*" and in particular "*value-oriented framework*" (VOF), since this standard aims to foster value creation through SE.

1.4 Thesis Structure

This thesis is written with engineers in mind, with the intent of providing them a perspective on problems and challenges in current SE practices. Besides pointing at SE challenges, it is also the intention both to offer a starting point for incorporating VOFs into ongoing projects and to provide the means to evaluate their claims. According to the rough structure of this thesis, Sections 2 to 4 provide the theoretical background to the development of a "VOF Evaluation Concept" (hereafter: VOF EvalCon), which is then formulated in Section 5 (*"Concept for Value-oriented Framework Evaluation")*. This concept is then applied to evaluate the theoretical foundations and methodology of VSD and IEEE Std. 7000 in Section 6. Afterwards, results from testing the measurable part of this concept—namely, quality metrics for innovative and ethical potential—are presented in Section 7. Figure 2 gives an overview of the main subsections required for the formulation of the VOF EvalCon with theoretical background in green and the subsections where the concept is applied in orange.

Before one can hope to evaluate VOFs, one must first understand SE; that is, today's practice of how software is developed, which these frameworks aim to steer and contribute to. Therefore, in Section 2 (*"State of Practice in Software Engineering"*), I will first introduce how SE is typically practiced in industry, and then in Section 2.1 (*"Anchoring Ethical Issues"*), I will describe how harms and ethical issues are introduced and anchored in software, even if SE is performed by the book. Afterwards, I present a typical RE process—the first engineering step of SE—in Section 2.2 (*"Requirements Engineering"*) and articulate three necessary deliverables that VSD and IEEE Std. 7000 must contribute to. These deliverables are a primary aspect for the VOF EvalCon (Section 5 *"Concept for Value-oriented Framework Evaluation"*). It should also become clear in this section that from an SE perspective, VOFs must enable the specification of system requirements with innovative and ethical potential in accordance with their claim. Another important point to understand involves the harms that current IS are causing; only by understanding these can one assess whether VOFs are attempting to mitigate them and their origins. To approach this topic, Section 2.3 ("*Origins of Harmful Information Systems*") draws a relation between assumed origins of harmful IS, their effect on SE and consequences for sustainability. In the following section (Section 2.4 "*Impact on Sustainability Dimensions*"), and its subsections (Section 3.1.1 to 3.1.5), each sustainability dimension—individual, social, economic, environmental, and technical—is defined and the negative impact on these as a result of SE is exemplified. This is to show that VOFs are expected to have a positive impact on the sustainability dimensions and that a paradigm shift in the way SE is conducted is needed.

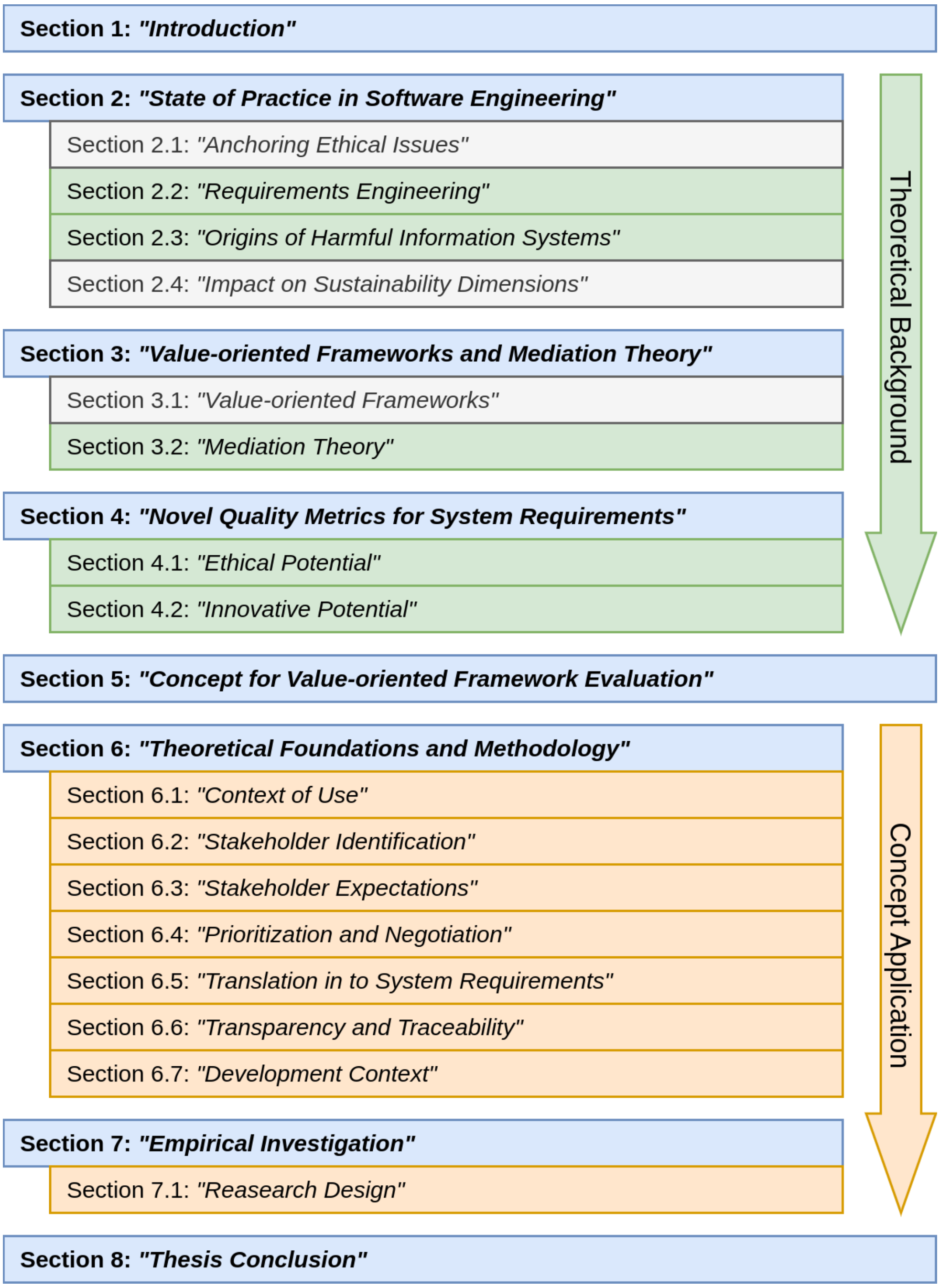


Figure 2: *Sections with theoretical background (green) for the VOF EvalCon and its application (orange).*

In Section 3 (*"Value-oriented Frameworks and Mediation Theory"*), it is first established that SE practices have changed in the past, and then Section 3.1 (*"Value-oriented Frameworks"*) presents VOFs that promise such a change or even paradigm shift. Subsequently, Sections 3.1.1 (*"IEEE Std. 7000"*) and 3.1.2 (*"Value Sensitive Design"*) introduce IEEE Std. 7000 and VSD specifically with their theoretical commitments, processes, and investigations intended to facilitate the development of innovative and ethical IS in particular. In Section 3.1.3 ("*Contribution to Software Engineering*"), it is shown where within the SE process these VOFs aim to contribute to the process and thereby steer it.

Subsequently, Section 3.2 ("*Mediation Theory*") introduces mediation theory as a philosophical perspective on the human-technology relation that could enable a paradigm shift in SE if successfully put into practice by VOFs. Based on the mediation theory considerations, in Section 3.2.1 (*"Theory Necessities"*) mediation theory necessities are formulated for which VSD and IEEE Std. 7000 should provide theoretical foundations and the methodology (Section 7). In addition, in Section 3.2.2 ("*Hygiene Necessities*") contextual development factors—hygiene necessities—based on mediation theory are described that should also be considered.

Based on knowledge from the previous sections, a relation is then drawn between sustainability and ethics and a novel quality metric is introduced for evaluating the ethical potential of requirements in Section 4.1 ("*Ethical Potential*"). Afterwards, in Section 4.2 ("*Innovative Potential*") an additional novel quality metric is introduced for evaluating the innovative potential of requirements. These two quality metrics become part of the VOF EvalCon (Section 6) and the results of testing these are presented in Section 7 (*"Empirical Investigation"*).

All previous insights are combined in Section 5 (*"Concept for Value-oriented Framework Evaluation"*) to form a comprehensive VOF EvalCon. The most essential background are the necessary RE deliverables (Section 2.2), the assumed origins of harmful IS (Section 2.3), the theory and hygiene necessities of mediation theory (Section 3.2.1 and 3.2.2) and the quality metrics for the ethical and innovative potential of system requirements (Section 4.1 and 4.2). This concept allows any VOF to be evaluated against the stated purpose of facilitating the development of innovative and ethical IS without the need to develop a final software product. Enabling theoretical evaluation of VOFs is seen as a crucial contribution and can, in particular, help to expand knowledge by identifying and filling theoretical gaps (Hevner et al., 2004).

This concept is used in Section 6 (*"Theoretical Foundations and Methodology"*) to examine whether and how VSD and IEEE Std. 7000 provide the necessary theoretical foundations and methodology to satisfy aspects of the formulated VOF EvalCon (Section 5 *"Concept for Value-oriented Framework Evaluation"*). As a practical contribution, Section 6 systematizes the theoretical and methodological contributions of VSD and IEEE Std. 7000 in line with the state of the practice of SE and RE in particular. This makes it easier for SE practitioners to get started in applying VOF aspects to the industry, which is much needed to increase the awareness and acceptance of these frameworks outside of academia (Detweiler & Harbers, 2014). From a research perspective, this section mainly contributes to identifying strengths and gaps in VSD and IEEE Std. 7000, and thus can help to improve these VOFs in the future. In addition, an overview of the theoretical foundations and methodology of the two VOFs is provided to help novices in this field get started (Section 6.8).

To go beyond theoretical considerations, in Section 7 (*"Empirical Investigation"*), I show the result of applying the newly introduced quality metrics (Section 4)—innovative and ethical potential—in the context of an empirical investigation. In particular, I compare the impact of stakeholder expectation types from typical SE practice with those from VSD and IEEE Std. 7000 on the proposed quality metrics. This allows to assess whether using different stakeholder expectation types on their own facilitates the development of innovative and ethical IS. If legitimate, such quality metrics could help companies validate the innovative and ethical potential of system requirements before these enter *system design*. From a research perspective, the result of the empirical investigation provides insights into the importance of different types of stakeholder expectations.

Finally, Section 8 (*"Thesis Conclusion"*) summarizes all the results and contributions of this thesis, discusses limitations and possible future research, and makes specific recommendations for VOF practitioners. In summary, this thesis provides the following specific contributions:

- A synthesis of the assumed origins of harmful IS and their impacts on sustainability (Section 2.3 *"Origins of Harmful Information Systems"* and Section 2.4 *"Impact on Sustainability Dimensions"*).

- Novel quality metrics that enable to measure the ethical and innovative potential of system requirements (Section 4 *“Novel Quality Metrics for System Requirements”* and Section 7 *“Empirical Investigation”*).
- A comprehensive list of values and their assumed relationship to sustainability dimensions (Section 4.1 *“Ethical Potential”* and Appendix A *“Values in Relation to Sustainability”*).
- A concept that enables the evaluation of the theoretical foundations and methodology of VOFs (Section 5 *“Concept for Value-oriented Framework Evaluation”*).
- A comparison and systematization of the theoretical foundations and methodology of VSD and IEEE Std. 7000 (Section 6 *“Theoretical Foundations and Methodology”*).
- A list of recommendations for practitioners interested in using VOFs for the first time (Section 8.3 *“Recommendations”*).

Each of these contributions aims to enable further research and increase the applicability of VOFs in practice. In the following, I present the current practice of SE and show how ethical issues are introduced and anchored, even if it is done by the book.

2. State of Practice in Software Engineering

Since there are many different types of software, ranging from industrial to consumer-oriented products, there cannot be one universally applicable SE practice (Sommerville, 2016). Although each practice has the habit of introducing its own terminology and varying activities, no one can deny that that software must be *a) specified*, *b) developed*, *c) validated*, and *d) evolved* (Sommerville, 2016). The habit of constantly disseminating new standards, textbooks and competing SE practices has become a source of ridicule for many engineers and has even led to mocking contributions at conferences (cf. Haase, 2016). This might be frustrating for academic scholars working in this domain, as it shows that engineers in industry do not take SE practices as seriously as they should. Indeed, there are many standards—even standard families—applicable to generic SE such as ISO 15288, ISO 12207, ISO 9001, ISO 90003, ISO 15289 and others (Mora et al., 2009). Other standards describe how a standard should be applied—e.g., ISO 24748 for applying ISO 12207 (ISO, 2011a)—and some are domain-specific, such as DO-178C for safety-critical software in aviation (Rierson, 2017). However, it is a fact that standards and SE practices are rarely analyzed and often ignored in industry unless mandated by domain-specific regulations (Mora et al., 2009). Startups, in particular, use any process that supports their business goals and simply don't invest the resources to figure out how to do SE the best way (Coleman & O'Connor, 2008). For example, in startups, requirements are often not discovered according to any state of practice, but are rather "… to a large extent invented, and are based on founders experience, and understanding about the domain…" (Klotins et al., 2019, p. 509). This is unfortunate, because by applying established practices and standards, common issues in SE could be avoided. One might assume that following established practices would save many startups from failure and generally lead to better software.

Although performing SE by the book might lead to better software, it certainly cannot lead to ethical and innovative IS as promised by VSD and IEEE Std. 7000. With upcoming European regulations such as the *Digital Services Act* or the *AI Act*, consideration of ethical issues during SE will increasingly become a legal obligation (European Parliament, 2022; European Commission, 2021). Since 2021, for example, larger Danish companies have been required by law to take ethical aspects into consideration (Folketing, 2020). This is, or at least will be, a challenge for current SE practices that seem unable to consider ethical issues. In the following, I will present SE activities that should be performed and explain how ethical issues in particular are introduced and anchored in the process.

2.1 Anchoring Ethical Issues

The SE activities I describe here are based on a different terminology, but correspond to the stages defined in ISO 12207 (2017a) and other standards—concept, development, production, utilization, support and retirement—as shown in Figure 3. The following considerations are accompanied by a hypothetical worst-case example of SE for geographic information systems (GIS). GIS assist users in estimating travel times and choosing a mode of transportation, but also offer other diverse functions such as finding restaurants and stores. Whether crowed sourced, like OpenStreetMap, or proprietary, like Google Maps or Apple Maps, there is no such thing as a perfect map, which makes GIS prone to biases (Quattrone et al., 2015; Wagner et al., 2021). Because of these potentially diverse functions and biases, GIS are a good case to show hereafter how ethical issues might be anchored during SE. First, it is explained how ethical issues might be introduced and formalized as system requirements (Section 2.1.1) and then implemented, obscured, and anchored in an operating system (Section 2.1.2).

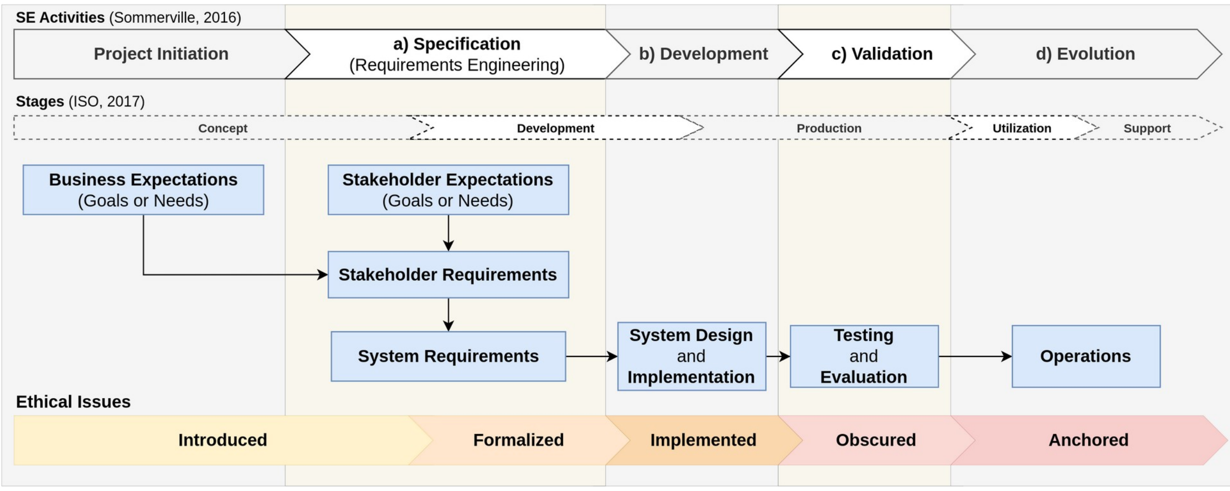


Figure 3: *Introduction of ethical issues into the state of practice SE.*

2.1.1 Project Initiation and Specification

An SE project is usually initiated by a series of management activities during *Project Initiation* that provide a Concept of Operations (ConOps) document. This document contains insights into business goals, gives a broad description of the intended system and its context of use, as well as a list of relevant stakeholders (Sommerville, 2016; ISO, 2011b). For the development of GIS, management could at this point introduce business expectations such as the goal of "*brokering ride-hailing*," with the key stakeholders, such as "*management*," "*users*," and "*ride-hailing provider*." An initial ConOps document is typically refined through financial and technical feasibility studies that evaluate whether the business goal can be achieved within budget and whether the technical resources are available to put an intended system into reality (Sommerville, 2016). Financial and technical feasibility studies are unlikely to raise awareness of potential ethical issues arising from business goals because such issues are simply not addressed. Neither estimating the cost of completing a project (financial feasibility) nor the technical expertise required (technical feasibility) provides insight into potential ethical issues impacting individuals, society or environment.

This ConOps document is the starting point for a) *Specification* of software, commonly referred to as Requirements Engineering (RE). From an engineer's perspective, a large part of RE involves understanding the problem to be solved by a piece of software (ISO, 2015). The problem to be solved is represented by stakeholder expectations expressed, according to the state of practice, as goals or needs (ISO, 2015). Following the hypothetical GIS example, engineers conducting RE might now involve other stakeholders to discover their expectations. In this case, a "*ride-hailing provider*," such as Uber or Lyft, might state the goal of *"selling rides."* The user, on the other hand, might states the goals of "*finding a mode of transportation without interruption from ads*" and to "*tracking next of kin*." The state of the practice would consider these goals as valid, since there is not concept to judge whether these are good or right goals, nor whether these aims have ethical implications or represent valuable problems to solve. SE also does not address the reasons for or behind a particular goal—reasons which might shed light on the potentially problematic nature of a particular goal. Ethical issues related to profiling, manipulation, or tracking next of kin are therefore not discussed and introduced in the project. Berenbach and Broy (2009) observed, that "[s]oftware engineers often engage in unprofessional or unethical behavior without realizing it" (p. 74). This is not surprising given the lack of frameworks or methodologies in SE practice to uncover ethical issues or unethical behavior. In other words, engineers lack the means to understand or judge whether the problem they are trying to solve is a right, good, or well-intentioned one. Therefore, regardless of how diligently or brilliantly SE activities are performed, the results can be questionable. According to Norman (2013), "[a] brilliant solution to the wrong problem can be worse than no solution at all: solve the correct problem" (p. 218). In the initial phases of SE, the means are needed to assess business and stakeholder expectations to identify and then solve the right problem.

Ideally stakeholder expectations—goals or needs—are then formalized into stakeholder requirements (Sommerville, 2016). Following the hypothetical example, stakeholder requirements might be formulated for the ride-hailing providers goals of *"selling rides"* related to *"promoting ride-hailing,"* and *"displaying ad banners."* Similarly, users goals ("*finding a mode of transportation without interruption from ads"* and *"tracking next of kin"*) could be formalized as "*show information for mode of transportation,*" "*do not show ads,*" and "*show position of next of kin on map.*" Before specifying system requirements, stakeholder requirements should be classified, organized, negotiated, and prioritized to ensure these are coherent and agreed upon (Sommerville, 2016). During the negotiation, a conflict between "*displaying ad banners*" (ride-hailing provider) and "*do not show ads*" (users) might be resolved in favor of the users. It is well known that the formulation and prioritization of requirements can be very consequential—not least for human well-being—and ethical issues often arise here (Van Gorp & van de Poel, 2001). Depending on the engineers performing RE, adjustments might be made, such as sharing anonymized data, and next of kin, as additional stakeholders, may have additionally requested the option to turn off location sharing. However, it is unlikely that "*selling rides*" would have been seen as a potential source for manipulation. It is also unlikely that considerations are given to the fact that even anonymized location data can easily be used to identify—despite anonymity—an individual (Christl & Spiekerman, 2016). Also, the "*show position of next of kin on map*" stakeholder requirement will probably not be second guessed or discussed in detail. Should the resulting feature be disabled by default? Should the system really match who is related to whom? What dangers and monitoring desires does this requirement entail? Such and other questions need to be discussed in order to prevent an unethical system with harmful consequences. To ask such questions, to find a solution, and also to better understand the problems a system is designed to solve, RE today typically uses high-level design frameworks such as Design Thinking (Brown, 2008) or Goal-directed Design (Cooper et al., 2014). However, those and others frameworks have the stated purpose of achieving a high user experience or providing innovative solutions (cf. Cooper et al., 2014; Brown, 2008)—and are not meant to uncover or resolve ethical issues.

Despite these and many other potential questions, RE continues to the next step to specify or translate stakeholder requirements to system requirements. This translation process is problematic if not done diligently, but for now we assume that all aspects are covered and these are now very formal—structured, organized, and brought to standardized form—requirements. The stakeholder requirement "*promoting ride-hailing*" might have resulted—in part—in a system requirement, such as: "*The travel-time calculation algorithm for ride-hailing shall be the only component using the closest street as a starting point,*" while *"show position of next of kin on map"* might have resulted in a system requirement like: "*The system shall provide a public API that returns location data.*" As can be seen, system requirements are usually barely understandable for people outside of engineering and therefore ethical issues can hardly be discussed any more. Engineers may still recognize that providing a public application programming interface (API) to any other piece of software could lead to ethical issues related to privacy, but this is not a validation criterion for such system requirements, which will be discussed in Section 2.2.3 ("*Validated System Requirements*").

2.1.2 Development, Validation and Evolution

After RE has delivered and documented all of the necessary insights—especially stakeholder requirements and system requirements—the *b) development* begins (Sommerville, 2016). This step starts with *system design*, during which a technical solution that meets the specified system requirements and thus satisfies stakeholder requirements—solving the specified problem—is chosen or conceptualized (Sommerville, 2016; Sharma & Pandey, 2013). As things stand, the question here is not whether it is sensible, good or ethical to offer a solution, or whether all the problems have been understood, but to choose and compose the right system components (Sommerville, 2016). On the basis of such a system design, the highly individual activity of implementation in terms of actual programming can begin (Sommerville, 2016). In other words, all the issues—ethical or otherwise—that software can entail are now implemented and brought into reality.

After implementation is done, the *c) validation* activity aims to prove that the system is ready and meets the specified requirements—representing the problem to be solved—and thus satisfies stakeholder expectations (Sommerville, 2016). During validation, firstly, individual components are tested, then the entire software, and finally stakeholders evaluate the product (Sommerville, 2016). While this activity helps to address immediate errors, it is unlikely that ethical issues will come to light, as these typically only play out in the future or in specific use cases. In the GIS example, there is a privacy issue due to the requirements—such as *“show position of next of kin on map”*—but ethical issues related to discrimination or surveillance can only occur in an operational system with multiple users and enough data (cf. Christl & Spiekermann, 2016). Potential issues related to discrimination or surveillance should have been discussed prior to the start of b) *development*.

Some issues might also impact people, but could stay obscured for a long time, such as those related to *“promoting ride-hailing,”* which were implemented based on the system requirement that *“The travel-time calculation algorithm for ride-hailing shall be the only component using the closest street as a starting point.”* Such a requirement could lead to software behavior as implemented in Google Maps, shown in Figure 4.

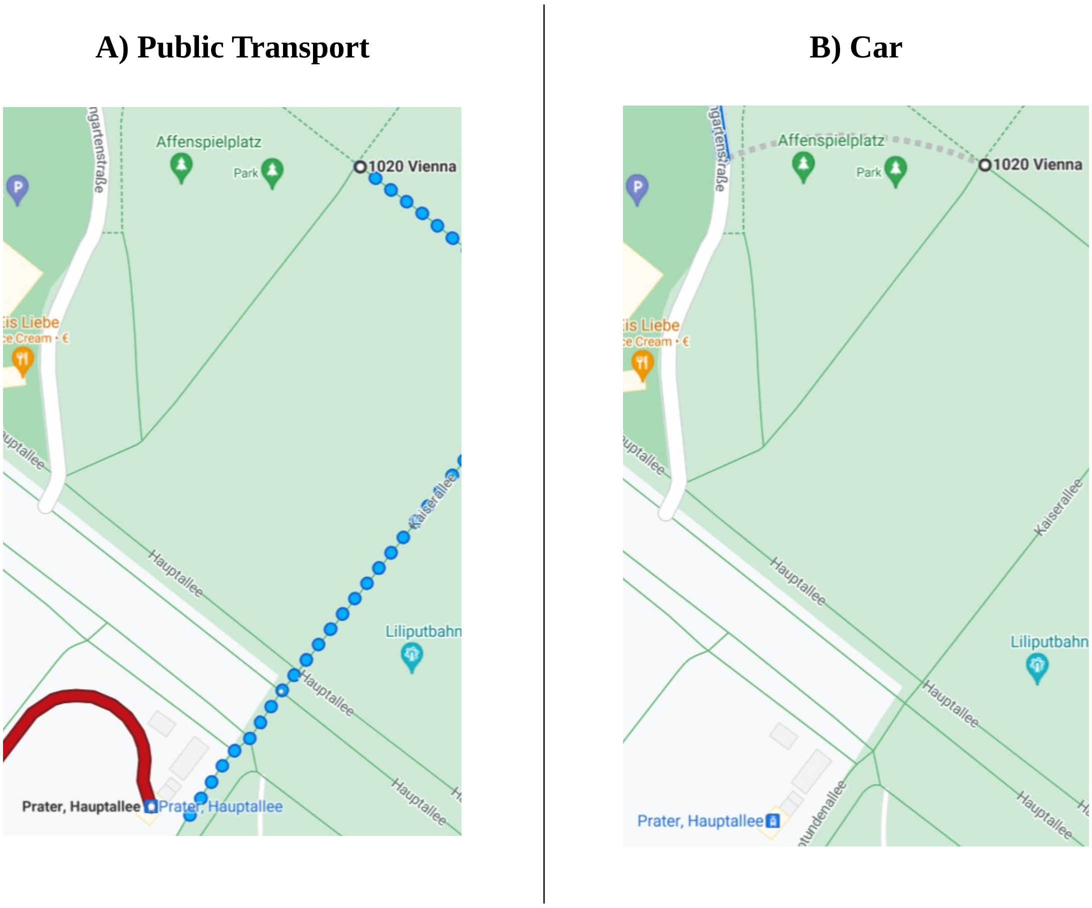


Figure 4: *Calculation bias in Google Maps (29.03.2023):* ***A)*** *user needs to walk,* ***B)*** *user jumps to next road (based on: Wagner et al., 2021).*

In Google Maps, the type of transportation has an impact on the calculation of travel times if the start or end point of a route is in a park or pedestrian area. For public transportation, the calculated travel time includes the walk to the next station (see Figure 4, A). However, car or ride-hailing does not take into account the time it takes to walk to the next street; instead, the user jumps to the closest street (see: Figure 4, B). Seeing the travel times side by side could lead to the assumption that using the car is faster, when in reality it takes additional time to walk to the next street. Thereby in some use case—unlikely to be part of c) *validation*—this could convince the user that taking the car is faster, while in reality the travel time algorithm is just biased. One might even assume that this could influence travel decisions in a city and thus indirectly affect urban planning. This is not to say that Google purposefully biases towards car or ride-hailing usage, but there are biases that stay obscured even for frequent Google Maps users (cf. Wagner et al., 2021). Presumably, even Google, as a recognized software development company that conducts state of the practice SE, is unaware of the issues with its system. In the hypothetical case of GIS development, such bias was introduced by stakeholder expectations, which would have been easy to identify had there been mechanisms in place to discuss them from the outset.

While in the past d) *evolution* or system *operations* was largely considered outside of the SE domain, ongoing RE, development, and validation is now considered state of the practice (Sommerville, 2016). Because a system is already in place—possibly on a global scale—ethical issues may arise but are unlikely to be resolved. Such issues are now anchored in a complex system and are expensive or even impossible to fix (Sommerville, 2016; De Lucia & Qusef, 2010; Spiekermann, 2015). In particular, when ethical issues are raised because of business objectives that are critical to the survival of the company, companies are unlikely to change them, as this could mean bankruptcy. Facebook's financial viability, for instance, depends on the tendency to violate privacy by collecting and analyzing user data, for which many hours of development have gone into creating a complex system that is difficult to change (Zuboff, 2015; Anonymous, 2022).

In summary, Section 2.1 (*“Anchoring Ethical Issues”*) shows the importance of the first steps —especially *project initialization* and a) *specification* (see: Section 2.1.1)—in preventing the development of harmful systems, as ethical considerations as an afterthought are likely to fail (Spiekermann, 2015). Mistakes or ethical issues that lead to harmful systems are introduced during ConOps development and/or RE and formalized in a more structured, organized, and standardized form called system requirements. In the GIS case, the problematic stakeholder expectation to *"promoting ride-hailing"* or "*tracking next of kin*" ended up as formalized and specified requirements that were subsequently implemented. Such requirements can result in a system with ethical issues, in this case a biased and seductive system that encourages ride-hailing, violates location privacy, and could be used to surveillance.

Many scholars argue that failure to consider values and ethics issues during *project initiation* and subsequent RE from the beginning can lead to project failure, harmful systems, and a lack of innovation as well (cf. Wright, 2011; Van den Hoven, 2017; Spiekermann, 2015). VOFs and especially VSD and IEEE Std. 7000 are frameworks that have the stated purpose of facilitating the development of innovative or ethical IS. Therefore, both VOFs must be able to steer relevant activities according to their stated purpose and facilitate the specification of system requirements with innovative and ethical potential. To achieve this from an engineering perspective, three deliverables are necessary: 1) insights into stakeholder expectations (Section 2.2.1), a coherent set of stakeholder requirements (Section 2.2.2) and validated system requirements (Section 2.2.3). These deliverables are described in more detail in the following sections. Understanding these deliverables is the first step toward a VOF EvalCon, which will be described in Section 6 ("*Concept for Value-oriented Framework Evaluation*").

2.2 Requirements Engineering

Specification of software or RE is generally considered particularly critical, as mistakes made here have serious and also expensive consequences (Sommerville, 2016; De Lucia & Qusef, 2010). Performing proper RE is considered by many as the most important area of SE, since "...anything that is (or is not) resolved at this time, will be carried down through the rest of the software development lifecycle" (Sharma & Pandey, 2013, p. 35). As already shown in section 2.1 (*"Anchoring Ethical Issues"*), this also applies to ethical issues that were likewise carried through the process to the point of being anchored in the final product.

Before RE can begin, the management of a company has to initiate a project. As part of this *project initiation*, business goals and an initial concept of operations (ConOps) is formulated. A ConOps document does not contain specified requirements, but helps to communicate overall business goals, intended context of use and a list of some relevant stakeholders (ISO, 2011b).

Once the financial and technical feasibility studies show that a system can and should be developed, a) *specification* of software—the RE process—forms the starting point of the ConOps document (Sommerville, 2016). As part of ConOps development, identification of relevant stakeholders begins, which, however, should be a recurring activity throughout the whole SE process (ISO, 2011b). RE seeks to produce a validated and agreed-upon requirements document that specifies a system—as system requirements—that meets the goals and needs of stakeholders (Sommerville. 2016; ISO, 2015). At a minimum, such a requirements document must include a system description, stakeholder requirements, and related system requirements (Sommerville. 2016). Without this content, subsequent b) *development*—system design and implementation—cannot begin. Figure 5 shows a more detailed view on relevant activities, with a particular focus on *project initiation* and a) *specification*.

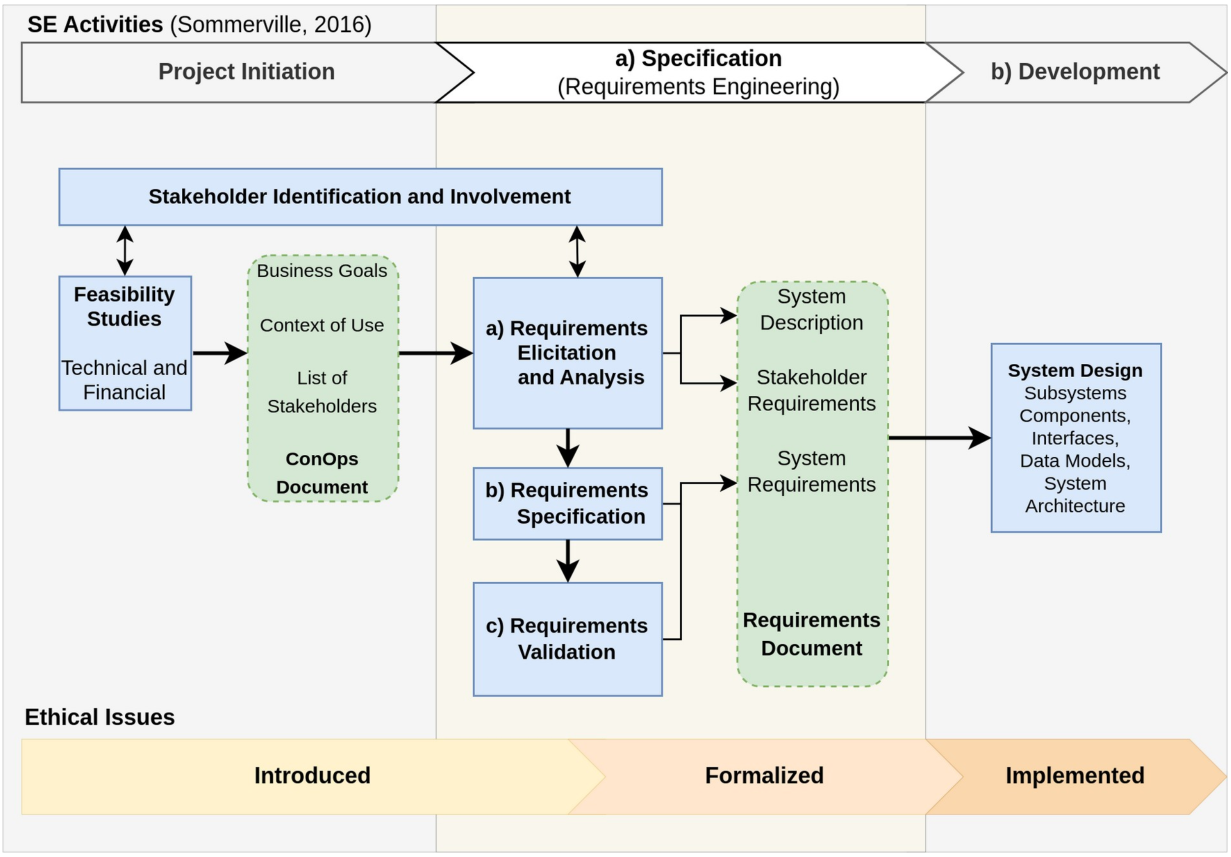


Figure 5: *Essential SE activities: Necessary steps (blue) and resulting documents (green) (based on: Sommerville, 2016).*

To gain a comprehensive and high-quality requirements document, RE involves the use of coherent frameworks such as Goal-oriented Requirement Engineering (GORE, Van Lamsweerde, 2001), Non-functional Requirement Framework (NFR, Chung et al., 2000), Design Thinking (DT, Brown, 2008) or Goal-directed Design (GDD, Cooper et al., 2014). Each of these frameworks is a unique compilation of principles, methods and processes—ideally justified by a theoretical foundation or practical experience—which aim towards a specific purpose. Common purposes are to achieve high user experience (GDD), satisfy stakeholder goals (GORE), consider non-functional aspects (NFR), or deliver particularly innovative solutions (DT, Cooper et al., 2014; Van Lamsweerde, 2001; Chung et al., 2000; Brown, 2008). With their tailored and orchestrated methodology, these frameworks steer SE—and specifically RE— toward their stated purpose, influencing the resulting software. Accordingly, IEEE Std. 7000 and VSD also must demonstrate that their theoretical foundations and methodology are able to steer RE; in this case, however, towards the purpose of facilitating the development of not only innovative, but also ethical IS (IEEE, 2021; Friedman & Hendry, 2019).

Software specification follows three basic steps: a) *requirements elicitation and analysis*, b) *requirements specification*, and c) *requirements validation*, as shown in Figure 5. Each of these steps contributes to deliverables and works towards achieving a comprehensive and high-quality requirements document with system requirements. In the following, I describe and define each of the deliverables, an overview of which is shown in Figure 6, and briefly discuss their importance for promoting the development of ethical IS. These deliverables are the first important part of the VOF EvalCon presented in this thesis (Section 5 *"Concept for Value-oriented Framework Evaluation"*).

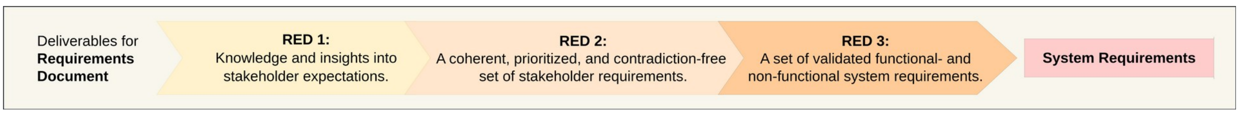


Figure 6: *Necessary RE deliverables (REDs)*

2.2.1 Insights into Stakeholder Expectations

The first RE step, a) *elicitation and analysis*, is performed as a continuous and iterative cycle, with engineers gaining a better understanding of who the stakeholders are and what their expectations—expressed as goals or needs—and thereby requirements are for the system with each pass (Sommerville, 2016; ISO, 2011b). This very important cycle can be seen in Figure 7, where the first step is the 1. *discovery and understanding* of stakeholder expectations. Each framework emphasizes how stakeholders can express their expectations. These expectations (goals or needs) should be discovered and understood; frameworks employ a multitude of methods for doing so, such as workshops, interviews, questionnaires, document analysis, prototyping and many more (ISO, 2011b; Tiwari et al., 2012; Sharma & Pandey, 2013). Stakeholder requirements are a representation of the understood and analyzed stakeholder expectations, or in other words, the problem to be solved (Sommerville, 2016). The definition of requirements "… begins with stakeholder intentions (referred to as needs, goals, or objectives), that evolve into a more formal statement before arriving as valid stakeholder requirements" (ISO, 2011b, p. 9). Stakeholder intentions, which I call here stakeholder expectations "… often lack definition, analysis and possibly consistency and feasibility" (ISO, 2011b, p. 9). Understanding, analyzing, and defining stakeholder expectations—sometimes referred to as conceptualization—and resolving conflicts, thus creating consistency, is achieved through the a) *elicitation and analysis* cycle.

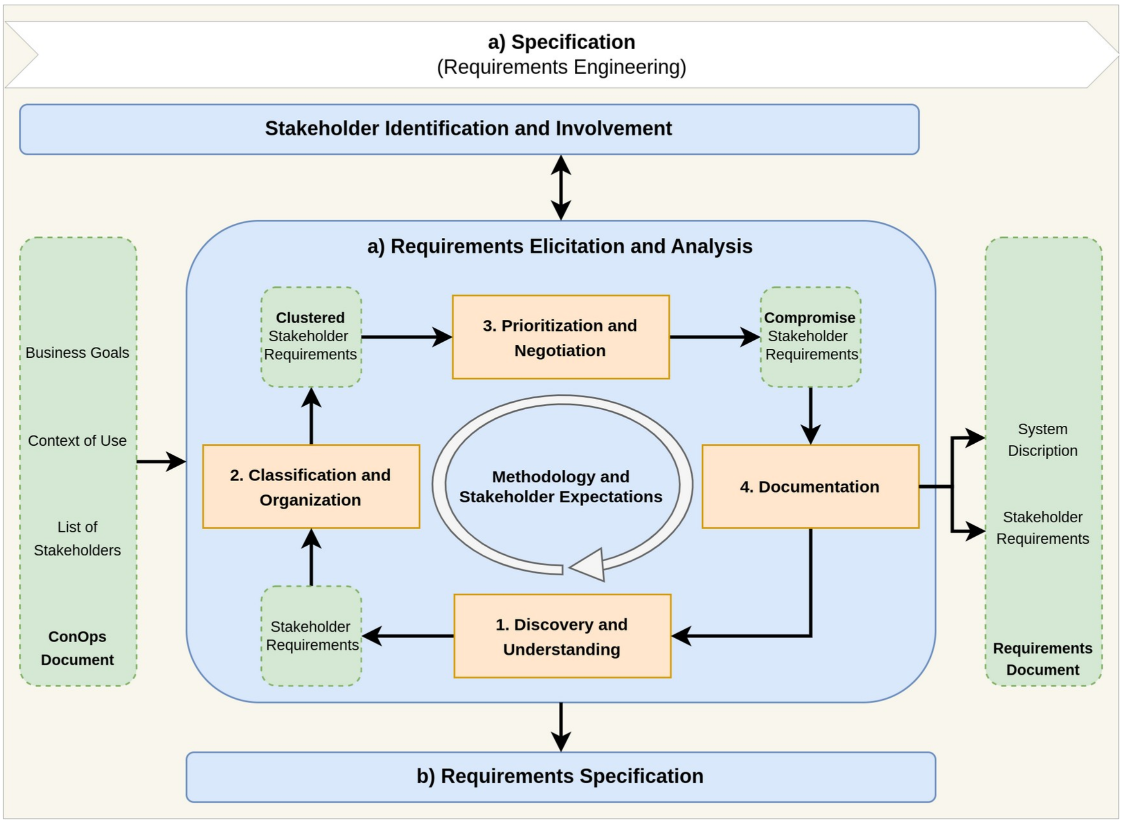


Figure 7: *Elicitation and analysis as an iterative cycle using framework-specific methodology and stakeholder expectation types (based on: Sommerville, 2016).*

Design-oriented frameworks in particular—DT, GDD or VSD—use framework-specific methods during this cycle, which may include design-related activities such as co-design workshops, prototyping and others (cf. Brown, 2008; Friedman & Hendry, 2019). Often unconsciously, such design activities serve all cycle tasks by helping to discover and understand, organize, negotiate, and document knowledge gained, for example, in the form of a paper prototype. Such design activities (referred to hereafter as high-level design) go further by also proposing a high-level concept to clarify and solve the understood problem (Hevner et al., 2004; Norman, 2013). However, such a high-level design is not a technical solution or a system design in the sense of SE, but still a description of the problem to be solved (Sommerville, 2016; Hull et al., 2005). Any engineering discipline is geared towards finding a solution to a given problem and, according to the state-of practice, this involves comprehending expectations (needs or goals) of the stakeholder (ISO, 2015; Sommerville, 2016). Finding a solution to a given problem —which must first be understood—is essentially the task of a designer (Hevner et al., 2004), which is achieved during the described RE step, a) *elicitation and analysis,* at a high-level compared to "*system design.*"

On the other hand, more engineering-oriented frameworks—GORE, NFR or IEEE Std. 7000 —tend to use schematic methods such as questionnaires, interviews or document analysis to discover and understand stakeholder expectation (Sharma & Pandey, 2013). Regardless of what type of methodology is used, all frameworks must discover and understand stakeholder expectations, thereby gaining knowledge in accordance with their stated purpose. For example, a framework such as GDD that aims to provide a system with a good user experience needs to gain insights into what stakeholders expect from that system in terms of user experience (Cooper et al., 2014). The same applies for VSD and IEEE Std. 7000, which at this point in the process must provide insights into what a stakeholder expects or considers to be an innovative and ethical IS. In order to formulate the first RE deliverable (RED), during the activity, 1. *discovery and understanding* frameworks must gain:

- **RED 1**: "Knowledge and insight into stakeholder expectations."

Whereas in the past SE focused primarily on users, today the goal is to engage as many stakeholders as necessary to properly understand the problem the system should solve (ISO, 2011b). There are methods that focus exclusively on document analysis or automated discovery from unstructured text (Meth et al., 2013). Since such methods are not typically part of VOFs, they are not considered in this thesis. After gaining knowledge and insight into stakeholder expectations and understanding them as stakeholder requirements, they must be organized.

2.2.2 Coherent Set of Stakeholder Requirements

After stakeholder requirements are *1. discovered and understood*, they are *2. classified and organized* into coherent clusters, which are then *3. prioritized and negotiated*, and finally *4. documented* in the requirements document (Sommerville, 2016). Since this requirements document is to be the starting point for the selection and conception of the technical solution (the system design) it should be free of conflicts and contradictions (Sommerville, 2016). Conflicts and contradictions usually arise from multiple stakeholders with unique needs and goals, that is, different expectations on the system, which must be resolved and a compromise agreed upon, resulting in a set of compromise stakeholder requirements (Sommerville, 2016). For example, a typical conflict or contradiction may arise when management wants to monetize location data as part of the business goals, but users have contrary expectations of the system. Such contradictions or conflicts must be resolved that result in a set of compromise stakeholder requirements. Finding compromises at this point has many practical reasons: First, system requirements specified later cannot be discussed with stakeholders, which is explained in the next Section 2.2.3 (*"Validated System Requirements"*). Second, specifying system requirements can be time-consuming and should only be done for stakeholder requirements that are undoubtedly important. Finally, resolving conflicts is much more difficult with system requirements because they are very specific and there are typically a larger number of requirements; a single stakeholder requirement is potentially the source of multiple system requirements (Sommerville, 2016).

Finding compromise requirements is a particularly important ethical activity, since there seems to be "…. a tendency to rethink or water down…" (Van Gorp & van de Poel, 2001, p. 21) requirements, which also might lead to ethical problems. In other words, IEEE Std. 7000 and VSD in particular, which claim to facilitate the development of ethical IS, need to ensure that this step is taken in accordance with their claim. From an RE perspective, it is critical at this point that the insights gained and knowledge about stakeholder expectations (RED 2) are delivered as:

- **RED 2:** "A coherent set of stakeholder requirements that is prioritized and free of contradictions and conflicts."

The documentation of stakeholder requirements can take various forms, ranging from statements, storyboards, prototype descriptions, to more concrete models (Sommerville, 2016). The cycle of of 1. *discover and understand*, 2. c*lassify and organize*, 3. *prioritize and negotiate*, and 4. *document* ends when gained insights and knowledge on stakeholder expectations is deemed “good enough” to proceed (Sommerville, 2016). Good enough here refers to a subjectively perceived state—often induced by the market to be fast and cheap—according o which insights are considered “...well enough to eliminate (or prevent) the right problems and also deliver the right benefits” (Bach, 1997, p. 98). Understanding and grasping the right problem to solve is essential to a successful system (Norman, 2013; Sharma & Pandey, 2013; De Lucia & Qusef, 2010; Breitman et al., 1999). Whether a subjective judgment of “good enough” is appropriate here should be debated.

2.2.3 Validated System Requirements

Documented stakeholder expectations—as stakeholder requirements—are translated into concrete system requirements during b) *requirement specification*, which further expands the requirements document (Sommerville, 2016). The aim of this step is “… to transform the stakeholder, requirement-driven view of desired services into a technical view…” (ISO, 2011b, p. 9) or in other words, specify system requirements.

Before subsequent SE activities (“*system design*” and implementation) can begin, the requirements document needs to also include system requirements. Each type of requirement, whether stakeholder or system, serves to communicate the expectations to different stakeholders (Sommerville, 2016). While stakeholder requirements are used to discuss expectations of the system with users, managers, designers or others, system requirements are specifically intended to inform engineers what to design (*system design*) and implement on a technical level (Sommerville, 2016). Accurate specification and communication of system requirements is critical to ensure that engineers don’t take shortcuts or make sloppy implementations (Sommerville, 2016). This is also important from an ethical perspective, as engineers seem to have a habit of choosing the easiest path, which could lead to an undesirable system design (Van Gorp & van de Poel, 2001). Therefore, both types of requirements—stakeholder and system—are critical.

System requirements need to be classified as functional and non-functional. Functional system requirements specify a service or feature that a system must provide, and non-functional system requirements describe the manner (constraint or quality) under which these are provided (Sommerville, 2016; Glinz, 2007). Experience has shown that successful functionality depends on the availability of adequate non-functional system requirements and that a lack of these leads to low software quality, dissatisfied stakeholder expectations and high costs (Chung et al., 2000; Chung & do Prado Leite, 2009). For example, in the development of the London Ambulance Service, the non-functional system requirement of "*performance efficiency*" was omitted, resulting in the system's inability to fulfill its function of "organizing ambulance operations" and thus compromising human well-being (Breitman et al., 1999). This shows that the absence of non-functional requirements can have serious consequences, because in this case patients had to walk to the hospital themselves (Breitman et al., 1999).

Returning to the hypothetical example for GIS development: Engineers would choose the "Google Play Services" component during system design if no non-functional constraints related to "privacy" or "data sharing" are documented. If part of an application, users can no longer restrict data exchange with Google by deactivating "Google Play Services"; an estimated 1.3 terabytes of data are collected via this component every 12 hours in the USA alone (Leith, 2021). This shows that the existence of necessary non-functional system requirements is also important from an ethical perspective. In particular, VSD and IEEE Std. 7000, which claim to facilitate the development of ethical IS, must provide the means to discover stakeholder expectations (stakeholder requirements) and translate these into functional and especially non-functional system requirements.

During the next RE step, c) *requirements validation*, the quality of system requirements should be evaluated (these should have certain characteristics) to correct errors in the requirements document (Sommerville, 2016). The validation of functional and non-functional system requirements, aims to insure "... that stakeholder requirements have been correctly transformed into system requirements" (ISO, 2011b, p. 32). The most important characteristic for this is upward traceability, which is the traceability of a system requirement from its source (stakeholder expectation) to its implementation as a system component. (ISO, 2011b). This is to ensure a logical and traceable chain from stakeholder expectations (goals or needs) through their understanding as stakeholder requirements and their specification as system requirements, to the system components to which they lead. Taken together, the last RE deliverable is to provide:

- **RED 3:** "A set of validated functional- and non-functional system-requirements."

A system requirement shall be consistent, "...free of conflicts with other requirements" (ISO, 2011b, p. 11). This is typically archieved in RE during the 3. *prioritization and negotiation*, as part of the elicitation and analysis step (Sommerville, 2016), as was described in Section 2.2.2. When there are conflicting system requirements, engineers are likely to aim for the simplest while ignoring a conflicting and complicated requirement, which could lead to ethical issues (Sommerville, 2016; Van Gorp & van de Poel, 2001). Additionally, system requirement should be explicitly clear, that is, understandable without further inquiry, and unambiguous (ISO, 2011a; Sommerville, 2016). Furthermore, this validation criterion is intended to prevent the aforementioned habit of engineers to opt for the simplest and easiest solution path. A system requirement should also be implementation free, which means the "… requirement states what is required, not how the requirement should be met" (ISO, 2011b, p. 11). This characteristic aims to avoid a technical solution—such as "Google Play Service", "AI" or "Blockchain Technology"—being introduced before the problem these should solve is understood. If the industry would take these particular criteria seriously, some ethical problems could be avoided. However, this is not the case, and the reasons for this are explained in the next Section 2.3 (*"Origins of Harmful Information Systems"*).

Note that despite this, no quality criteria of the state of practice directly addresses potential ethical issues or potential consequences of system requirements (cf. ISO, 2011a). This gap is addressed in this thesis in Section 4.1 (*"Ethical Potential"*) by proposing a quality criterion to validate the ethical potential of system requirements. In Section 4.2 (*"Innovative Potential"*) a quality criterion regarding the innovative potential of system requirements is proposed. For this criterion the established "technical feasibility" criterion is relevant, which validates whether a system requirement can be achieved and ensures that it "… does not require major technology advances, and fits within system constraints (e.g., cost, schedule, technical, legal, regulatory) with acceptable risk" (ISO, 2011b p. 11). An unfeasible requirement can never reach technical maturity, that is, the absence of technical obstacles and errors once implemented (ISO, 2017a), and therefore cannot lead to any innovation. Such novel quality metrics would allow VSD and IEEE Std. 7000 claims to be evaluated at the requirements level without the need to develop a working system.

To summarize Section 2.2 ("*Requirements Engineering*"), just like other frameworks—NFR, GORE. GDD, DT—VOFs must contribute to the development of a requirements document by accomplishing three deliverables: Knowledge and insights into stakeholder expectations (RED 1), a coherent set of stakeholder requirements that is prioritized and free of contradictions and conflicts (RED 2), and a set of validated functional- and non-functional system-requirements (RED 3). Only if this can be achieved can IEEE Std. 7000 and VSD hope to guide the development of software in a way that facilitates the development of innovative and ethical IS. Therefore, the previously described RE deliverables are an essential part of the VOF EvalCon (Section 5 *"Concept for Value-oriented Framework Evaluation"*). Another important part of this concept is to understand the common causes of harmful IS, because only then can we assess whether they are sufficiently mitigated, which is discussed below.

2.3 Origins of Harmful Information Systems

From a classical SE's perspective, software is simply a tool for solving a particular problem and producing results that depend on inputs (Hansen et al., 2019). This view is referred to as the value-neutrality thesis, according to which only misuse or malicious use of systems lead to harmful effects (Miller, 2021). While it may to some extent be true that malicious use can never be prevented and will result in harm, this perspective does not help to build better software. From an SE perspective, malicious use is only possible because potential malicious use cases were not considered and mitigated at the outset or during SE iterations. However, as noted in Section 2.1 (*"Anchoring Ethical Issues"*), in practice it is difficult to pre-identify all malicious use cases because there is no concept of assessing whether goals (or needs) are good or right, or for second-guessing the underlying motivations of stakeholders' expectations.

VOFs attempt to mitigate this problem by introducing value considerations into SE practice. Considering values as stakeholder expectations allows for discussing what should or ought to be done, and therefore could be a path towards ethical IS (Gogoll et al., 2021). With a call for value considerations, countless scholars have already overcome the false assumption that technology is amoral or a neutral tool (cf. Friedman & Nissenbaum, 1996; Van Gorp & van de Poel, 2001; Verbeek, 2011; Johnson, 2015; Miller, 2021; Spiekermann, 2015). Mediation theory, as a philosophical perspective on human-technology relations, assumes that technology has moral significance in that it embodies values that shape the context and humans themselves (Verbeek, 2011). Putting this perspective into practice, as intended by VSD and IEEE Std. 7000, could mean a paradigm shift in the way we view and develop software and systems. Section 3 ("*Value-oriented Frameworks and Mediation Theory*") presents how VOFs aim to integrate with SE

(Section 3.1), and in particular discusses the mediation theory necessities that arise from this philosophical perspective (Section 3.2).

Before doing so, however, it is necessary to clarify what other suspected origins of harmful IS exist, how they affect SE, and to what end. This is important because VSD and IEEE Std. 7000, which claim to enable innovative and ethical IS, must be able to mitigate at least some origins of harmful IS and steer the process towards more desirable results. Figure 8 is the result of literature synthesis and provides an overview of the suspected origins of harmful IS and their impact on the sustainability dimension. The following is an explanation of the assumed origins, while the impacts on the sustainability dimensions are the subject of the next section, Section 2.4 (*"Impacts on Sustainability Dimensions"*).

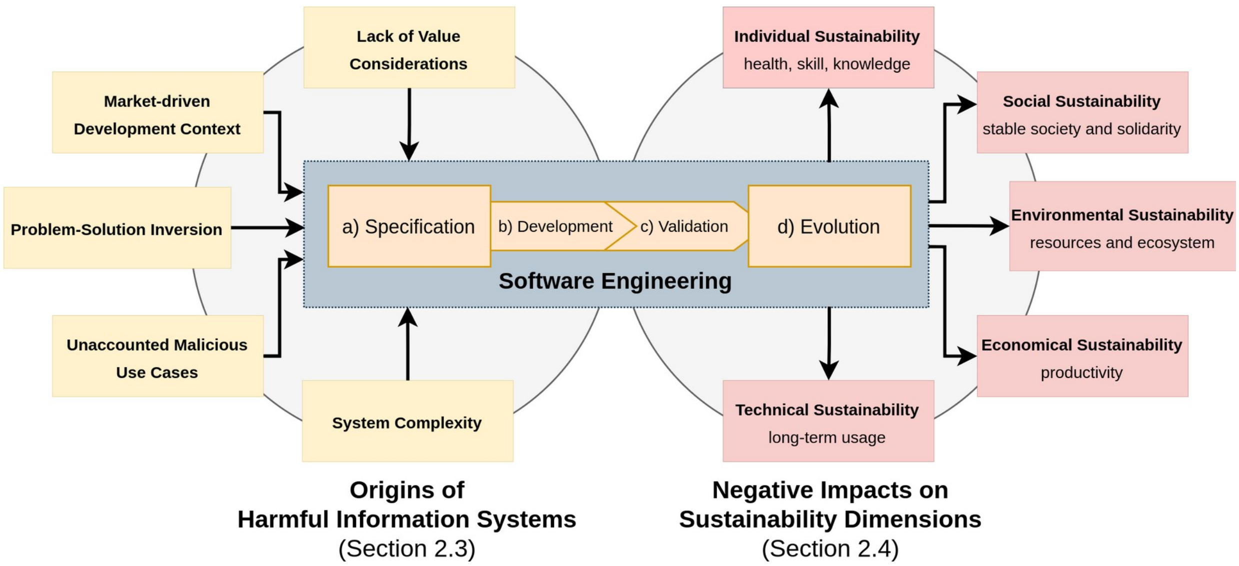


Figure 8: *Origins of harmful IS influencing SE, leading to systems with negative impacts on sustainability dimensions.*

The origin of the harmful IS that comes mainly from engineers and their management, ignoring established SE practices, is what I will call problem-solving inversion. As a reminder of Section 2.2.3 (*"Validated System Requirements"*), a system requirement should be implementation-free, by not specifying how it should be met (ISO, 2011b). In other words, a requirement—from stakeholder- to the system-level—is a representation of the problem a system is intended to solve and should not propose a technical solution (Sommerville, 2016). The search for a technical solution takes place during *system design* and therefore after RE has delivered an understanding on the problems to solve within a requirements document. This is an extremely simple logic, which is however oft ignored in the industry. Many organizations seem to fall to Maslow's hammer bias, which he formulated in the following way: "If the only tool you have is a hammer, it is tempting to treat everything as if it were a nail" (Maslow, 1966, p. 15). In other words, if you already have a technical solution available—also only in your head—such as a hammer, a blockchain or artificial intelligence (AI) system, you are likely to think it is applicable to your problem. Especially with regard to hyped technologies such as blockchain or AI, many companies do not seem to follow the simple logic—instead inverting it—of identifying and specifying the problem first and only then choosing an appropriate solution.

Companies often decide to implement blockchain technology even if it cannot be a solution for their problem and does not fulfill stakeholder expectation (cf. BSI, 2021). The same goes for AI systems, which are known to cause bias and ethical problems when implemented in a system (cf. O'Neill, 2016). Based on the fact that only 40% of European companies whose management claims to use AI technology actually do so (Olsen, 2019), one might suspect that there is a disconnect or communication problem between engineering and management. Surprisingly, managers who consider themselves competent in SE tend to have a negative impact on project success, for example, by insisting on suboptimal approaches due to unperceived knowledge gaps (Engelbrecht et al., 2017). Engelbrecht et al. (2017) conclude that the involvement of such stakeholders "… can actually work detrimentally and confound and confuse proceedings, even cause errors" (p. 1002). Since excluding management is not an option, one mitigation strategy would be to educate management and the team involved and follow established SE practices. A list of all assumed origins of harmful IS can be seen in Table 1, which also summarizes potential mitigation strategies.

Table 1: *Assumed origins of harmful IS that should be addressed by VOFs*

Assumed Origins	Potential Mitigation Strategies
Unaccounted Malicious Use Cases	• Consider malicious use cases from the beginning • Second-guess stakeholder expectations • SE iterations
Lack of value considerations	• Take a mediation theory perspective on technology • Consider values from the onset

Assumed Origins	Potential Mitigation Strategies
Ignoring State of the Practice SE	• Training and education • Follow established practices
System Complexity	• Simple system design • SE iterations • Take necessary time • Subsystem control
Problem-Solution Inversion	• First understand the problem • Adhere to state of the practice SE
Market-driven Development Context	• Create an adequate development context

Others suspect the origin of harmful IS to be due to the increasing complexity of today's software systems, which makes it difficult to understand them or predict their side effects or general impacts (Brooks & Bullet, 1987; Sommerville, 2016). Some assume that software is more complex than any other human creation (Brooks & Bullet, 1987). Today's IS can often be classified as SOS, which is a collection of multiple systems with policies, processes, organizations, and people behind them (Sommerville, 2016). The growing complexity of systems has led to iterative SE processes with ongoing RE, development and validation, and system changes implemented as slowly as possible (Sommerville, 2016; Schneberger & McLean, 2003). The complexity of software is highly dependent on the number, interactions and dependencies between components or subsystems, with a more than linear increase (Schneberger & McLean, 2003; Brooks & Bullet, 1987). While system complexity is a problem that typically arises during system design (the selection of components or subsystems), SE practice should aim to manage complexity from the outset (Schneberger & McLean, 2003). This could be done, for example, by allowing sufficient time and diligence to inspect and document the selected components and subsystems.

The largest and most critical security vulnerability of the last decade, affecting some 3 billion devices, is a good example of why this could be an appropriate mitigation strategy (Unknown, 2021). In this case, "Apache Log4j" was selected as a component; it turned out to have a problematic feature that was documented and could have been disabled (Unknown, 2021). With enough time and diligence, this should have become apparent. But even subsystems without an obvious problem can change over time if system engineers do not have the necessary control over them. A system design that includes a payment system, such as that of VISA or others, may not violate privacy from the get-go, but that subsystem could be modified in the future by its provider with problematic consequences (Christl & Spiekerman, 2016). Humans, such as engineers and managers, are generally very bad in dealing with complexity and have the tendency to make a solution more complex than necessary (Adams et al., 2021). The best strategy against this seems to be to take time, make careful component decisions, iterate, and ensure that one has control over the subsystems.

Others suggest that it is the market-oriented development context that encourages the violation of rights and laws and orients SE practices toward cost-cutting and speed to market (Zuboff, 2015; Savolainen et al., 2010; Schmidt, 2016). For instance, originally intended as a framework to give developers the needed autonomy to deal with complexity, uncertainties and emerging practices, agile development is now a market-driven practice with a focus on cutting costs and fast time-to-market (Fowler & Highsmith, 2001; Savolainen et al., 2010; Schmidt, 2016). According to Sommerville (2016), "[i]t is natural for a system developer to interpret an ambiguous requirement in a way that simplifies its implementation" (p. 108). Such behavior is usually not a malicious intent on the part of the engineers, but a consequence of the working conditions—the development context—with limited time and autonomy, to which they fall victim. When there are conflicting requirements, engineers are likely to aim for the simplest while ignoring a conflicting and complicated requirement, which could lead to ethical issues (Sommerville, 2016; Van Gorp & van de Poel, 2001). Perhaps out of desperation, some engineers even follow their fictional hero—Montgomery Scott—and multiply the estimated development time by a factor of four in order to create appropriate working conditions and the necessary autonomy to perform "miracles" (Bennett, 1984). In most cases, however, engineers must create or live with schedules that are impossible to meet and release a system that "… still lacks key functionality or has known software defects" (Berenbach & Broy, 2009, p. 75). Such time pressure also leads engineers to focus on meeting milestones rather than delivering the required quality, for example, by covering up unforeseen problems such as ethical issues, or generally shortening the RE (Berenbach & Broy, 2009).

A company or organization plays an important role in providing training, time, and setting standards to create an appropriate working condition or development context. Using the example of incorporating privacy by design and addressing security concerns, nearly half of engineers believe that their company does not enable the necessary time investment (Spiekermann et al., 2018). It was observed that between 31% and 38% of companies have weak norms for privacy and security, with some even instructing the employees to ignore privacy (11%) and/or security design (8%, Spiekermann et al., 2018). This is exactly where an ethical dilemma can occur, since engineers must "... make a choice between competing values, such as personal versus professional" (Berenbach & Broy, 2009, p. 74). In this case engineers personally value "privacy" and "security," however the development context does not have these values.

The two main smartphone systems, iOS and Android, have developed independently, but both constantly violate their users' privacy. While Android's Google fork transmits a larger amount of data compared to iOS (1 MB vs. 52 KB every 12 hours), iOS sends additional high-value data—including location, IP- and MAC address of network devices—that allows Apple to create a social graph of users (Leith, 2021). In a sense, privacy violation is a feature implemented in both operating systems. In these cases, it is the development context—both systems were theoretically developed independently of each other—that leads to the privacy violation (Zuboff, 2015). Open-Source Software (OSS) developed outside of a market-driven development context do not tend to have such harmful characteristics (Bitcom, 2021). More than half (51.65%) of open-source developers are paid by their employer to work on OSS projects, but this work is largely done outside of the control of companies (Nagle et al., 2020). The most common reasons are a) the need for a new feature related to their paid job, b) to fix bugs, or c) the joy of learning and creative expression which lead people to develop OSS (Nagle et al., 2020). Open-source projects are thus typically developed outside of the market-driven development context.

If VSD and IEEE Std. 7000 are to live up to their claim of enabling innovative and ethical IS, the previously mentioned origins of harmful IS should be mitigated by these VOFs. Specifically, these VOFs must enable value considerations, account for malicious use cases, seriously consider SE practices, deal with system complexity, and provide an appropriate development context. These assumed origins of harmful IS are therefore also part of the VOF EvalCon discussed in Section 5 (*"Concept for Value-Oriented Framework Evaluation"*). The next section uses real-world examples to show how the assumed origins of harmful IS lead to systems with negative impacts on individual, social, economic, environmental, and technical sustainability.

2.4 Impact on Sustainability Dimensions

In the following, I will show that software in particular has negative effects, regardless of how it is used, but mainly because of the way the requirements were specified. Despite the fact that IS has myriad positive effects, I will focus exclusively on specific negative examples and structure them along five dimensions of sustainability (Penzenstadler & Femmer, 2013). The examples provided also intend to show that the triumph of IS cannot be explained by pure cost reduction (cf. Hansen et al., 2019), but also by the obfuscation and distribution of the real costs among individuals, society and the environment. In particular, VOFs that claim to promote the development of ethical IS should have a positive impact on each sustainability dimension. Understanding each sustainability dimension contributes to the formulation of the new quality metric of ethical potential in Section 4.1 (*"Ethical Potential"*), in which I will explain the relation between sustainability and ethics. This quality metric is an important part of the VOF EvalCon (Section 5 *"Concept for Value-Oriented Framework Evaluation"*), and the results of applying this metric are presented in Section 7 (*"Empirical Investigation"*).

For sustainability to serve as a quality metric, it must be viewed not just as environmental sustainability, but as a concept with multiple and interrelated dimensions. Sustainability in general is viewed as the process of achieving or maintaining a condition that promotes present human well-being without harming future generations (Penzenstadler & Femmer, 2013; de Paula & Cavalcanti, 2000). The literature on sustainability is vast, and there is generally no comprehensive or specific definition of sustainability or its dimensions. The dimensions presented below are based on considerations by Penzenstadler and Femmer (2013), who developed a sustainability concept specifically for SE. All subsequent sections follow the same structure: First I formulate each sustainability dimension in such a form that these can be understood by participants of the empirical investigation (Section 7); I then discuss the negative impact of existing IS software in relation to their origins in terms of SE.

2.4.1 Individual Sustainability

The dimension of individual sustainability is concerned with the long-term preservation of human capital (Penzenstadler & Femmer, 2013; Goodland, 2002). Human capital as a social science concept encompasses all aspects that are considered useful for individual potential including people’s health, knowledge and skill (Woodhall, 1987; Penzenstadler & Femmer, 2013; Goodland, 2002). For example, health can be improved through access to health care, while access to education is generally seen as beneficial to the acquisition of knowledge and skills (Penzenstadler & Femmer, 2013; Goodland, 2002). Individual sustainability can be summarized as follows:

- “**Individual sustainability** refers to long-term individual potential. This includes a person’s health, knowledge, and skills, as well as their access to education and health care.”

Much of today’s software is intentionally designed to be seductive or even addictive, through design elements such as infinite scrolling, pull-to-refresh features such as buttons, or the implementation of dark patterns or gamification principles (Mathur et al., 2021; Anderson, 2011; Neyman, 2017). Such design elements do not arise by chance, but are the result of stakeholder requirements obtained during *project initialization* or *software specification* that lead to the specification of problematic system requirements that were subsequently implemented. One might assume that these could be introduced as a business goal to attract people’s attention to the product by triggering a dopamine release that can lead to addiction (Anderson, 2011; Neyman, 2017). Other high-level design elements seem to follow dark patterns, such as “Bait and Switch” or “Attention Grabber,” which try to influence the user’s decision-making and are thus seductive (Mathur et al., 2021).

Addictive and seductive design elements affect people's health, undermine their time for education and thus their skills and knowledge, and thereby negatively impact individual sustainability and individual well-being. Negative health effects can be physical, such as a smartphone neck, or psychological, such as stress or even symptoms of depression (AlAbdulwahab et al., 2017; Barley et al., 2011; Twenge et al., 2018). While the relational direction is still unclear—depression as cause or symptom—exceeding 5 hours screen time is significantly associated with symptoms of depression among college students (Rosenthal et al., 2021). Excessive screen time is not a result of the users’ conscious decision to use a system, but a consequence of addictive and seductive design elements. It is not the malicious use of a system by users, but the lack of consideration of individual well-being—a value—in the specification of software that leads to a harmful product.

Image filters implemented in Instagram harm teenagers' self-esteem and body image, which leads many to undergo dangerous cosmetic surgery to more closely resemble their filtered selves (Walker et al., 2021; Well et al., 2021). Such filters are part of the system because they were introduced during project initiation as a business goal, or as a stakeholder expectation—for example, a need to beautify images—during RE. Their functionality was specified and formalized during system requirements definition and implemented during development. Had the value of "natural beauty" been a part of RE, perhaps these filters would work differently and cause less negative physiological and psychological harm.

Other concerning health symptoms—stress, depression, or reduced psychological well-being—are the result of constant availability via email or messenger (Barley et al., 2011; Twenge et al., 2018). Also, in this case, it is the built-in push notification feature and not the way an email client or messenger is used that leads to negative effects. One could argue that such features can be easily turned off, which is true in most cases, but this presupposes the user being aware of negative consequences and their own vulnerability. Here, the increased productivity from IS (constant availability) and reduced cost due to cheap information deliverable (digital instead of analog) imposes cost in the form of reduced individual health. These costs for health care could remain obfuscated for a long time. Such features with negative impacts on people's health exist because they were considered during *system design* based on harmful and not second-guessed system requirements. A framework that claims to facilitate the development of ethical IS would be expected to avoid producing such harmful system requirements.

All of the previously mentioned consequences on individuals suggest that harmful IS arise because of a lack of value considerations, such as human well-being or natural beauty in the examples given, from the outset of SE (cf. Wright, 2011; Spiekermann, 2015; Van den Hoven, 2017). This underscores that VOFs that claim to facilitate the development of ethical IS should allow for the consideration of values from the outset. Research has shown that travel time estimates in Google Maps are biased in favor of car use because the algorithm calculates time for other modes of transportation based on different starting and ending points (Wagner et al., 2021). Such bias can limit physical activity, thereby affecting health, cause higher carbon emissions, and result in financial costs to maintain a car. This shows that inadequate RE can have negative impacts on several sustainability dimensions, which therefore cannot be considered in isolation.

2.4.2 Social Sustainability

The social sustainability dimension focuses on the long-term preservation of society and its solidarity, for which shared values, equal rights, laws and access to information are essential (Penzenstadler & Femmer, 2013; Goodland, 2002). Social sustainability can be supported by strengthening active participation and a productive mode of communication within a society (Penzenstadler & Femmer, 2013; Goodland, 2002). Social sustainability can be summarized as follows:

- "**Social Sustainability** refers to a long-term stable society based on solidarity. For this, shared values, equal rights, laws and information, as well as active participation and communication within society are essential."

Numerous studies have shown that social media can negatively impact the way people communicate within a society, especially on political issues (Törnberg et al., 2021). A social media platform can reinforce identification with a political in-group, which leads to a situation in which political debates are no longer about rational arguments but about a battle of demarcation against the out-group perspective (Törnberg et al., 2021). This so-called "echo chamber effect" leads to a particular emotional mode of communication that promotes social fragmentation and thus jeopardizes social sustainability. While one could argue that it is the misuse of social media that leads to such effects, in reality it is—in part—the algorithms implemented in the platforms. During high-level design in RE, algorithms were devised to rank the available information according to users' assumed interests, thereby creating filter bubbles (Pariser, 2011). This high-level design (or conceptualization) of algorithm functionality was then specified (formalized) as system requirements and implemented in the *system design*. Regardless of how people use social media, these filter bubbles created by algorithms only present information from the presumed political in-group, which increases user identification and leads to echo chambers with severe negative impact on social sustainability (Törnberg et al., 2021; Pariser, 2011). If "transparency" or "user control"—both values—had been part of the RE process, the high-level design, resulting system requirements, and subsequent system design would have allowed users to gain insight into and control ranking parameters. However, as noted earlier, such a value consideration must be part of SE from the outset before less harmful systems can be achieved (cf. Wright, 2011; Van den Hoven, 2017; Spiekermann, 2015).

Algorithms that give users access to information are also deliberately used by political interest groups to influence voters, often against their own interests (Epstein & Robertson, 2015). Cambridge Analytica, along with similar companies, used selective information access to allegedly tip the choice in favor of the Brexit, which was decided by only 1% of registered British voters (Cadwalladr, 2017). The same company also worked with Donald Trump's campaign team, targeting US voters with selective information (Cadwalladr, 2017). In this case the malicious use of Facebook by Cambridge Analytica led to an erosion of society and thus to a negative impact on social sustainability. It is safe to assume that Facebook was not created for political manipulation. However, the platform's business goal of influencing consumers via advertisement by providing companies insights into user interests is a use case that is strikingly similar to political manipulation (Zuboff, 2015).

Such manipulation of the democratic process was only possible because Cambridge Analytica had access to large amounts of information on user preferences and thus could forge political messages (Cadwalladr, 2017). In other words, the ability to collect and analyze vast amounts of information at relatively low financial cost has imposed costs on society through social fragmentation, as shown by Brexit, and potentially the aftermath of Trump's tenure. Social fragmentation, for instance, threatens the basic fabric of society and can increase the cost of collaboration through reduced trust between people (Goodland, 2002).

In a recently leaked document a Meta engineer states, "We do not have an adequate level of control and explainability over how our systems use data, and thus we can't confidently make controlled policy changes or external commitments such as 'we will not use X data for Y purpose'" (Anonymous, 2022, p. 1). This lack of control and explainability is not only the result of bad RE, but also due to system complexity that makes it difficult to predict negative effects (Sommerville, 2016). This example shows that complex systems such as Meta's Facebook can also be the source of harmful IS, as suspected by many in the SE community (cf. Sommerville, 2016). With the claim of facilitating the development of ethical IS, VSD and IEEE Std. 7000 must provide appropriate practices to deal with complexity.

2.4.3 Economic Sustainability

Economic sustainability refers to the long-term preservation of value creation and productivity by protecting goods, time, money and investments from risks and depletion (Penzenstadler & Femmer, 2013; Goodland, 2002). Economic sustainability can be summarized as follows:

- “**Economic Sustainability** refers to long-term value creation and productivity. To achieve this, goods, time and money must be protected from depletion, and investments must be protected from risk.”

On an individual level, addictive video game design elements like loot-boxes and micro-payments are known to be a severe threat to the economic sustainability of an individual (Reer & Quandt, 2021). Loot boxes work according to the same logic as slot machines: A user buys a Loot Box, which offers a random reward such as in-game currency, items, or other things (Reer & Quandt, 2021).

At the organizational level, a shortage of money and investment is also dangerous, as it can lead to bankruptcy and the loss of jobs, income and the living basis for individuals. It is estimated that an investment of between 450 and 750 engineering years is required to bring Meta’s Facebook into compliance with the General Data Protection Regulation (GDPR, Anonymous, 2022). For Meta, such an investment is a barrier to productivity, as engineers and thereby money and time (also called opportunity costs) must be engaged in “fixing” Facebook, which prevents the development of additional features. This shows that fixing a complex system retroactively can require a tremendous amount of effort and that it can be a risk for a firm’s economic sustainability (Sommerville, 2016; De Lucia & Qusef, 2010). The company is struggling to comply with the GDPR because its original business goal—monetizing user data—is in direct conflict with stakeholders’ privacy expectations, which has become EU law. The origin of Facebook’s monetization clearly lies in the spirit of surveillance capitalism, which invites the violation of rights and laws (Zuboff, 2015). Although the GDPR did not exist when Facebook was originally conceptualized, Meta’s engineers would now be in a better position if they had followed existing EU data protection laws such as Directive 95/46/EC (Hustinx, 2013). Even without this directive, a properly conducted RE would have revealed a conflict between the goal of monetizing user data and the privacy expectations of stakeholders and mandated a resolution of that conflict (Sommerville, 2016). This shows that startups (like Meta or Facebook once was) that don’t initially invest the resources necessary to figure out how best to conduct SE will pay for it in the long run (cf. Coleman & O’Connor, 2008).

The Meta example shows that both the development context and disregard for established SE practices can have consequences for economic sustainability and potentially also for the survival of a company. In fact, in some cases the loss of image resulting from a general disregard for privacy is so great that other projects like the Libre Coin fail from the start, since nobody believed Meta is capable of developing a product in a highly regulated area such as banking (Dwoskin & De Vynck, 2022).

A related risk to economic sustainability is the implementation of a hyped technical solution without verifying that the technology meets stakeholder expectations. For instance, the "ID Wallet" stayed with blockchain technology after the German Federal Office for Information Security concluded that this technical solution introduced complexity and security vulnerabilities without fulfilling any purpose (BSI, 2021). Similarly, a single bitcoin transaction consumes 2,188 kW/h, while 100,000 VISA transactions consume only 148 kW/h, resulting in a huge cost for each bitcoin transaction (Digiconomist, 2022). If the primary purpose of VISA and the blockchain-based transaction system is to provide a technical solution for conducting transactions, it is clear that the blockchain-based system is not an economically sustainable solution. In both cases, the decision to use a blockchain-based solution was made before the problem to be solved was understood, which I refer to as problem-solution inversion in Section 2.3 (*"Origins of Harmful Information Systems"*). Adherence to the state of the practice in SE, including the development of a good understanding of the problem and validation of the requirements according to the free implementation criteria (see Section 2.2.3), could have prevented negative impacts on economic sustainability in these cases. The promise of VSD and IEEE Std. 7000 to facilitate the development of innovative IS is also accompanied by high hopes for economic sustainability, discussed in detail later in Section 4.2 (*"Innovative Potential"*).

2.4.4 Environmental Sustainability

The environmental sustainability dimension focuses on the protection of natural resources and ecosystem services (Penzenstadler & Femmer, 2013). To ensure environmental sustainability, it is important to consider resource consumption and the release of emissions and waste (Goodland, 2002; Penzenstadler & Femmer, 2013). It is necessary to consider the limits of our planet, including natural resources such as water, land, air, minerals and others, but also the capacity of ecosystems—also called services—to absorb emissions or waste. Environmental sustainability can be summarized as follows:

- "**Environmental Sustainability** refers to the protection of natural resources and ecosystem services. For this, impact on the environment through resource consumption and the release of emissions or waste must be considered."

According to a recent report by the Association for Computing Machinery, the information and communications technology sector contributes up to 2.8% of the global carbon footprint. This is a similar amount to the contribution of the entire aviation sector (Knowles, 2021). However, a large part of these emissions is not due to use, but to the manufacture, transport and disposal of hardware. For 2018, Apple reported a carbon footprint of 25.2 million metric tons, of which 79% was from device manufacturing and transportation (Apple, 2019). Considering Apple's relatively small market share, this is just the tip of the iceberg. It shows that while energy consumption through digitization, streaming and cryptocurrencies is often criticized, it is to a large extent unnecessary production and disposal of devices that harms the environment (de Vries & Stoll, 2021). The annual energy consumption through Bitcoin mining of 206 TWh is worrying, but even more alarming is the annual production of 64.340 tones of e-waste (de Vries & Stoll, 2021). In Bitcoin mining, the hardware simply wears out due to constant and very intensive use, which would not be necessary if the implemented blockchain system was built according to requirements for environmental friendliness. There are several cryptocurrencies that rely not on an energy and computationally intensive *proof-of-work*, but on a *proof-of-stake* consensus algorithm for which a simple Internet-enabled device suffices (de Vries & Stoll, 2021). For example, the Ethereum network recently made such a transition to *proof-of-stake* consensus, reducing its annual energy consumption from 23 TWh to 2600 Mwh, a decrease of 99.998% (Calma, 2022). It is estimated that this switch will save about 11 million tons of carbon emissions per year, not even including the carbon savings from reducing e-waste (Calma, 2022). This shows how impactful it can be when requirements such as environmental friendliness are considered during system design, in this case when choosing a proof-of-stake over a proof-of-work algorithm.

In other cases, a device’s lifespan is artificially shortened by implementing questionable features that were previously established as system requirements. Modern software constantly sends user metrics, which (in part) unnecessarily increase energy consumption and the complexity of the product. For example, a very popular word processor consumes 387% more energy during normal use than a comparable free and open sources (FOSS) product which uses just 0.93 watts per hour (Gröger et al., 2018). To put this in perspective, an unnecessary 2.7 watt LED light bulb burns for many hours in millions of offices just because questionable system requirements made it into the requirements document. Unnecessarily high energy consumption—induced by software—wears out the battery of mobile devices—more charging cycles are required—and thereby causes e-waste. To make matters worse, in modern cell phones, replacing defective components, such as a screen or a battery, is actively prevented by the software (iFixit, 2019). Personally, I consider this a malicious use of software whose requirements I can only explain with unethical business goals. These examples show that software has a negative impact on environmental sustainability regardless of how it is used, but depending on how it was specified during RE.

Many still believe that recycling is a solution, but only up to 19% of a smartphone can be recycled, and only a tiny fraction of the seventeen increasingly rare elements used to make them can be recovered (Geyer & Doctori Blass, 2010; EuChemS, 2021). The use of the IS has reduced the cost of information processing, but the constant need to generate energy and dispose of virtually non-recyclable devices puts a strain or cost on our environment.

While many scholars argue that environmental sustainability simply must be a prerequisite or value for RE (Naumann et al., 2011; Calienes, 2013), I believe that we need a general paradigm shift in SE toward VOFs that should positively impact all relevant sustainability dimensions, not just the environment. Whether such a paradigm shift is possible and what would be necessary for it from a theoretical point of view will be discussed later in Section 3 (*"Value-oriented Framework and Mediation Theory"*).

2.4.5 Technical Sustainability

Specifically introduced by Penzenstadler and Femmer (2013) for the SE field, technical sustainability refers to the long-term usage of a system. To enable long-term usage, it is important that a system or software can evolve and be adapted, for which continuous development and updates are essential (Penzenstadler & Femmer, 2013). Technical sustainability can be summarized as follows:

- "**Technical Sustainability** refers to the long-term usage of an app. Essential for this is the continuous development (updates) as well as the adaptability of an app."

Considering that the average lifespan of a device depends on the availability of security updates, it becomes clear that technical sustainability also has implications for economic (cost for new device) and environmental sustainability. Three software-related aspects can hinder the long-term use of IS:

1. If the original system requirements result in a biased or harmful system, it will not be used or be successful in the long-run (Spiekermann, 2015).

2. If a system violates rights and laws favored by its development context, legislation such as the GDPR will sooner or later catch up and prevent a long-term usage (Zuboff, 2015).

3. If a system is additionally complex, it is difficult to predict, change, update, and therefore impossible to maintain in the long-run from a technical perspective (Sommerville, 2016).

A good example of all three aspects are again products by Meta. The company is aware of Instagram's harmfulness for its teenage users, but despite all their capabilities and resources, Meta was not able change this yet (Well et al., 2021). In this case, Meta clearly did not consider the welfare of youth during RE and does not seem to be able to change their complex system. For Facebook, the GDPR has caught up with the privacy violation, and the system complexity makes years of engineering work necessary to adapt it to this legislation (Anonymous, 2022). All of these problems are initiated in part by a lack of value considerations from the outset, presumably as a result of a development context embedded in surveillance capitalism (Zuboff, 2015). VOFs such as VSD and IEEE Std. 7000 should, therefore, take into account the development context if they are to meet the claim of facilitating the development of ethical IS.

The previous examples on sustainability show that the triumph of IS cannot be explained by pure cost reduction (cf. Hansen et al., 2019). Instead, the costs are spread across the individual (reduced health), society (increased social fragmentation) and the environment (energy consumption and e-waste). Given the severity of the negative effects on all dimensions of sustainability, we can no longer afford to overlook the need for a paradigm shift in SE. This becomes even more clear if one considers how many projects fail or how much engineering work and investment is required to "fix" a product (cf. Meta) that is built based on harmful goals or needs, and without value considerations (Wright, 2011; Van den Hoven, 2017; Anonymous, 2022; Sommerville, 2016; Spiekermann, 2015).

2.5 Summary

Summarizing the state of practice in SE, there are many sophisticated SE practices that, if followed, could prevent common problems such as proposing a technical solution before understanding the problem to be solved. However, these practices are not able to prevent the introduction of ethical issues (Section 2.1: *“Anchoring Ethical Issues”*) or mitigate other suspected origins of harmful IS, such as lack of value considerations, market-driven development context, unaddressed malicious use cases, or system complexity (Section 2.3: *“Origins of Harmful Information Systems”*). Ideally, VOFs—IEEE Std. 7000 and VSD—that claim to facilitate the development of ethical IS should provide strategies to mitigate such issues, which are an important aspect of the VOF EvalCon (Section 5 *“Concept for Value-oriented Framework Evaluation”*).

Frameworks such as GORE, NFR, DT, and GDD, as well as VOFs IEEE Std. 7000 and VSD, contribute to SE with their unique theoretical foundations and methods, thereby steering the whole process towards an intended purpose. SE begins with management formulating a ConOps document that describes the business goals, intended context of use, and some relevant stakeholders (ISO, 2011b). This ConOps document is the starting point for RE (software specification), whose overall goal is to create a requirements document that includes a system description, stakeholder requirements, and system requirements (Sommerville, 2016). To successfully steer SE, VOFs must contribute to the necessary requirement engineering deliverables (RED), as described in Section 2.2 (“*Requirements Engineering*”).

In short, knowledge and insights into stakeholder expectations consistent with the stated purpose of VOFs must be gathered (Section 2.2.1; RED 1). In a departure from the current state of practice, VOFs focus on values—rather than goals and needs—as a type of stakeholder expectation. In order to formulate a requirements document, VOFs must enable prioritization of stakeholder expectations (stakeholder requirements) and ensure that these are free of contradictions and conflicts (Section 2.2.2; RED 2). In addition, these higher-level requirements must be translated into specific and validated functional and non-functional requirements (Section 2.2.3; RED 3). These requirements engineering deliverables (RED 1 to 3) are another important aspect of the VOF EvalCon (Section 5 *“Concept for Value-oriented Framework Evaluation”*).

Validated system requirements should demonstrate, among other things, feasibility, traceability and absence of conflicts as well as being free of implementation (cf. ISO, 2011a). At this time, there are no quality metrics that allow for validating the ethical and innovative potential of requirements in accordance with the stated purpose of IEEE Std. 7000 and VSD. To address this gap, I will propose such quality metrics in Section 4 (*“Novel Quality Metrics for System*

Requirements”) based on sustainability considerations for ethical potential (Section 4.1) and on the creativity literature for innovative potential (Section 4.2).

Given the harmful impact on sustainability, a paradigm shift in SE, as promised to be put into practice by VOFs, seems urgently needed. Therefore, in the following section I will take a look at whether SE practices can change—whether a paradigm shift is possible—and introduce VOFs and IEEE Std. 7000 (Section 3.1.1) and VSD (Section 3.1.2) and show where these contribute to SE (Section 3.1.3). Then, by introducing mediation theory (Section 3.2), it becomes clear in what sense these frameworks are attempting to shift paradigms and what the necessities are for doing so (Section 3.2.1 and Section 3.2.2).

3. Value-oriented Frameworks and Mediation Theory

In the past, SE practices have changed significantly, usually due to so-called “Software Crises”. By the late 1960s, it became clear that current practices could not keep pace with the increasing complexity and performance of new hardware, resulting in time and cost overruns as well as failing to meet stakeholder expectations. This so-called “Software Crisis 1.0” led to the conception of new SE frameworks—waterfall and spiral models—and methods—object-oriented programming—which still form the basis of SE practice today (Sommerville, 2016; Fitzgerald, 2012). In the 1990s, public Internet access, high data exchange rates, greater variety of devices, increasing computing power, and the desire for more software could no longer be satisfied by SE practices (Fitzgerald, 2012). This so-called “Software Crisis 2.0” was met with agile development—an alternative to waterfall and spiral models—which kept pace with the growing demand for rapid software development (Fitzgerald, 2012). In the beginning, the use of agile development gave engineers the autonomy to deal with the complexity of SOS, uncertainty in requirements, and emerging practices (Fowler & Highsmith, 2001).

In agile development, all mentioned SE activities are performed (see: Section 2.1 *“Anchoring Ethical Issues”*), but in an interwoven and informal manner (Sommerville, 2016; Schmidt, 2016). Similarly, all necessary RE steps are performed in agile, but intermixed and integrated throughout the whole development process (Ramesh et al., 2010). In contrast to classic RE (see: Section 2.2 *“Requirements Engineering”*), agile starts with a rough approximation of final requirements and adds details during the whole SE process, relying on strong requirement prioritization (Ramesh et al., 2010; Schmidt, 2016).

Influenced by the market-oriented development context, agile development has now, however, primarily become a tool for reducing costs and accelerating development without gaining autonomy (Zuboff, 2015; Savolainen et al., 2010; Schmidt, 2016). This form of development has resulted in highly complex systems, often pieced together from existing ones (a system of systems (SOS) that can be incomprehensible, are often undocumented, and have a myriad security vulnerabilities (Shin et al., 2010). The production of complex, harmful and unsustainable systems of low quality— containing bugs and security vulnerabilities—is what I would call “Software Crisis 3.0.” Given the shortage of skilled engineers forcing companies into AI-driven development—"Google Code AI” or “GitHub Copilot”—one can only guess how complex, bug-infested, unpredictable, and harmful the systems of the future might be (Knight, 2021).

Given the negative effects of current IS on sustainability, described in Section 2.4 (*“Impact on Sustainability Dimensions”*), the “Software Crisis 3.0” is already here. Howsoever SE practices may have changed in the past, we now need a paradigm shift in the way software is developed, for instance by employing VOFs that mitigate the assumed origins of current IS (Section 2.3: *“Origins of Harmful Information Systems”*). In the following section, I will look at VOFs, which promise to put such a paradigm shift into practice. Next, in Section 3.2 (*“Mediation Theory”*), I will present two types of necessities that VOFs must address in order to put mediation theory's philosophical perspective on technology into practice.

3.1 Value-oriented Frameworks

As a counter-movement to traditional frameworks used during RE (GORE, NFR, DT, GDD), several value- and ethics-oriented frameworks have been developed in recent years (Donia & Shaw, 2021; Palm & Hansson, 2006). Given the recognition that technology is not neutral but value-laden, active consideration of values through their discussion and ethical reflection seems to be a popular direction to take (Verbeek, 2011; Van den Hoven, 2017; Miller, 2021). In fact, it has been shown that considering values can minimize bias, make systems more accessible and desirable, help address sustainability, and even prevent projects from failing (cf. Friedman & Nissenbaum, 1996; Penzenstadler & Femmer, 2013; Van den Hoven, 2017; Wright, 2011). Under the umbrella terms “Values in Design” and “Design for Values,” an entire field of research and several VOFs have emerged that attempt to put value considerations and ethics into practice (Grunwald, 2015). While Donia and Shaw (2021) list 18 VOFs, including VSD and IEEE Std. 7000, this number can easily be increased. For instance, in addition, there are technology-specific frameworks such as “Values in Design Methodologies for AI” and those outside academia such as “Ethics for Designers” or “Ethical OS Toolkit” (Aldewereld & Mioch, 2021; Gispen, 2017; Praca, 2018). Each VOF, see list with brief description in Table 2, makes a unique contribution and advances the field of "Values in Design" and should therefore be included in a systematization of its theoretical foundations and methodology. This, however, would go beyond the scope of this thesis. In addition to these practical constraints, some frameworks, such as “Critical Technical Practice” and “Disclosive Computer Ethics,” have a stronger focus on analysis and description than on facilitating the steps necessary to develop systems. Others, such as "Feminist HCI," "Post-colonial Computing," or "Values at Play," focus on specific issues or particular types of systems. Finally, I consider some frameworks, such as "Virtues Practice Design," to be relatively new, lacking the literature base for in-depth systematization. Based on such considerations, I focus on VSD and IEEE Std. 7000 because both have either a long academic history or are recognized by standards bodies and do not focus on specific issues or system types (Friedmann & Hendry, 2019; IEEE, 2021; ISO, 2022a).

Table 2: *Ethics and "Values in Design" frameworks (according to: Donia & Shaw, 2021)*

Framework Name	Short Description
Critical Technical Practice	Critically reflecting on unconscious assumptions or values in practice
Design for Existential Crisis	Designing by being attentive, critical and original, and working together for the common good
Design Justice	Considering the distribution of risks, harms, and benefits among stakeholders
Disclosive Computer Ethics	Moral decoding of values and norms in systems and practices
Embedded Ethicist	Supports ethicists to co-shape technology in an ethical way
Ethics as Designer	Step-by-step uncovering, reviewing, and translation of values into technical terms by an ethicist
Feminist HCI	Design and development of interactive system with a commitment to feminism
IEEE Std. 7000	Ethical engineering design based on SE, VSD, DT, participatory design, and material value ethics
Positive Design	Design for the subjective well-being of individuals and communities
Post-colonial Computing	Analyzing and designing with a particular sensitivity to the conditions of postcolonialism
Reflective Design	Reflecting on unconscious cultural assumptions that persist in the development of technology

Framework Name	Short Description
Responsible Design	Pragmatic design with an emphasis on reflexivity, responsiveness, inclusion, and anticipation
Value-led Participatory Design	Dialogic process to consider stakeholder values, as well as how values emerge and are implemented in practice
Value Sensitive Design	Accounting for human values through an integrative and iterative tripartite methodology
Values as Hypotheses	Using values as a hypothesis to grasp a setting, guide actions, and change situations
Values at Play	Discovery and identification of values and value conflicts and their implementation in design
Virtues Practice Design	Alternative VSD-based approach with an emphasis on virtue ethics
Worth-centered Design	Focusing on creating “worth” that motivates investing time, money, energy or commitment

All of the aforementioned VOFs share some key ideas with mediation theory, such as “... that technologies support certain activities and values while discouraging others” (Verbeek, 2011, p. 115) and that “... technological functionalities should be replaced as the primary focus of design activities” (Verbeek, 2011, p. 114). I view VOFs as frameworks that put mediation theory into practice. Before I go deeper into mediation theory in Section 3.2 (*“Mediation Theory”*) and explain what necessities VOFs (Section 3.1.1 and Section 3.1.2) must address in order to put mediation theory into practice, I will now first introduce IEEE Std. 7000 and than VSD. Following the exemplary anchoring of ethical issues during the development of a GIS (Section 2.1 *“Anchoring Ethical Issues”*), I will tease how VOFs try to prevent this.

3.1.1 IEEE Std. 7000

First drafted by Sarah Spiekermann in 2017, this framework—referred to as “Value-based Engineering”—was developed in a five-year IEEE standardization process that led to the 2021 publication of “A Model process for addressing Ethical Concerns during System Design” (IEEE, 2021). Because of its rigor and desirable claims, IEEE Std. 7000 has been adopted as

ISO/IEC/IEEE 24748—7000 (ISO, 2022a). The framework's main objective is to help organizations involved in concept exploration, requirements definition, or development to engage in value-based system development (IEEE, 2021). It aims to provide engineers "… with an implementable process aligning innovation management processes, system design approaches, and software engineering methods to help address ethical concerns or risks during system design" (IEEE, 2021, p.12). This self-description already indicates that IEEE Std. 7000 goes beyond RE by including management processes such as innovation management or project initialization, and activities such as system design.

The IEEE Std. 7000 framework states that it helps companies with "… anticipating value implications and consequences of their systems …" and supports "… avoiding or mitigating value harms or ethical pitfalls" (IEEE, 2021, p. 13). Furthermore, the framework, helps to "… address ethical concerns or risks ..." (IEEE, 2021, p. 12). These statements underscore that the framework aims to facilitate the development of ethical IS. Moreover, one of the first IEEE Std. 7000 activities is to identify stakeholders who are "… driving the innovation effort" (IEEE, 2021, p. 37), which clearly indicates a focus on facilitating innovation. This stated purpose of the framework and its relationship to values is reinforced by "… creating ethical value …" (IEEE, 2021, p. 9), leading to IS that are "… more responsive to and inclusive of ethical values of the stakeholders and society at large" (IEEE, 2021, p. 31). These self-descriptions show that IEEE Std. 7000 should be seen as a VOF that aims to facilitate the development of ethical and innovative IS.

The most important theoretical and methodological contributions of this framework include a value understanding based on material ethics, ethical investigations for value discovery, a concept for specifying system requirements based on values and a risk-based system design process (IEEE, 2021; Bednar & Spiekermann, 2020). In what follows, I will always use the term "material values" when referring to the IEEE Std. 7000 value concept, and use the term "human values" when referring to the VSD value concept as coined there (cf. IEEE, 2021; Friedman & Hendry, 2019). The precise theoretical differences between these concepts will be the subject of Section 7.3.2 ("*Novel to SE: Value Flavors*"). The IEEE Std. 7000 framework commits to five processes, which I will now briefly introduce and which are shown in overview in Figure 9.

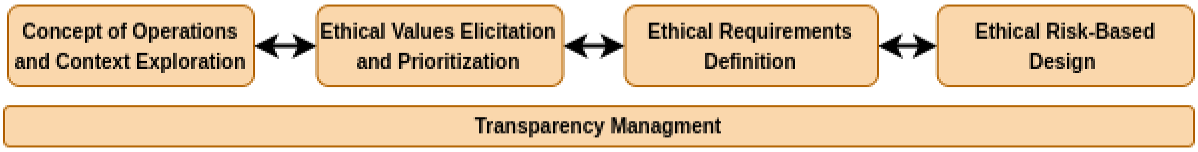


Figure 9: *Five processes of IEEE Std. 7000 (based on: IEEE, 2021, p. 15)*

The first process critical from an SE perspective is the "Concept of Opertations (ConOps) and Context Exploration Process," which addresses the ConOps formulation, including "… how a system is expected to operate from the users' perspective and its context of use" (IEEE, 2021, p. 35). Given the hypothetical example of GIS development (see Section 2.1 "*Anchoring Ethical Issues*"), this process is intended to ensure that all relevant stakeholders and comprehensive use contexts, such as the problematic use cases of tracking next of kin, are considered.

The subsequent "Ethical Values Elicitation and Prioritization Process" aims to discover, prioritize and negotiate material values—a type of stakeholder expectations (IEEE, 2021). Furthermore, stakeholders are chosen for inclusion in the discovery of material values based on three ethical investigations—utilitarian, virtue and duty ethics—as well as any relevant alternative ethical theory (IEEE, 2021). Subsequently, gathered insights are analyzed, conceptualized and structured as values clusters in accordance with material value ethics and subsequently negotiated and prioritized followed by an additionally in-depth conceptualization (IEEE, 2021). This process is primarily aimed at mitigating the lack of a concept to judging stakeholder expectations in SE practice. Using GIS development as an example, it is assumed that when using material values as the basis for stakeholder expectations—rather than goals or needs—ethical investigation and in-depth conceptualization will reveal ethical issues related to profiling, manipulation, or tracking next of kin.

The third process, the "Ethical Requirements Definition Process," helps formulate "Ethical Value Requirements" (EVRs), a special form of stakeholder requirements, and specify these requirements into validated "value-based system requirements" that are an "equivalent" to system requirements (IEEE, 2021). Specifying system requirements in IEEE Std. 7000 is essentially formulating non-functional and functional system requirements that mitigate EVR risks and support value demonstrators—an essential part of the material value concept that will be discussed in Section 6.3.2.2 ("*Material Values*"). Furthermore, during this process qualitative or quantitative quality metrics are identified for each system requirement (IEEE, 2021). The purpose of this process is to ensure that when, for example, values such as privacy or freedom are identified for the development of a GIS, they are specified correctly and included as system requirements in the requirements document.

The last step is the Ethical Risk-Based Design Process, a “*system design*” activity in which components that meet system requirements are selected based on a risk assessment (IEEE, 2021). For the GIS development example, this process aims to ensure that privacy-invasive components, such as “Google Play Services,” do not become part of the system design when privacy is identified as an important value. Finally, the “transparency management process” is an essential support process that underlies every other process of IEEE Std. 7000.

The theoretical and methodological details of IEEE Std. 7000 are discussed and assessed in greater detail later, in Section 6 (*“Theoretical Foundations and Methodology”*). In the following section, the VSD claims and their theoretical commitments are presented.

3.1.2 Value Sensitive Design

As the name—Value Sensitive Design—suggests, it is a design framework that should not be confused with *system design* in the SE sense. From the SE perspective, VSD is a high-level design framework that is not specifically intended for IS development, but its theories and methods can make an important contribution to RE specifically. VSD was first conceptualized in 1996 and has evolved over 25 years to its current form (Friedman & Nissenbaum, 1996; Friedman & Hendry, 2019).

By considering human values as a high-level design criterion and providing language for discussing harms and social consequences, as well as seeking “...remedies that promote human well-being” (Friedman & Hendry, 2019, p. 56), VSD also aims to facilitate the development of ethical IS. Furthermore VSD also states that it supports “… envisioning, designing, and implementing technology in moral and ethical way that enhance our futures” (Friedman & Hendry, 2019, p. 2). In addition to this statement, and with the aim of assessing the consequences of technological innovations and enabling future-oriented design (Friedman & Hendry, 2019), VSD also seeks to promote the development of innovative IS.

VSD’s pathway to these claims involves nine theoretical commitments (Friedman & Hendry, 2019). The first is a perspective on systems as a composition of tools, technology, and infrastructure that impacts human ways of living and meaning-making (Friedman & Hendry, 2019). The second is a commitment to a human value concept as a representation of what is considered important in life, with an emphasis on ethics and morality (Friedman & Hendry, 2019). As a third commitment—as opposed to technological determinism—VSD recognizes that individuals within organizations or societies create and shape technologies, which in turn shape the human experience and society as a whole—which is an interactional stance (Friedman & Hendry, 2019). The fourth commitment is "...an iterative methodology that integrates conceptual, empirical, and technical investigations" (Friedman & Hendry, 2019, p. 32), which is the process by which VSD seeks to steer SE. The focus on extensive stakeholder identification and involvement in the design process is the fifth theoretical commitment of VSD (Friedman & Hendry, 2019). The sixth is an acknowledgement of the interrelationships between human values, and thus of possible tensions between them for which trade-offs must be found (Friedman & Hendry, 2019). The seventh commitment is a focus on the co-evolution of technology and socio-structural aspects that are intertwined and mutually shape each other "... in an ongoing, delicate, dynamic balance" (Friedman & Hendry, 2019, p. 49). The eighth theoretical commitment is to a multi-lifespan design that includes consideration of a long-term perspective (Friedman & Hendry, 2019). The final theoretical commitment is the focus on progress or practice over perfection and is considered relevant for all aspects of this framework (Friedman & Hendry, 2019).

VSD aims to incorporates human values into the SE process by using conceptual, empirical, and technical investigations (Friedman & Hendry, 2019). Each investigation can be the starting point for a project, and these should be used integratively and iteratively to inform and reshape each other (Friedman & Hendry, 2019). Figure 10 is intended to illustrate this idea.

Figure 10: *Iterative VSD investigations (based on: Friedman & Hendry, 2019)*

During the conceptual investigation, direct and indirect stakeholders, their values, potential harms and benefits, appropriate ethical or cultural justification frameworks, potential value understanding, and success criteria are identified (Friedman & Hendry, 2019). With this broad scope, this investigation contributes to many activities in SE. When developing a GIS, this investigation aims to ensure that, for instance, the value of privacy is recognized and understood. For the hypothetical example of GIS development, this could help mitigate ethical issues related to profiling or tracking relatives from the outset and prevent anchoring (see Section 2.1 *“Anchoring Ethical Issues”*).

During the empirical investigation, quantitative and qualitative methods are used to examine the system’s context of use, stakeholders’ understanding of values, the gap between stated and practiced values, prioritization of competing values, and resolution of value tensions (Friedman & Hendry, 2019; Davis & Nathan, 2015). This investigation is intended to provide additional insight into the context of use and particularly relevant values on a larger scale. Conflicts of values are negotiated in GIS development, for example, between “*ride-hailing providers*” who want to maximize their profits (e.g., by manipulating toward selling more rides) and users' values for uninterrupted use (e.g., no advertising for ride-hailing).

The technical investigation focuses on requirements, which may result from policies, laws, or regulations; experience with existing systems that support or hinder values; or as a proactive design activity to promote the values identified during the conceptual investigation (Friedman & Hendry, 2019). This investigation is not a “*system design*” but a form of high-level design that helps specify values as system requirements based on certain values such as privacy or unbiasedness.

In the next section, I will align the IEEE Std. 7000 processes and VSD investigations with the state of practice SE.

3.1.3 Contribution to Software Engineering

For VSD as a design discipline—not to be confused with *system design*—the b) *development*, c) *validation* and d) *evolution* activities of SE, fall mostly out of scope. IEEE Std. 7000 also does not cover all SE activities and focuses on project initialization, software specification, and to some extent development, as implementation of system design is not covered (cf. IEEE, 2021). Figure 11 shows an alignment of VSD investigations and IEEE Std. 7000 practices with the key SE steps to which they contribute and intend to steer.

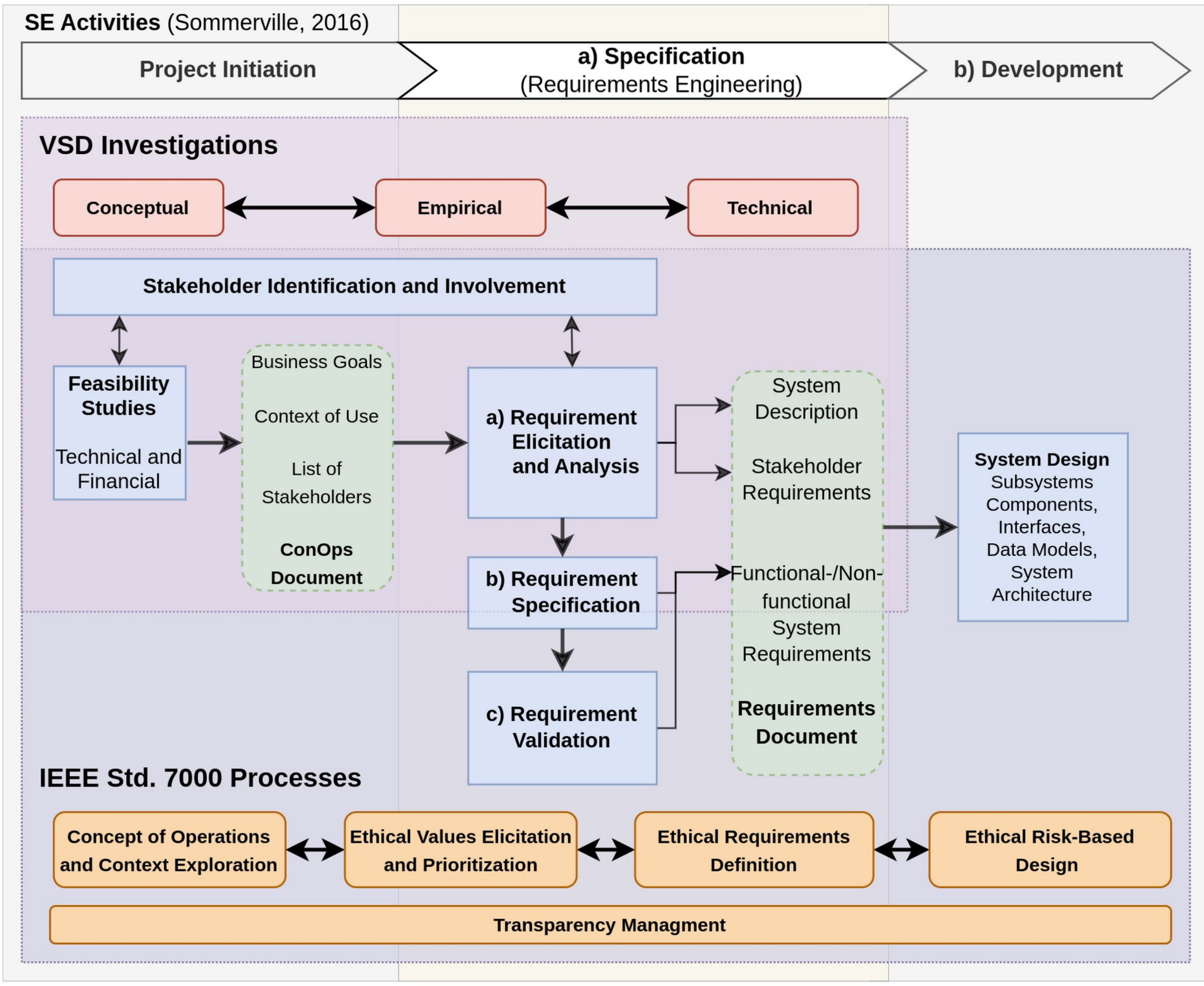


Figure 11: *Contribution area of VSD and IEEE Std. 7000 mapped on SE activites*

As can be seen in Figure 11, the VSD framework does not fully cover area b) *Specification*—RE—as it may rely on the state of the practice in the specification and validation of system requirements. In comparison, IEEE Std. 7000 provides its own methodology for specifying system requirements, which is discussed in Section 6.5 ("*Translation of Values into System Requirements*"). The fact that any VSD investigation can be the starting point of a project and its integrative and iterative nature make it difficult to specifically assign these investigations (Friedman & Hendry, 2019). For example, conceptual investigation while identifying stakeholders can be understood as contributing to the formulation of ConOps; determining their expectations in terms of values, harms, or benefits can contribute to a) Requirements Elicitation and Analysis in RE. This is also the case with the empirical investigation: while from the SE perspective, understanding the context of use contributes to the development of ConOps, understanding and further analyzing values in practice contributes to 1. *Discovery and Understanding*, and resolving value tensions facilitates 3. *Prioritization and Negotiation* of the a) *Elicitation and analysis* step in RE. The technical investigation, on the other hand, mostly seems to facilitate the formulation of stakeholder requirements and their specification into system requirements.

In contrast, it is much easier to align IEEE Std. 7000 since it is a VOF that is clearly based on and conceptualized for SE. The "Concept of Opertations (ConOps) and Context Exploration Process" is highly in line with the *project initiation* but extends the state of the practice by also requiring additional feasibility studies and analyzing the control over subsystems of the system to be developed (Sommerville, 2016; IEEE, 2021). Furthermore, the "Ethical Values Elicitation and Prioritization Process" is especially in line with the 1. *Discovery and Understand* part of a) *Requirement Elicitation and Analyze*, while the "Ethical Requirements Definition Process" is a hybrid step, which includes a) *Requirement Elicitation and Analysis*, b) *Requirement Specification* and c) *Requirement validation* according to the state of practice. Finally, the "Ethical Risk-Based Design Process" is mostly concerned with system design. The "transparency management process" is a support process that is essential for framework claims but not directly necessary for SE activities, which is the topic of Section 6.6 ("*Transparency and Traceability*").

It is, however, clear that both VOF concentrate on the first activities, especially *project initiation* and a) s*pecification*, where ethical issues are assumed to be introduced. The additional emphasis on system design in IEEE Std. 7000 can certainly prevent the introduction of new issues, but it is unlikely to mitigate issues already introduced and formalized as system requirements (see: Section 2.1 *"Anchoring Ethical Issues"*). During its "Ethical Risk-Based Design Process," the probability and consequences of potential harms are assessed and controls are selected in the form of system components—which provide a technical solution to system requirements (IEEE, 2021). While a similar approach is common in the development of software in the aerospace industry, it did not prevent the crash of two Boeing 737 Max 8s (Travis, 2019; Rierson, 2017). In this case, the cause of the crashes was due to business goals of "minimizing pilot training" while "increasing fuel efficiency," which are highly desirable to airlines, Boeing's most important customers (Travis, 2019). To minimize pilot training, an airframe already in service had to be used, and to increase fuel efficiency, larger engines are required, which however change an aircraft's flight characteristics (Travis, 2019). These are essentially contradictory requirements, since a change in flight characteristics mandates additional pilot training. To circumvent this unresolved contradiction, the Maneuvering Characteristics Augmentation System (known as: MCAS) was designed based on a risk-based design (Travis, 2019). During the risk assessment, engineers concluded that the system was unlikely to cause a crash because the airframe was already in operation and therefore the system was designed without redundancies (Travis, 2019). This example shows that risk-based system design cannot solve the issues introduced in earlier steps, ethical or otherwise. For this reason, and because other VOFs do not address “system design,” the IEEE Std. 7000’s “Ethical Risk-Based Design Process” is not considered further in this thesis.

It now seems clear where VSD and IEEE Std. 7000 are trying to put their theoretical foundations and methodology into practice, but it is still unclear whether SE can change and what kind of paradigm shift these VOFs are putting into practice. Next, I will present key ideas from mediation theory that IEEE Std. 7000 and VSD seek to put into practice. This theory represents a paradigm shift in the way technology is viewed and should be developed. However, to put these into practice, VOFs must meet theory and hygiene necessities from mediation theory, which are derived and formulated in Section 3.2.1 (*“Theory Necessities”*) and Section 3.2.2 (*“Hygiene Necessities”*). These necessities are an essential part of the VOF EvalCon, as later described in Section 5 (“*Concept for Value-oriented Framework Evaluation*”).

3.2 Mediation Theory

In mediation theory, technology is viewed as a mediator between humans and their surrounding world (Verbeek, 2011). According to this mediation view, technology molds its own operational context by influencing our world and society, shapes our perceptions, embraces new behaviors, and in the long run, could imply social practices and lifestyles (Verbeek, 2011). Mediation theory has a post-phenomenological underpinning that helps balance an instrumental with a deterministic perspective on technology.

In line with post-phenomenological philosophy, mediation theory assumes that humans and technology shape each other (Verbeek, 2011). As Ihde and Malafouris (2019) put it, “...we become constituted through making and using technologies that shape our minds and extend our bodies (p. 194). While classical phenomenology typically analyzes the link between humans and the world with technology-related aspects, post-phenomenology goes further by “… claiming that they actually constitute each other” (Verbeek, 2011, p. 15f). This philosophical underpinning allows for an analysis without reducing the role of technology to a mere value-neutral tool or instrument and without the fear of technological determinism (Verbeek, 2011). According to determinism, technology controls our society by setting means or meaning, which is particularly dangerous when this is seen as an inevitable end (Heidegger, 1977). For example, the ability to split the atom gave us the means for cheap annihilation, which led to societies bent on mutual destruction, a billion-dollar nuclear weapons industry, and the acceptance of frequent severe accidents (Schlosser, 2013). The atomic bomb is a technology often treated as an inevitable end (Jaspers, 1958). Worryingly, every U.S. president who has attempted to control the nuclear arsenal has failed to bring about the necessary societal and technological change (Schlosser, 2013). However, technological determinism is not very productive, as one could simply conclude that it is best not to develop any technology at all.

Mediation theory can be seen as a paradigm shift, as it opposes the widely accepted thesis of value-neutrality (instrumentalism) and offers an alternative perspective on technology and its development. Other theories besides mediation theory, such as moral deliberation, could have been used as a basis for formulating a VOF EvalCon, but I choose mediation theory in particular because it focuses on technology development as well as values and provides a balanced instrumental and deterministic perspective on technology. In the past, the value-neutrality thesis has often been used by engineers to evade responsibility—it being impossible to prevent malicious use—and most importantly prevented them “… from asking moral questions about their labor” (Miller, 2021, p. 70). This could be the reason why there are currently no frameworks for SE that ask moral questions (see Section 2.1 *“Anchoring Ethical Issues”*).

In one of the most shocking examples in history, Nazi architect Albert Speer denied responsibility for the Holocaust because he only dealt with its engineering aspects by designing the necessary facilities (Miller, 2021). Shockingly, at the time of the Nuremberg trials, this argumentation was sufficient to obtain only a lenient sentence. It is undeniable that engineers themselves “… are shaped by organizational, political and economic forces” (Friedman & Kahn, 2007, p. 1179) and that these forces thereby have an impact on technology development; however, engineers should not be allowed to “… evade moral responsibility for the consequences of their products by arguing that they are morally neutral...” (Miller, 2021, p. 72). According to mediation theory “… technologies do help to shape our experience and the moral decisions we take, which undeniably gives them a moral dimension” (Verbeek, 2011, p. 2). This makes ethics a “hybrid affair” since technology has moral significance, the subject—a human—makes “… moral decisions and acts morally on the basis of its interweaving with the technologies it uses” (Verbeek, 2011, p. 88). If the recognition that systems are not neutral but value-laden is transferred into SE practice and engineers are enabled to take responsibility for a system and recognize that it shapes not only people and the world but also experiences and moral choices, this would be a major paradigm shift in SE.

VSD is considered as an “...interesting possibility for anticipating and designing ‘moralizing technologies’” (Verbeek 2011, p. 115). However, Verbeek (2011) considers some aspects of this VOF to be underdeveloped, such as the analyses of the impact on human practices and values, the connection to future use contexts, or the fact that the VOF does “…not offer sufficient basis for a moral assessment…” (Verbeek, 2011, p. 116). Although much has changed since 2011, some theoretical and methodological challenges remain, which are the subject of Section 6 (*“Theoretical Foundations and Methodology”*). I will argue, that both VOFs (see: Section 3.1 *“Value-oriented Frameworks”*) share key ideas with mediation theory, such as “... that technologies support certain activities and values while discouraging others” (Verbeek, 2011, p. 115) and that “... technological functionalities should be replaced as the primary focus of design activities” (Verbeek, 2011, p. 114). To evaluate VOFs and assess whether these can put mediation theory into practice, this must first be understood. While mediation theory typically focuses on technology and people in general, I will put a particular emphasis on software systems and stakeholder.

I will introduce two types of necessities VOFs must address: mediation theory necessities (MTN) and associated hygiene necessities (HN). While MTN have specific focus tasks VSD and IEEE Std. 7000 must accomplish, HN refer to the general context or situation that must be created to properly accomplish relevant tasks. These necessities are essential for the VOF EvalCon, which is described in Section 5 (*“Concept for Value-oriented Framework Evaluation”*).

3.2.1 Theory Necessities

While the value-neutral thesis may partially hold for traditional tools—a hammer or a hair dryer—under the complete control of their users, IS operate largely opaquely, outside of people’s perception, and outside of any control (Van den Eede, 2010). As put by Mark Weiser (1999), the father of ubiquitous computing, technologies "...weave themselves into the fabric of everyday life until they are indistinguishable from it" (p. 94). This makes it extremely difficult to analyze desired mediation effects and, more importantly, to build a system accordingly.

Since systems can be used in many different contexts, the mediating effect between stakeholder and the world (context of use) is typically very complex (Ihde, 2010; Verbeek, 2011). Systems can provide access to reality because these show a representation of it that requires interpretation—hence a hermeneutic relationship (Verbeek, 2011). On a hermeneutic micro-level, systems influence how we perceive or grasp the world (Verbeek, 2011). A medical IS, such as a magnetic resonance imaging scanner (MRI), allows us to detect, for instance, cancer—otherwise not perceivable—at an early stage. In this way, a person perceives her or himself as sick or, in other words, as a patient, although there are no other signs except for a digital image—a representation of reality—of tumor cells. On a hermeneutic macro-level, such a system influences how we interpret the world and therefore our living context (Verbeek, 2011; Kremer, 2018). An MRI scan indicating cancer may lead to reinterpretation of life context from a cancer patient's perspective; for example, by leading to people realizing how many other cancer patients there are in their circle of friends. Moreover, both hermeneutic levels—micro and macro—interact with each other; only what we perceive (micro level) can we understand (macro level). Or, indeed, the other way around, in the case of a confirmation bias, for instance—what we understand (macro level) influences what we perceive (micro level) (Baybutt, 2018). The mediation effects of the IS between the world and stakeholders are shown in Figure 12 and are discussed in more detail below.

At an existential micro level, systems affect our immediate behavior; or, if the behavior is sustained, at a macro level it leads to new social practices and ways of living (Verbeek, 2011; Kremer, 2018). An MRI scan that indicates cancer might lead to immediate healthier behavior, e.g., quitting smoking, and, in the long-run, to a society that condemns smoking in order to reduce cancer deaths. Also, these two existential levels—micro and macro—interact with each other. Consistent behaviors (micro level) can lead to new social practices such as healthy lifestyles (macro level), and these practices (macro level) encourage certain behaviors (micro level), such as not starting to smoke.

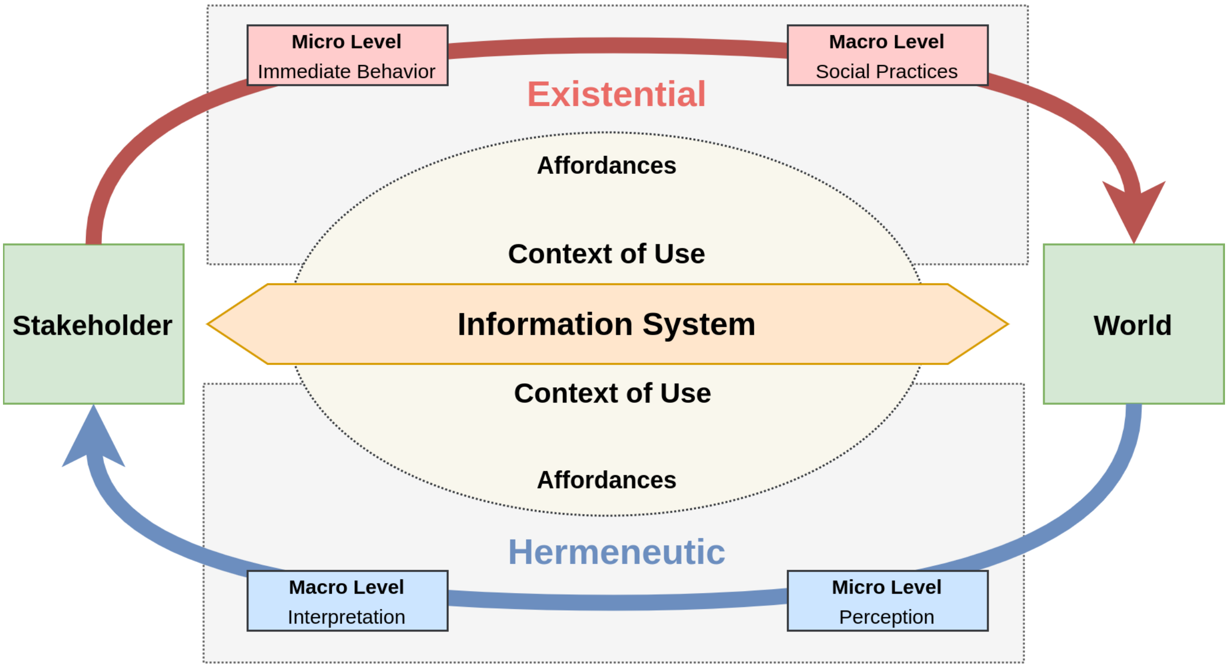


Figure 12: *Technological mediation adapted for IS with affordances (based on: Kremer, 2018; Klenk, 2021; Verbeek, 2011)*

There are multiple slightly different concepts including scripts, Norman's affordances or Gibson's affordances, which explain how technology influences stakeholders (Verbeek, 2011; Norman, 2013; Gibson, 2014; McGrenere & Ho, 2000). According to Klenk (2021), the effect of an affordance depends on the design of the system in combination with the use context and the perceiving stakeholder. In terms of SE, an affordance is a property of a system that is introduced through stakeholder expectations (goals, needs or values), specified as a system requirement and later implemented. As can be seen in Figure 12, affordances have an influence on stakeholders' perception and interpretation (hermeneutic) as well as behavior and social practices (existential). Scripts or affordances can have the intent to amplify or reduce perception (Verbeek, 2011). For example, an MRI image showing cancer cells in red was intentionally set to enhance the perception of those cells. Considering the existential aspect, an affordance or script of a system "… suggest[s] specific actions and discourage[s] others" (Verbeek, 2011, p. 10). A system with a user interface that has, for example, a large button that says "Accept all cookies" was intentionally designed to encourage the action of clicking on it. These intentionalities of a system —hermeneutic or existential—are dependent on the way it is embedded in the context of use, and thus “...always dependent on the specific stabilities that come about” (Verbeek, 2011, p. 9)—this is what Ihde calls multistability (Ihde, 2010).

Multistability—dependence on the context of use—and the various, largely opaque mediation effects—hermeneutic and/or existential—a system can have require the conducting of an in-depth analysis of the context of use (Van den Eede, 2010; Ihde, 2010; Verbeek, 2011). In other words, VOFs that want to put mediation theory into practice must:

- **MTN 1:** “Provide an in-depth analysis of the context of use”

To establish a connection between the context of use and SE, it seems recommendable to involve all relevant stakeholders (Verbeek, 2011), since only these can bring the necessary experience and insight on potential contexts. Gaining and considering insights from all stakeholders “...can be seen as a democratization of the designing process” (Verbeek, 2011, p. 103). Because systems can influence human perceptions, behavior, and social practices, they should be developed through a democratic process (Verbeek, 2011). Stakeholder identification and subsequent engagement opens up a space for deliberative democracy in SE, which is especially important when systems are intentionally “moralizing” or “behavior-influencing” in nature (Verbeek, 2011, p. 112). Moreover, the responsibility for the mediating effects of the systems should not lie solely with the engineers, as this would be a form of technocracy (Verbeek, 2011). According to Verbeek (2011), including stakeholders can “...lay bare all moral arguments that are relevant to a given ethical problem…” (p. 106) and help identify negative consequences and moral obligations.

While affordances exist as properties of a system even without a stakeholder, whether they have an effect, however, depends on the perceiving stakeholder, and factors such as their intention to a system (Klenk, 2021). Identifying stakeholders can help understand how they interpret and appropriate the system and its affordances (Verbeek, 2011). Not considering this interpretative role of the stakeholder would entail a technology deterministic perspective, where the system simply determines behavior and societies (Verbeek, 2011). In contrast to the value-neutrality thesis, the impact of technology is to a certain extent the result of engineering and stakeholders; as Verbeek (2011) puts it, both “… users and designers can have moral responsibility for technologically mediated actions” (p. 109). Therefore, to bring about a real paradigm shift in SE practice, VOFs should identify and subsequently involve diverse stakeholders.

- **MTN 2:** “Identify and involve diverse stakeholders”

Depending on the type of implemented affordance a mediation can be coercive, persuasive or even seductive (Verbeek, 2011). This means that people’s behavior can be nudged through deliberately engineering persuasive or seductive affordances (Thaler & Sunstein, 2009). An example of such seductive or even addictive affordance is UI design following dark patterns or gamification (Mathur et al., 2021; Anderson, 2011; Neyman, 2017). For instance, a dark pattern like “Sneak into Basket” has affordances that prevent the customer from perceiving (hermeneutic) that an additional product has been placed in the basket. Addictive design elements can have severe negative consequences for individual sustainability (see Section 2.4.1 *“Individual Sustainability”*)

Explicitly designing mediation into systems, as most VOFs intend, essentially means organizing people’s experiences, behaviors, and actions, which can be seen as invasive (Verbeek, 2011). Strictly speaking, even the presentation of a subset of options influences a user’s behavior and could be considered an act of paternalism (Thaler & Sunstein, 2009). According to mediation theory, systems “… shape the quality of our lives and of our moral actions and decisions” (Verbeek, 2011, p.5f). In other words, through affordances or scripts, systems embody morality, which means that any engineering decision can have moral consequences (cf. Verbeek, 2011; Johnson, 2015). The development of moralizing systems should be done in a responsible way, not only through a democratic process (together with stakeholders) but also with the help of moral reflection (Verbeek, 2011). Since SE requires an infinite number of choices with moral consequences, engineers must be empowered to take responsibility for their decisions (Stolterman, 2008; Verbeek, 2011). It is not only a matter of responsibility to consider ethics in SE, but is increasingly required by law; for instance, since 2021, larger Danish companies are legally obliged to consider ethics (Folketing, 2020). In addition, upcoming European regulations, such as the Digital Services Act or the AI Act, can be seen as a push for ethical considerations to become a legal obligation (European Parliament, 2022; European Commission, 2021). As Verbeek (2011) puts it, “If ethics is about how to act and designers help to shape how technologies mediate action, designing should be considered a material form of doing ethics” (p.

91). From an SE perspective, this is a paradigm shifting revelation; however, theoretical foundations and methods are needed to put this into practice.

Furthermore, to ensure that discovery leads to the identification of morally relevant values, reflection and commitment to an ethical framework or a “philosophical mode” is also required (Jacobs & Huldtgren, 2021; Reijers & Gordijn, 2019; Flanagan et al., 2008). The discovery of values without ethical investigation runs the risk of being a collection of mere preferences of individual stakeholders, without a judgment of right or wrong or a contribution to a good life (Reijers & Gordijn, 2019; Vallor, 2016). Taken together, to justify potentially invasive decisions, assume moral responsibility, comply with the law, and establish values that are more than preferences, VOFs should conduct sound moral investigations.

- **MTN 3:** “Conduct an investigation founded in moral philosophy”

In mediation theory, the technology is not only seen as having moral significance, but it is also value-laden (Verbeek, 2011). Systems embody values, but whether these unfold depends on the individual stakeholder and the context of use (van de Poel & Kroes, 2015). In other words, systems embody context-specific values that engineers need to discover, discuss and morally reflect upon (Miller, 2021). According to Gogoll et al. (2021) considering moral values enables normative thinking by providing a starting point for considering what should be or ought to be done in a particular context. Morally relevant values could thereby be the vehicle for the consideration of ethical issues within SE. For example, using the value of “privacy” as a starting point raises certain ethical issues and entails related values such as “accessibility” and “security” that must be considered, specified and implemented. Many SE projects have failed in the past, such as Google Glass, the Dutch smart meter, or the UK’s electronic health record, because implicated values were not sufficiently considered (c.f. Van den Hoven, 2017; Wright, 2011). Traditionally, SE has focused on a limited number of values—security, privacy, accessibility, or pleasure—and left a large portion of potential values out of the equation (Hussain et al., 2020). While proponents of instrumentalism insist that value depends on how a system is used, in reality, values are embodied in the system—as affordances—that contribute to valuable action (Klenk, 2021). Because embedded values often remain epistemically opaque, discovering them can be challenging (Klenk, 2021). VOFs must therefore provide a means of discovering value if they are to put mediation theory into practice.

- **MTN 4:** “Discover what stakeholder value”

From a practitioner’s standpoint, not all values that are discovered can be considered. Not only might values from diverse stakeholders contradict each other and therefore need to be negotiated, fulfilling too many value obligations could lead to a moral overload (Friedman & Hendry, 2019; Davis & Nathan, 2015; van den Hoven, et al., 2012). Prioritizing discovered values can be a big challenge, since values are incommensurable with others’, making this activity into a multi-criteria decision process (Van de Poel, 2015). It is often unfeasible to create a system that meets stakeholder values of “security” while also providing “flexibility” and “convenience.” For example, full disk encryption for your laptop would increase security, but it is very inconvenient as it requires an additional password entry for encryption before starting the operating system. System requirements can only be specified, if such value contradictions (in this case security vs. convenience) are resolved on a high level and a solution or compromise is found (see Section 2.2. *“Coherent Set of Stakeholder Requirements”*). A common solution for this example is to store the encryption key on the hardware in the Trusted Platform Module (TPM), which makes the process relatively secure and convenient. However, this leads to inflexibility because the hard disk can only be encrypted with the TPM content and such a module has to be present. Microsoft's upcoming Windows 11 requires a TPM for conviction reasons, which older hardware does not have (Yee, 2021). In other words, millions of devices will have to be disposed of, which has a very negative impact on environmental sustainability (see: Section 2.4.4 *“Environmental Sustainability”*). This shows that prioritizing and negotiating only three values is anything but trivial and can lead to ethical issues. VOFs that want to successfully meet the claim of promoting the development of ethical IS should therefore ensure the prioritization and negotiation of the values found.

- **MTN 5:** “Ensure prioritization and negotiation of values”

After values are discovered and understood, they must be “materialized” or embodied in a system in a way that supports their aim (Verbeek, 2011, p. 117). In other words, a value such as “freedom,” “privacy” or “autonomy” must be translated into system requirements, which are then incorporated into the system design (see Section 2.2 *“Requirements Engineering”*). It is a common challenge for the field to embed normative values into design or system requirements (Mittelstadt, 2019). From an SE perspective, values are a new and “fuzzy” concept and therefore might be difficult to translate into functional and non-functional system requirements. Manders-

Huits (2011) warns that values might be formulated ambiguously and can be interpreted in different ways, and can thus lead to incorrect norms and actions. In terms of SE, this is highly problematic, since system requirements should be explicitly clear and unambiguous (ISO, 2011a; Sommerville, 2016). In addition, system requirements should be traceable from the source—in this case, a value—to a related system requirement and then to an implemented system component or property (ISO, 2011b). VSD and IEEE Std. 7000 should provide the theory and methods to translate "fuzzy" values into concrete system requirements and logically chain them together to enable traceability.

- **MTN 6:** "Translate values into system requirements in a traceable way"

The hygiene necessities defined below are not explicitly required for the implementation of mediation theory in practice, but aim to create the right conditions for the MTNs defined in this section.

3.2.2 Hygiene Necessities

Deliberately influencing human perception and behavior as done through SE, is likely to "...raise moral objections, because it might limit human freedom, and because of fears of a technocracy..." (Verbeek, 2011, p. 91). Therefore, all decisions made during SE should be documented in a transparent and traceable manner. Mediation theory provides the philosophical foundations to influence humans' decisions in a systematic way, which "… cannot be left to the responsibility of individual designers" (Verbeek, 2011, p. 96). While stakeholder engagement (MTN 2) and inquiry based on moral philosophy (MTN 3), and thus moral justifications, help to ensure responsibility for a final product, at a minimum, it should be made transparent which values were considered. Transparency is also important from a long-term perspective, as embodied values "...have long-term implications that surpass their designers and builders" (Miller, 2021, p. 54).

Even when carefully put into practice, a system can be used in unforeseen ways. Such malicious use cases have unexpected consequences, and cause unforeseen mediations or human behavior (Verbeek, 2011). According to Verbeek (2011), there is always a risk of a rebound effect; for instance, a more energy-efficient technology could stimulate energy-consuming behavior. Moreover, users might bypass a system (not use it at all) or use it radically differently than was intended (Verbeek, 2011). In all these cases, it is important to have transparency and traceability about what has been done in the past to improve the system in further SE iterations.

In general, SE is a collaborative activity carried out by many stakeholders that are not all involved in each decision, therefore many might be held responsible for the immoral actions or decisions of a few (Floridi, 2016). Transparency and traceability of decisions enable the acceptance of joint responsibility and make it clear when and by whom a problematic decision, for example with unintended consequences, was made. In SE "...transparency generally refers to a product or a development process's visibility to stakeholders" (Tu et al., 2016, p. 1039). While this should not be the main aim of transparency, it is only natural that, if technology—for instance, due to complexity—behaves unexpectedly especially due to accidents or mishaps "...we often want to know why and who is to blame" (Johnson, 2015, p. 713). As mentioned earlier, engineers often behave unprofessionally or unethically, without being aware (Berenbach & Broy, 2009). Transparency and traceability can help identify such behavior and prevent it in the future, as well as allowing for the improvement of a system.

Ensuring transparency can, however, also increase the quality of the resulting system and is typically the starting point for effective communication (Tu et al., 2016). Effective communication helps stakeholders to understand the system to be developed, enables them to provide prompt feedback, and supports resolving issues or concerns (Tu et al., 2016). Transparency also helps to improve the relationship between stakeholders, "… and thus helps in developing a successful software system that meets stakeholders' expectations" (Tu et al., 2016, p. 1038). It is also well known in SE practice that systematic documentation leads to a better understanding of needs (Kauppinen et al., 2007), which is certainly true for understanding values. Therefore, it is recommended that the VOF:

- **HN 1:** "Enable transparency and traceability of responsibility"

The next hygienic necessity focuses on the development context. During SE, ethical issues may arise that require reflection beyond compliance with code (Van de Poel & van Gorp, 2006). Recognizing and addressing such issues requires an appropriate development context, which, in contrast to the current state of practice, requires time, ethical guidance and good working conditions (Berenbach & Broy, 2009). Furthermore, dealing with values also requires time to understand their interpretations and nuances (Steen & van de Poel, 2012). The market-oriented development context currently practiced (see Section 2.3 *"Origins of Harmful Information Systems"*), is ill-suited to putting mediation theory into practice. In line with mediation theory, Zuboff (2015) argues that "[t]echnologies are constituted by unique affordances, but the development and expression of those affordances are shaped by the institutional logics in which technologies are designed, implemented, and used" (p. 85). To ensure that such affordances can be created in the sense of mediation theory, an appropriate development context must be established. In general, developing a good product requires the right development context that provides time, ethical guidance and good working conditions (Berenbach & Broy, 2009). VSD and IEEE Std. 7000 should therefore recommend and establish an appropriate development context that allows these VOFs to properly implement mediation theory in practice.

- **HN 2:** "Establish a development context that ensure time and ethical guidance"

This is an extremely important hygiene necessity that is not only important for VOFs but also useful for SE in general.

3.3 Summary

In order to prevent the impending "Software Crisis 3.0"—producing even more complex and harmful systems—we need a paradigm shift in SE. VOFs promise to put this paradigm shift into practice by steering SE, and especially its first critical activities, project initiation and RE. Mediation theory as a philosophical perspective on human-technology relations provides the basis for such a paradigm shift, but several necessities must be addressed for its implementation in practice.

To account for the multistability of systems, engineers need a methodology that enables an in-depth analysis of the context of use (MTN 1). To establish a connection between the context of use and SE, shared responsibility through a democratic process identification (MTN 2) and subsequent involvement of diverse stakeholders is recommendable. In order especially to justify potentially invasive decisions, assume moral responsibility and establish values that are more than preferences, VOFs should conduct sound moral investigations (MTN 3). Since considering moral values is a vehicle for normative decisions, VOFs must provide a valid method to discover values (MTN 4). Due to practical and ethical relevance, methods must be available to set and negotiate these priorities (MTN 5). Since values from the SE perspective are a new concept and a "fuzzy" way to address stakeholder expectations, the framework should provide the means to traceably translate them into system requirements (MTN 6). To meet other mediation theory necessities, improve communication with stakeholders, mitigate unintended outcomes and enable the demonstration of responsibility, VOFs should enable transparency and traceability of responsibility (HN 1). Finally, an appropriate development context should be created to ensure necessary time, ethical guidance, and good working conditions (HN 2). These necessities, based on mediation theory together with RE deliverables (see Section 2.2 "*Requirements Engineering*"), are the two essential parts for the VOF EvalCon (Section 5). In the following section, I will propose ethical potential (Section 4.1) and innovative potential (Section 4.2) of system requirements as quality metrics that allow for the measurement of claims made by the VOF.

4. Novel Quality Metrics for System Requirements

As mentioned earlier, engineering should be about finding the best solution to a given problem, which today is usually expressed in terms of stakeholder needs or goals (ISO, 2015; Sommerville, 2016). To a large extent these initial needs or goals—expressing stakeholder expectations—and the resulting system requirements are the source of harms and ethical issues (see Section 2.1 *“Anchoring Ethical Issues”* and Section 2.4 *“Impact on Sustainability Dimensions”*).

Since a final RE step is to validate the characteristics of the system requirements before they serve as a starting point for system design, one might hope that they would be screened for potential ethical issues or inherent innovative relevance, but this is not the case (see Section 2.2.3 *“Validated System Requirements”*). It would be useful not only for SE in general but also for the evaluation of VOF claims to facilitate the development of both innovative and ethical IS (see Section 3.1 *“Value-oriented frameworks”*), if such quality measures existed. Therefore, quality measures for the ethical (Section 4.1) and innovative (Section 4.2) potential of system requirements are proposed now below. These quality measures are part of the VOF EvalCon (Section 5) and in Section 7 (*“Empirical investigation”*) the results of the application of these measures are presented.

4.1 Ethical Potential

It has been stated before that sustainability is the process of achieving or maintaining a condition that promotes present human well-being without harming future generations (Penzenstadler & Femmer, 2013; de Paula & Cavalcanti, 2000). Sustainability is therefore seen as something desirable, which ascribes the concept of the good or right to the activities under investigation—which is similar to the aims of most traditional moral investigations (Shearman, 1990). With its focus on human well-being, sustainability covers aspects related to the quality of human life and also provides a long-term perspective (de Paula & Cavalcanti, 2000). For instance, its well-known concern with environmental destruction, which “...represents a potential threat to future human viability and therefore involves a question of the moral responsibility of people with respect to other people” (Shearman, 1990, p. 5). The goal of promoting human well-being is consistent with Socrates’ definition of ethics as active reflection on what constitutes a life worth living compared to alternatives (Vallor, 2016). Moreover, sustainability focuses on the long-term effects of decisions on human well-being and additionally considers the effects on non-human beings, which is not necessarily the case with traditional moral investigations (cf. Shearman, 1990; Palm & Hansson, 2006; Penzenstadler & Femmer, 2013). Considerations of sustainability are therefore consistent with the goals of traditional moral investigations, with additional emphasis on a long-term framework and also on non-human beings.

Using sustainability as an evaluation criterion has the additional practical advantage that compared to other moral investigations, this is a common concept in industries, with between 30–40% of companies listed on the UK/US stock exchange providing sustainability reports (Bhatia & Tuli, 2018). Moreover, it is increasingly recognized that today's decisions should "... be defensible also in relation to coming generations" (Palm & Hansson, 2006, p. 553), for which a case for sustainability may be a suitable approach.

Verbeek (2011), while referring exclusively to environmental aspects of sustainability, considers a good example of the need for frameworks to take "...technological mediation seriously is the design of sustainable technology" (p. 92). VOFs that put mediation theory into practice and claim to facilitate the development of ethical IS should therefore enable system design for sustainability by specifying system requirements with a potential to do so. However, sustainability must not be viewed solely in terms of the environment but should also take into account the individual, social, economic and technical dimensions. Based on the five sustainability dimensions explicitly proposed for SE that were exemplified and defined in Section 2.4 (*"Impacts on Sustainability Dimensions"*), system requirements should ideally have positive partial impacts on all of these dimensions.

Therefore, I propose to evaluate the ethical potential of system requirements in terms of their impact on individual (Sub-Impact 1), social (Sub-Impact 2), economic (Sub-Impact 3), environmental (Sub-Impact 4), and technical sustainability (Sub-Impact 5). Based on the previous definitions of these sustainability dimensions (Sections 2.4.1 to 2.4.5), I will briefly explain and then formulate these sub-impacts.

Individual sustainability refers to the long-term preservation of human capital including people's health, skills and knowledge, which can be supported through education and health care (Goodland, 2002). Being educated, knowledgeable, productive and thereby realizing one's full potential is known to contribute to self-actualization and thereby increase human well-being

(Ivtzan et al., 2013; McGillivray, 2007). This dimension could benefit, for example, from system requirements that specify functions that enable users to acquire knowledge or that motivate further education. On the other hand, system requirements that specify seductive or addictive system elements (see: Section 2.4.1 *"Individual Sustainability"*) would have a negative impact on this dimension. VOFs should therefore help to specify:

- **Sub-Impact 1**: "System requirements with a positive impact on individual sustainability, including people's health, skills, and knowledge."

Social sustainability focuses on the long-term preservation of society and its solidarity, for which shared values, equal rights, laws and access to information are essential and can be promoted by strengthening active participation and communication within society (Penzenstadler & Femmer, 2013; Goodland, 2002). For example, gender equality or equity is known to lead to better academic performance, such as better math skills (Brown & Alexandersen, 2020), which thus also contribute to self-realization and the enhancement of human well-being (Ivtzan et al., 2013; McGillivray, 2007). According to Goodland (2002) for the cohesion of community or society "...reciprocity, tolerance, compassion, patience, forbearance, fellowship, love, commonly accepted standards of honesty, discipline and ethics" (p. 490) are essential. For social sustainability, system requirements that promote "user control" over ranking algorithms (which lead to social fragmentation) or enable communication and participation might be beneficial (see Section 2.4.2 *"Social Sustainability"*). VOFs should therefore help to specify:

- **Sub-Impact 2:** "System requirements with a positive impact on social sustainability, by focusing on a long-term preservation of society and its solidarity."

Economic sustainability refers to the long-term preservation of value creation and productivity by protecting goods, time, money and investments from risks and depletion (Penzenstadler & Femmer, 2013; Goodland, 2002). At the individual level, economic sustainability is critical to human well-being, as living in poverty is known to pose a risk to well-being (McGillivray, 2007). In this regard, functional system requirements that specify addictive game features can be harmful, while requirements that ensure an efficient system without wasting time or money can be beneficial (see Section 2.4.3 *"Economic Sustainability"*). VOFs should therefore help to specify:

- **Sub-Impact 3:** "System requirements with a positive impact on economic sustainability by protecting goods, time, money and investments from risks and depletion."

The environmental sustainability dimension focuses on the protection of natural resources and ecosystem services, for which it is important to consider resource consumption and the release of emissions and waste (Goodland, 2002; Penzenstadler & Femmer, 2013). For instance, specifying that non-functional system requirements related to "computational efficiency," which might reduce energy consumption, or "maintainability" aimed at system longevity, could be useful here (see Section 2.4.4 *"Environmental Sustainability"*). VOFs should therefore help to specify:

- **Sub-Impact 4:** "System requirements with a positive impact on environmental sustainability by protecting natural resources and ecosystem services."

Technical sustainability refers to the long-term usage of a system for which continuous development, updates and the long-term evolution of a system is essential (Penzenstadler & Femmer, 2013). Non-functional system requirements related to "maintainability" or "system modularity" can increase long-term use by promoting the changeability and updatability of complex systems (see Section 2.4.1 *"Individual Sustainability"*). VOFs should therefore help to specify:

- **Sub-Impact 5:** "System requirements with a positive impact on technical sustainability by providing updates and ensuring that a system continues to exist and evolve."

When considering the sustainability dimension and the assumed impact that VOFs are expected to have on it, it cannot be overlooked that many values such as knowledge, equality, tolerance, efficiency and others have been mentioned. It even seems that values can directly support the building of sustainable systems (Penzenstadler & Femmer, 2013). With this in mind, Winkler and Spiekermann (2019) compiled a list of 355 values and related them to the five sustainability dimensions, which can be seen in Appendix A (*"Values in Relation to Sustainability"*). Consideration of such values can be a helpful starting point for novices in achieving sustainable software development. In addition, Umbrello and Van de Poel (2021) suggest aligning with the Sustainable Development Goals (SDGs, General Assembly, 2015) proposed by the United Nations (General Assembly, 2015) as "… the best approximation of what we collectively believe to be valuable societal ends" (p. 288).

Given that values appear to be essential to sustainability, one might expect VOFs that focus on values to have a natural advantage over the state of practice in SE that focuses on goals or needs when it comes to sustainability. Besides showing the use of novel quality metrics, this was an additional motivation for conducting the empirical investigation (Section 7 *"Empirical Investigation"*).

In summary, a requirement that ideally has a positive impact on all sustainability dimensions can be considered to have ethical potential. VSD and IEEE Std. 7000, which claim to facilitate the development of ethical IS, should demonstrate that they enable the specification of requirements with ethical potential. Only with such potential can one expect that during "system design" appropriate technical solutions are chosen or conceptualized, which is summarized in Figure 13. This proposed quality metric is part of the overall VOF EvalCon (Section 5) and was tested as part of the empirical investigation (Section 7). Next, in order to also fulfill the claim of facilitating the development of innovative information services, the innovation potential of system requirements is proposed as an additional quality metric.

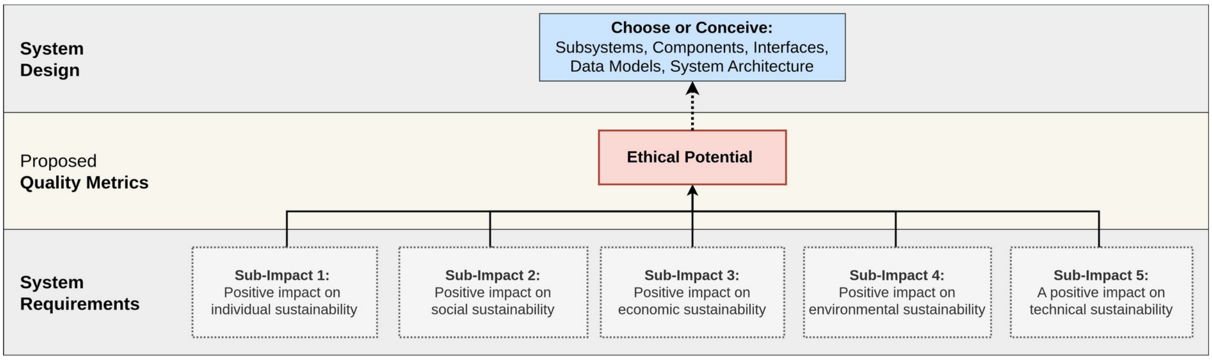


Figure 13: *System requirements with ethical potential affecting system design*

4.2 Innovative Potential

Since they can otherwise only compete on price, which in the long run leads to commoditization of their products, it is important for companies to innovate in order to grow in an existing market (Kauppinen et al., 2007). According to Hauschildt et al. (2016) an innovation is an original—that is, novel—idea that achieves commercial or productive application, either by discovering new purposes or new means of fulfilling these. To translate these into requirements, a requirement with innovative potential should not only be original, but also have the potential to lead to something applicable or of practical use. In the following, I will specify and clarify this idea of system requirements with innovation potential.

Form an engineering perspective, companies typically have three paths to innovation: 1) discovering hidden stakeholder needs, 2) developing new functions to satisfy existing needs, or 3) supporting the functions with an innovative technical solution (Kauppinen et al., 2007). Especially for the first path (the discovery of hidden stakeholder needs) but also for the second one (specify new functions), RE is of crucial importance, while the last path falls more into the realm of "*system design*." Since discovering and understanding stakeholder expectations, such as needs, is an important part of RE, there is great potential for innovation here in the form of novel system requirements (Kauppinen et al., 2007). Discovering hidden needs can lead to innovation and thus a competitive advantage, but it is anything but easy, as stakeholders are usually unable to express these expectations (Kauppinen et al., 2007).

This is where VOFs come in, working with values—instead of goals or needs—to discover and understand stakeholder expectations. Their claim to facilitate the development of innovative IS (see Section 3.1 "*Value-oriented frameworks*") relies in part on the use of values, which might enable the expression of aspects which cannot be formulated as goals or needs. In support of this claim, research has shown that the use of VOFs—methods of IEEE Std. 7000 in particular—generates more original ideas than traditional product roadmapping (Bednar & Spiekermann, 2020). Moreover, according to Nonaka and Takeuchi (2011), values drive innovation, which could also support the notion that values introduce more innovative potential compared to goals or needs. It can be assumed that stakeholders may find it easier to express their expectations with values than, for example, with needs, which often remain hidden (cf. Kauppinen et al., 2007). This assumption is explained in more detail in Section 6.3 ("*Stakeholder Expectations*"), where each type of expectation is discussed in more detail.

In addition to the type of stakeholder expectations, the level of stakeholder involvement and collaboration can also facilitate innovation. RE is generally understood as a process with creative potential, where stakeholders and designers collaborate and use techniques such as use cases, scenarios, and context modeling to make a creative contribution to SE (Maiden & Robertson, 2005; Kauppinen et al., 2007). Accordingly, in recent decades, 54.4% of all relevant innovations —across various industries—were due to the direct involvement of lead users as stakeholders (Bradonjic et al., 2019). For example, the inventor of the mountain bike, Gary Fisher, had a novel, previously hidden expectation of being able to ride his bike off-road. Following SE logic, this expectation led to the specification of the “off-road capability” requirement during RE, resulting in a technical solution with large wheels and a reinforced frame during the “system design” (Bradonjic et al., 2019). If Gary Fisher had not been involved or had not been able to express his expectations, the mountain bike as an innovative product might not exist. Without any—or especially the right—requirements, innovations are not possible, which shows that requirements can have an enormous innovation potential.

Many may believe that unrestricted engineering without requirements is the way to innovate, but this is might be a fallacy, since it usually leads to overengineering, unnecessary system complexity, or failure of the project altogether (cf. Kidder, 2011). In a (likely) historically unique case, the MV/8000 minicomputer was developed simultaneously by two competing teams, one with unlimited resources and nearly no constraints, and another with self-imposed constraints (Kidder, 2011). Only the team with the constraints managed to develop a working product that saved the company and produced innovative solutions that are still relevant today (Kidder, 2011).

A novel quality metric therefore is needed to validate the claim of VOFs to facilitate the development of innovative IS; that is, in terms of RE, to enable the specification of system requirements with innovative potential. Only by defining the innovation potential of system requirements as a novel quality metric is it possible to evaluate VOFs without having to develop a finished product. To achieve this, knowledge on what constitutes a creative contribution is necessary.

A major creative contribution is defined as something which a) *has a high level of originality* and b) *possesses the capacity to solve diverse problems* (Mumford & Gustafson, 1988). The first part of this definition highlights the importance of originality. Originality is defined by Thys et al. (2014) as “statistical rarity among more popular solutions” (p. 367). For a requirement, this means that it is original if it is rarer—less common or unexpected—compared to other requirements. For example, if a usability requirement appears a hundred times in the RE document, it is less original than a safety requirement that may have been mentioned only once. Following this logic, an originality score can be calculated for each requirement, which is demonstrated later in Section 7 (“*Empirical Investigation*”). Consistent with the first part of the creative contribution definition, a requirement with innovative potential should have the following:

- **Originality:** “Statistical rarity among more popular requirements”

Originality is generally recognized as the most important aspect of creativity and the starting-point for innovation, and therefore should also be considered for requirements (Batey, 2012; Amabile, 1997). Since originality as a quality aspect is related to quantity—more ideas might increase the likelihood of novel or original ideas—the number of requirements is also considered in the empirical study (Section 7).

The second part of Mumford and Gustafson’s (1988) definition of a creative contribution emphasizes that it should be useful by being capable of solving problems. This part of the definition needs careful consideration, as paintings by Pablo Picasso or Albrecht Dürer are widely recognized as important creative contributions but appear to have little problem-solving ability (Schuler & Görlich 2006). This is exactly the point where a creative contribution and an innovation are different from each other. While a creative contribution such as a painting does not need to have a practical use, an innovation should have a high practical use, for example, by solving a problem (Schuler & Görlich, 2006). Therefore, a painting or other artwork is definitely a creative contribution, while a mountain bike is an innovation that solves the “off-road” problems someone might have with an ordinary bike. Intuitively, hardly anyone would call a mountain bike a creative contribution or work of art.

A requirement has the potential for practical use only if it is feasible, which is a validation criterion that every requirement should meet (see Section 2.2.3 “*Validated System Requirements*”). A feasible requirement should be achievable within cost, time, technical, legal or regulatory constraints (ISO, 2011a; ISO, 2011b). Only if it is feasible, a technically mature solution without technical obstacles and bugs can be found, for which inconsistencies or difficulties have to be solved during development (ISO, 2017a). However, only when a technically mature solution based on a feasible requirement is possible can a product or system have a practical impact and thus be considered an innovation. As an example, would have Gary Fisher’s expectation to off-road resulted in the unachievable “flight capability” requirement, it is unlikely that a technically mature solution would have been found at that time; thus, the mountain bike would not have been an innovation. Therefore, consistent with the second part of the creative contribution definition, a requirement with innovative potential should be feasible and reach:

- **Technical Maturity:** “Reachable implementation quality and the absence of technical obstacles and bugs, as well as the elimination of inconsistencies and difficulties during development.”

In summary, based on previous considerations a requirement that is original (rarer than others) and can achieve technical maturity (implemented without technical obstacles and bugs) has an innovative potential. VOFs, specifically VSD and IEEE Std. 7000 in this case, which claim to facilitate the development of innovative IS, should demonstrate that they enable the specification of requirements with innovative potential. Only with such potential can one expect that during “system design” appropriate technical solutions are chosen or conceptualized. Figure 14 summarizes the novel quality metric for innovative potential, which is part of the VOF EvalCon (Section 5) and its use is demonstrated as part of the empirical investigation (Section 7).

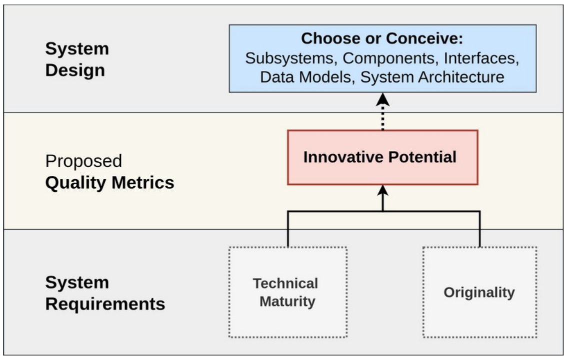


Figure 14: System requirements with innovative potential effecting system design

4.3 Summary

Based on sustainability considerations, the ethical potential of system requirements was described as having a positive—or at least not negative—impact on five dimensions of sustainability. Given the close connection between values and sustainability, one might assume that VOFs offer an advantage here. In addition, the innovative potential of system requirements was defined as requirements that are original (rarer than others) but feasible and with technical maturity. VSD and IEEE Std. 7000, which claim to facilitate the development of innovative and ethical IS, should enable the specification of system requirements with such potential. These potentials may allow the claims of these VOFs to be measured without the need to develop a working product, even before system design begins. The ethical and innovative potential of system requirements is part of the VOF EvalCon, condensed below, and their use is demonstrated in an empirical investigation (Section 7 *“Empirical Investigation”*).

5. Concept for Value-oriented Framework Evaluation

The claims of VSD and IEEE Std. 7000 to facilitate the development of ethical and innovative IS (see Section 3.1 *"Values-oriented Frameworks"*) is highly desirable to companies. Companies generally strive for innovation, as this can give them an advantage over their competitors (Lengnick-Hall, 1992). In addition, branding a product as ethical can also be a competitive advantage (Lengnick-Hall, 1992; Fan, 2005). An ethical branding is, however, only convincing in the long-run if it is in fact truly ethical, since this "… could benefit the company with a differential advantage over competition…" and "…could help overcome the increasing consumers' scepticism and cynicism towards branding communications" (Fan, 2005, p. 14).

At this point, it is already clear that focusing on values and conducting ethical investigations will require an additional investment of time, money, expertise, and change in the development context (Rotondo & Freier, 2010; Van de Poel & van Gorp, 2006; Berenbach & Broy, 2009). For many, such an investment is justifiable only if VOFs can demonstrate that they are fulfilling their stated purpose. However, the lofty ambition to facilitate the development of innovative and ethical IS could also provide a motivating vision for the commitment of the time and energy required (Donia & Shaw, 2021). Such ambitions should, however, also be supported by adequate theoretical and methodological underpinnings. If VSD and IEEE Std. 7000 can demonstrate their claims, this could increase awareness and acceptance of these frameworks outside of academia, which is currently not necessarily the case (Detweiler & Harbers, 2014). As discussed in Section 2.4 (*"Impacts on Dimensions of Sustainability"*), a paradigm shift is urgently needed given the detrimental impacts of current IS on the individual, and on society, the economy, the environment and technology itself.

Framework evaluation is a difficult undertaking because it is hardly possible to develop the same product in parallel with different VOFs, which would allow for the comparison of two functional systems using technology assessment frameworks (cf. Wright, 2011; Grunwald, 2015). At the moment, VSD and IEEE Std. 7000 have only been able to demonstrate through case studies that their theoretical foundations and methodology might lead to beneficial results (cf. Winker & Spiekermann, 2018; Spiekermann-Hoff et al., 2019; Bednar & Spiekermann, 2020). Case studies are a form of observational evaluation method, intended to demonstrate the applicability to a certain setting or problem (Hevner et al., 2004). Both VOFs have conducted a considerable number of case studies. The VSD community has published many case studies since 1996, focusing not exclusively on IS (Friedman & Nissenbaum, 1996; Friedman & Hendry, 2019). Most famously, VSD has also demonstrate its applicability to developing IS, with case studies like "Cookies and Informed Consent in Web Browsers," "UrbanSim," "Security for Mobile Devices," "Human Robot Interaction" and many others (Friedman et al., 2013; Winkler & Spiekermann, 2018). IEEE Std. 7000—being a framework anchored in SE—has many IS related case studies, such as "Bicycle Courier App," "Intelligent Teddy Bear," "Telemedicine System," UNICEF's "Yoma Project" and "Ghostplay" (Bednar & Spiekermann, 2020; Spiekermann-Hoff et al., 2019; Wedenig, 2021; Hofstetter, 2022).

Case studies as a means of evaluation are not without limitations, as they only demonstrate applicability and rarely utilize the entirety of a framework (Hevner et al., 2004; Winkler & Spiekermann, 2018). At the qualitative level, VSD case studies tend not to use all three—conceptual, empirical and technical—investigations and rarely embrace their integrative and iterative commitment or utilize the whole set of methodologies (Winkler & Spiekermann, 2018). This is not uncommon for case studies, and even IEEE Std. 7000 case studies do not use the full theoretical and methodological range of available options (cf. Bednar & Spiekermann, 2020; Hofstetter, 2022).

Furthermore, case studies typically only show that frameworks can deliver what they promise, for which there might be several reasons. The most optimistic option is that VOFs can actually deliver on the promise of facilitating the development of innovative and ethical IS. A second possibility for a desirable outcome would be that most case studies are conducted by experienced and ethically trained researchers in an academic setting. In this case, it is almost impossible to distinguish between the contribution of the framework or of the ethically qualified researchers to the desired outcome. It is also generally questionable whether case studies conducted in an academic setting can be carried out in an industry setting. Given the academic setting, one might also suspect that there is a publication bias in which only studies with desirable results are published (Dwan et al., 2008). If this is the case, it is recommendable that VSD and IEEE Std. 7000 scientists also publish "failed" case studies, as they provide valuable insights for applied sciences such as SE. Since case studies have their limitations, I propose a theoretical approach to systematize VOFs and evaluate their claims to facilitate the development of innovative and ethical IS.

5.1 Need for Theories

Without theories, SE would be a trial-and-error process because we would have no idea what kind of knowledge is needed, how that knowledge relates to each other, or how to obtain it (Sjøberg et al., 2008; Johnson et al., 2012). SE is viewed by many as an applied science for which theories must be useful by providing answers to important disciplinary questions (Sjøberg et al., 2008; Johnson et al., 2012). Mediation theory seems to provide the theoretical foundations to answer to how better technologies can be developed by considering their moralizing and value-laden nature (see: Section 3.2 *“Mediation Theory”*). VSD and IEEE Std. 7000, which are frameworks in the spirit of this theory, are essentially an operationalization of this and other related theories by providing the necessary orchestrated methodology that can be used in reality. These VOFs must demonstrate an awareness of the key aspect of this theory and provide the means—theoretical foundations and methodology—to put this into practice.

Theories suggest and structure necessary knowledge, what is important and how to obtain such insights (Sjøberg et al., 2008; Johnson et al., 2012). For example, a theory such as mediation theory suggests that technology is value-laden (Verbeek, 2011); therefore, according to this theory, the discovery of important values becomes necessary knowledge for building technology. A good theoretical understanding of what values are in a subsequent step enables insights to be gained in line with value theory. A methodology for discovering values is an operationalization, put into practice, of a theory for which it is intended to be valid (Trochim & Donnelly, 2001). A method should be content-valid in that it reflects the substance of the underlying theory, which is commonly referred to as “content validity” (Trochim & Donnelly, 2001). For example, a method that measures a person’s intelligence by his or her height would not be content valid because it does not reflect a generally accepted theory of what constitutes intelligence.

Compared to other scientific disciplines, SE is rarely concerned with theories (Johnson et al., 2012). Some even go so far as to claim that “[s]oftware engineering is a practical engineering discipline without scientific ambitions where rules of thumb and guidelines assume the role of theory” (Johnson et al., 2012, p. 94). Considering how important theories are for acquiring and structuring knowledge (Sjøberg et al., 2008; Johnson et al., 2012), such an assumption seems like a massive pitfall. Not only is this a pitfall, but it is also a fallacy, since SE uses theories from psychology, cognitive science and marketing in practice that enable the specification of requirements that lead to dark patterns or seductive and addictive designs (Anderson, 2011;

Neyman, 2017; Mathur et al., 2021). Without a theory on how to trigger a dopamine release such systems would not be achievable and could not have such a devastating effect on, for instance, individual sustainability (see Section 2.4.1 *“Individual Sustainability”*). Without understanding theories, which “… supports the cumulative building of knowledge, rather than the re-invention of design artifacts and methods under new labels in the waves of ‘fads and fancies’ that tend to characterize IS/IT” (Gregor & Jones, 2007, p. 314), we are doomed to constantly reinvent the wheel. There seems to be a general tendency in the SE sector to reinvent the wheel; similar methods or practices are constantly being reinvented and introduced under new labels or brands. This tendency also partly explains why engineers tend not to take new standards, textbooks, and competing SE practices as seriously as they should (see Section 2 *“State of Practice in Software Engineering”*). This could also explain why there are more than 18 different VOFs (Donia & Shaw, 2021) with varying degrees of sophistication and high claims. Without systematizing these VOFs to allow for mutual improvement or meaningful extensions, the wheel will be constantly reinvented. Not only would this be unproductive, but it would also increase engineers’ ignorance of these promising frameworks. Therefore, based on previous insights, I propose a VOF EvalCon that allows for the systematization of the individual theoretical and methodological contributions of these VOFs. This evaluation concept is formulated with a focus on generalizability and is therefore also capable of evaluating and systematizing the other 18 different VOFs (cf. Donia & Shaw, 2021). Thus, while I only demonstrate its application to VSD and IEEE Std. 7000 in Section 6 (“*Theoretical Foundations and Methodology*”), it should be applicable to other VOFs with relatively little effort, requiring just background knowledge of a particular VOF of interest. For practitioners, this could help to rethink, clarify, and improve existing theoretical considerations or methods, for example, by combining the strengths of different frameworks (Hirschheim & Klein, 1994).

5.2 Interrelations and Overlaps

Formulating a VOF EvalCon allows for a form of evaluation that provides a descriptive informed argument by using “… information from the knowledge base (e.g., relevant research) to build a convincing argument for the artifact’s utility” (Hevner et al., 2004, p. 86). In other words: Information from the key literature on VSD and IEEE Std. 7000 is used to demonstrate the utility, which in this case is the ability to achieve the stated purpose of facilitating the development of innovative and ethical IS (see Section 3.1 *“Value-oriented Frameworks”*). A

VOF and its methods must prove that it is useful in relation to its purpose, that it can transform input (insights and knowledge) into an output (for instance, a design solution or in the case of RE, system requirements) (Hevner et al., 2004). Especially in the case of VSD, with an academic history of more than 25 years, it is not possible to cover in depth all the theoretical foundations and all the methodologies that can help to achieve a particular aspect.

At a very high level, VSD and IEEE Std. 7000 should demonstrate awareness for the necessities put forth by mediation theory (see Section 3.2 *"Mediation Theory"*) and ideally have the theoretical foundations and methodology to achieve these. However, the necessities for putting mediation theory into practice are interrelated, as illustrated in Figure 15 and explained below.

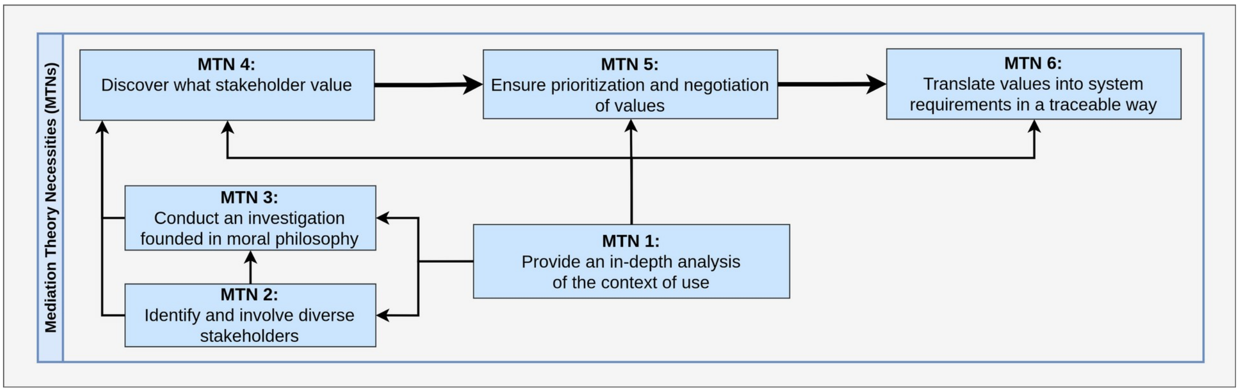


Figure 15: *Interrelation between mediation theory necessities (MTNs)*

Since these are interrelated, VSD and IEEE Std. 7000 cannot meet one necessity without having the requisite theory and methods for the other. From a practitioner's standpoint, identifying diverse stakeholders (MTN 2) is only possible when the use context of the system (MTN 1) is known in advance. Without knowing the context of use, it would be easy to include too many stakeholders, the wrong stakeholders, or ignore important ones. Successful discovery of values (MTN 4) depends on stakeholder availability (MTN 2), should be done with consideration of the context of use (MTN 1), and should be supported by an investigation founded in moral philosophy (MTN 3). Appropriate moral investigation can only work if the context of use is known (MTN 3) and the potentially affected stakeholders (MTN 2) have been identified and can thus be involved. To prioritize and negotiate values (MTN 5), these must be known in advance (MTN 4), and such activities should take into consideration the context of use

(MTN 1). Since also software properties—described as system requirements—are context-dependent, the use context must be known (MTN 1). And since specification of system requirements can be time-consuming only prioritized values should be subjected to a translation activity (MTN 5). Hygiene requirements related to transparency and traceability of responsibility (HN 1) and an appropriate development context (HN 2) were considered essential for all other five mediation theory necessities (see Section 3.2.2 *“Hygiene Necessities”*).

Next, I extend this basic concept to its final form by including insight on necessary RE deliverable from Section 2.2 (*“Requirements Engineering”*) and the proposed quality metrics for the ethical and innovative potential from Section 4 (*“Novel Quality Metrics for System Requirements”*). An overview of the entire VOF EvalCon with its assumed relations can be seen in Figure 16.

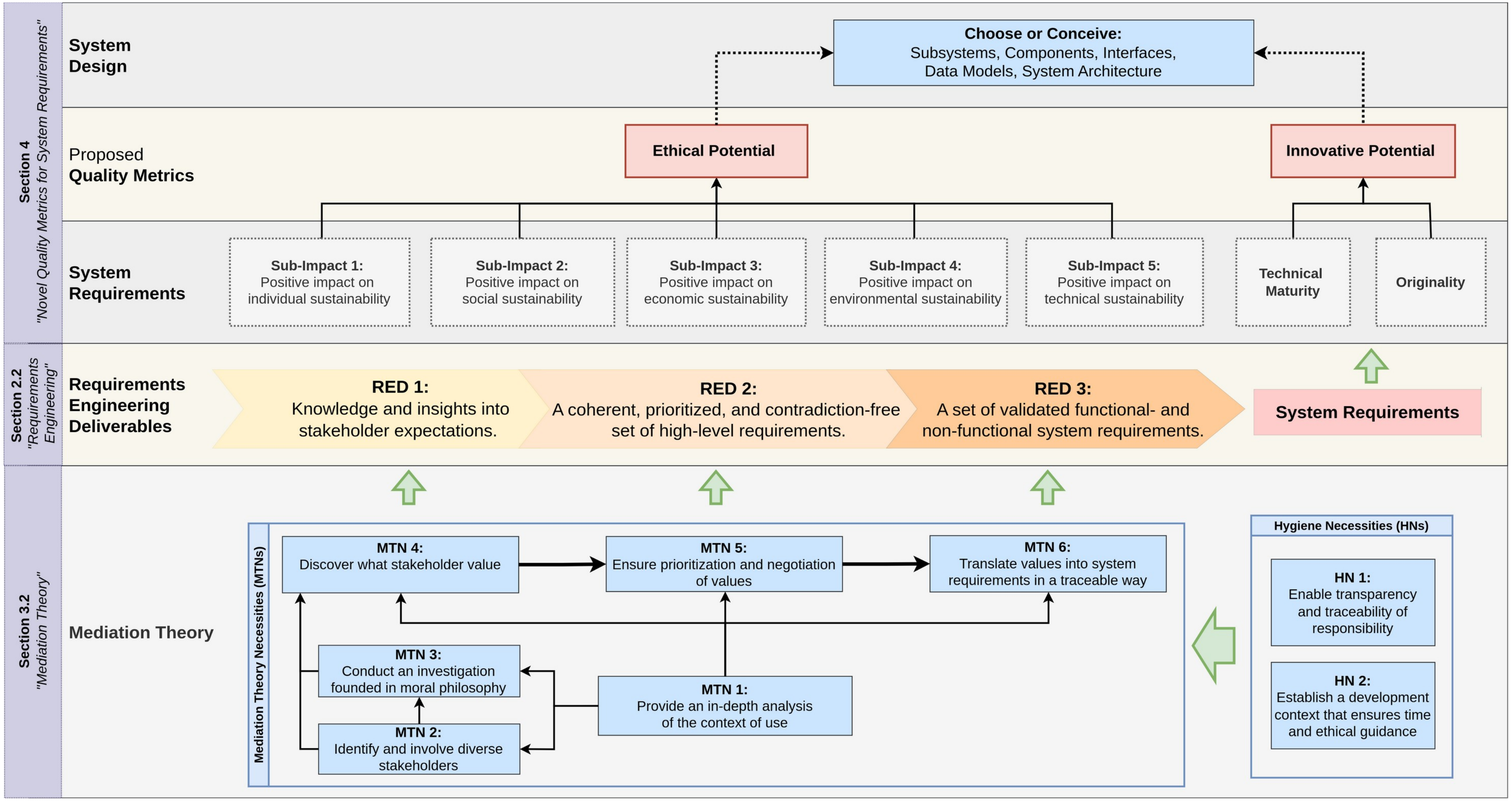


Figure 16: *Concept for VOF evaluation (VOF EvalCon) based on Section 3.2, 2.2 and 4*

There are three overlaps between mediation theory necessities and the RE deliverables. In particular, the fourth necessity to discover what stakeholder value (MTN 4) is essential to achieving the first RE outcome and thus to gaining knowledge and insight into stakeholder expectations (RED 1). VOFs, in comparison to the state of practice in SE, gain knowledge and insight into stakeholder expectations with values instead of goals or needs. Theoretically, if these values are discovered with the help of an investigation founded in moral philosophy (MTN 3), knowledge on ethical issues is therefore available, which can inform later RE steps and subsequently system design. The fifth necessity from mediation theory to provide prioritized and negotiated values (MTN 5) overlaps with the second RE deliverable to gain a coherent, prioritized and contradiction-free set of stakeholder requirements (RED 2). As a reminder, a stakeholder requirement is a more formalized description of stakeholder expectations (see Section 2.2.2 *"Coherent Set of Stakeholder Requirements"*), in this case values. The sixth mediation theory necessity in translating values into system requirements in a traceable way (MTN 6) overlaps with the third RE deliverable to obtain a set of validated functional and non-functional system requirements (RED 3). Since system requirements describe properties that a system should have—from the perspective of mediation theory, these are affordances or scripts for values—such requirements must be available. These system requirements should cover functional and non-functional aspects and should be validated before entering system design (see Section 2.2.3 *"Validated System Requirements"*). The current state of the practice does not provide any quality metrics for assessing the ethical or innovative potential of these system requirements. Such quality measures would not only be a good extension of the state of the practice, but might also allow the claims made by VSD and IEEE Std. 7000 to be measured to facilitate the development of innovative and ethical IS. It was to this end that I proposed such quality metrics in Section 4 (*"Novel Quality Metrics for System Requirements"*) and defined that a system requirement with ethical potential should ideally have a positive sup-impact on all five sustainability dimensions and have innovative potential, being original and achievable with technical maturity. These quality metrics could be used to measure the output of RED 3—system requirements. The VOF EvalCon, as shown in Figure 16, allows for the systematization of all necessary steps to which VSD and IEEE Std. 7000 should contribute.

5.3 Summary

SE requires theories to know what kind of knowledge is needed and how that knowledge relates to each other. Mediation theory is one such theory that VOFs want to put into practice, but this is not possible without considering the deliverables required for RE. Due to a lack of theories and systematization there seems to be the general tendency in the SE sector to reinvent the wheel. The proposed concept allows for the systematization of VOFs, which would allow mutual improvement or meaningful extensions. Such systematization can also help to implement VOFs in industrial practice. Based on the VSD and IEEE Std. 7000 literature, in Section 6 (*"Theoretical Foundations and Methodology"*), I will compare step by step the theoretical foundations and methodology used to address the necessities of mediation theory. Afterwards, in Section 7 (*"Empirical Investigation"*), the use of the proposed quality metrics will be demonstrated.

6. Theoretical Foundations and Methodology

In this section, I will assess the extent to which VSD and IEEE Std. 7000 extend the state of the practice and meet the necessities of mediation theory. In addition, I will highlight the potential impact of the theoretical foundations and methodology provided on the necessary RE deliverables and the presumed impact on the sustainability dimensions (see Section 2.4 *"Impact on Sustainability Dimensions"*).

The following sections are structured according to the theory necessities of mediation theory formulated in Section 3.2.1 ("*Theory Necessities*"). Section 6.1 ("*Context of Use*") addresses how VSD and IEEE Std. 7000 intend to perform an in-depth analysis of the context of use (MTN 1), while Section 6.2 ("Stakeholder Identification") addresses the necessity to identify and involve diverse stakeholders (MTN 2). Section 6.3 ("*Stakeholder Expectations*") addresses the need to discover values (MTN 3) and conduct a moral philosophy-based investigation (MTN 4) required to assess the ethical values of stakeholder expectations. Section 6.4 ("*Prioritization and Negotiation*") addresses how VSD and IEEE Std. 7000 intend to meet the necessity of ensuring negotiation and prioritization of values (MTN 5), while Section 6.5 ("*Translation of Values into System Requirements*") addresses their traceable specification into system requirements (MTN 6). Finally, Sections 6.6 ("*Transparency and Traceability*") and 6.7 ("*Development Context*") address the theoretical underpinnings and methodology of VSD and IEEE Std. 7000 for achieving the hygienic necessities formulated in Section 3.2.2 ("*Hygienic Necessities*") that are required to create an adequate development situation.

6.1 Context of Use

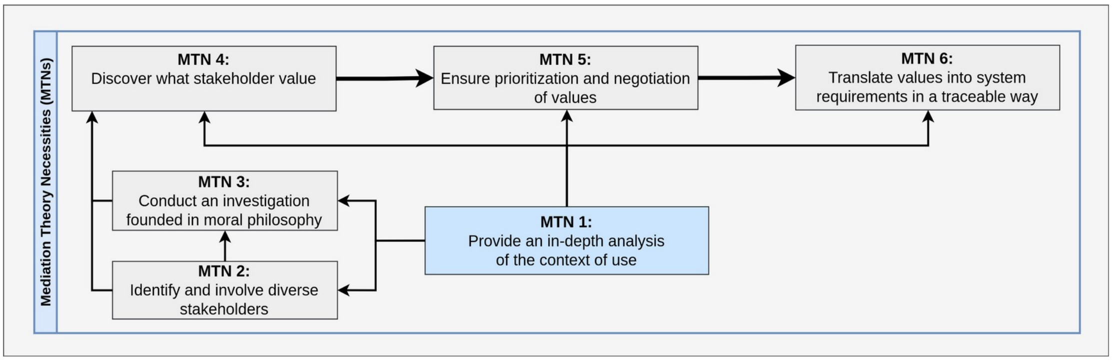
Understanding the planned system and its context of use is considered the most important task for any SE project (Pereira & Baranauskas, 2015; Briand et al., 2017). Without knowledge of a system's context of use, elicitation and analysis—the first step in software specification—is not possible. Stakeholders cannot express expectations—either as goals, needs, or values—if they do not understand the intended purpose of the system, the general situation, and especially the contexts of use. If you ask directly for stakeholder expectations and especially values, you may only get a spontaneous, non-specific, or generic response (Spiekermann, 2015). SE can only yield results if it is conducted "… in clearly defined contexts, enabling us to identify realistic working assumptions and identify important, well-defined problems, as well as create opportunities for realistic evaluations" (Briand et al., 2017, p. 74f). From an SE perspective, understanding the context of use enables us to understand the problem a system is designed to solve and assess (during software validation) whether a solution was actually found (Sommerville, 2016; Briand et al., 2017).

In line with the state of the practice SE, mediation theory also requires that an in-depth analysis of the context of use is provided (MTN 1). According to mediation theory, IS have different mediating effects depending on their context of use (multistability) and the contextual complexity; therefore, the dynamics of the human-technology relationship must be taken into account (Verbeek, 2011; Ihde, 2010). Since VSD and IEEE Std. 7000—putting mediation theory into practice—aim to identify and incorporate context-dependent values, a good understanding of the context of use is also critical for discovering stakeholder values (MTN 4). Obtaining values is also essential to gain the necessary knowledge and insight into stakeholder expectations (RED 1). In addition, the priority or importance of values depends on the context of use (Burmeister, 2016), so knowing the context is also critical to prioritizing values (MTN 5). This, in turn, is an essential prerequisite for delivering a coherent, prioritized, and contradiction-free set of stakeholder requirements (RED 2). Values enter a system as an affordance (software properties specified as a system requirement) whose triggering condition is determined by the context, influencing whether it is perceived and can have an effect (Klenk, 2021). Moreover, software properties are themselves highly context-specific (Briand et al., 2017), which makes it clear that understanding the context is also essential for translating values into validated functional and non-functional system requirements (MTN 6, RED 3). For the identification of stakeholders, it is necessary to distinguish between relevant and non-relevant stakeholders (MTN 2), so that understanding the context of use is also vital. Without such an understanding, it would be easy to conclude that everyone is a relevant stakeholder. Last but not least, many moral investigations only lead to reliable results (MTN 3) if they are conducted for a specific context. Taken together, the importance of a good understanding of the context of use for five other mediation theory necessities and three RE deliverables makes this a highly important task. Without adequate knowledge of context of use, VSD and IEEE Std. 7000 cannot hope to facilitate the development of innovative and ethical IS. From an engineering perspective, the task of understanding the context of use, and thus the specific problems a system is intended to solve, is a single point of failure for frameworks.

In SE, the starting point of the context of use exploration is the creation of a ConOps document that includes the business goals, the initial system description, a list of stakeholders, and especially a context of use description (Sommerville, 2016; ISO, 2011b). The purpose of a

ConOps document is to "… communicate the quantitative and qualitative system characteristics to all stakeholders and serve as a basis for stakeholder discussions about the system" (Mostashari et al., 2012, p. 1). Improved by insights from financial and technical feasibility studies, this document helps management to make a decision about whether to proceed with a project and thus start with RE (Sommerville, 2016). Despite the importance for decision-making, communicating system characteristics and context of use understanding, many engineers feel that creating a ConOps document is more of a burden than an important step (Mostashari et al., 2012). This belief, and the associated inadequate contextual knowledge, may also be a partial explanation for why so many projects fail. The development of a ConOps can take between three and thirty months, depending on the complexity of the planned system, which may be an SOS—a collection of multiple systems (Mostashari et al., 2012; Sommerville, 2016). Because engineers are currently bound to a fast-paced and market-driven development context, their reluctance to schedule time for ConOps development is understandable. However, in doing so, the market-driven development context as the assumed origin of harmful IS (see Section 2.3) may hinder the important task of developing an in-depth understanding of the context of use. Figure 17 visualizes the situationality of MTN 1 in the VOF EvalCon (Figure 17, A) and summarizes key commitments (Figure 17, B), which will now be discussed in more detail.

A) Situationality



B) Commitment

VSD	IEEE P7000
Theoretical: Multi-lifespan perspective, Iterations	**Theoretical:** Long-time frame, Pervasive perspective, ConOps, SOS-Controllability, Iterations
Methodological: Mock-up, Prototype, Field Deployment, Ethnography, Multi-lifespan Methods	**Methodological:** Feasibility Studies, Market Research, RACI Matrix

Figure 17: *MTN 1 within the VOF EvalCon (A), and VOF commitments (B)*

VSD recognizes the importance of context of use analysis. It does not explicitly create a ConOps document, but can make essential contributions. In particular, the empirical investigation uses quantitative and qualitative methods to examine, among other things, the system and its context of use (Friedman & Hendry, 2019; Davis & Nathan, 2015). Recognizing that larger issues, such as climate change, might only be solvable with a long time frame in mind, VSD incorporates a multi-lifespan perspective (Friedman & Nathan, 2010; Friedman & Hendry, 2019). This perspective emphasizes analysis of future use contexts and is consistent with the growing recognition that today's decisions must be justified with future generations in mind (Palm & Hansson, 2006). On a practical side, having a long time frame in mind—spanning multiple generations—might make it difficult to predict, understand and analyze the use context. VSD assumes that the task of developing an understanding of the context of use can only be achieved through continuous iterations (Friedman & Hendry, 2019). An iterative approach certainly increases the knowledge gain, as it is difficult to predict technological development over a long period of time, it might even be inevitable.

VSD states that "… after a period of discovery and analysis, the design team might similarly decide not to build a new technology or not to intervene" (Friedman & Hendry, 2019, p. 30). This is an impactful decision that must also be made according to the state of the practice; however, without good justification, it is difficult to simply stop a project in which time and money have already been invested.

The VSD framework proposes four main methods that can be employed to understand the use context, including "Value-oriented mock-up, prototype or field deployment," "Ethnographically informed inquiry on values and technology," "Mutli-lifespan timeline," and "Multi-lifespan co-design" (Friedman & Hendry, 2019). Despite the practical problems of predicting future use contexts, VSD's multiple lifespans perspective and its methods could make an important contribution to the development of ethical IS. Looking at the ethical potential of system requirements (Section 4.1), one could assume positive impacts, by considering a long time-frame, on environmental, financial, and technical sustainability. For example, assuming that a long time frame also implies a long system service, this could lead to system requirements in terms of "*maintainability*," which is beneficial for several dimensions. This long-term perspective could also lead to a system design that focuses on security or privacy by design, rather than short-sighted after-the-fact considerations common in SE today (cf. Schmidt, 2016). In general, considering a long time frame is in stark contrast with the short-term focus of the current development context and agile development (Andreessen, 2011; Schmidt, 2016).

The IEEE Std. 7000 framework also recognizes the importance of understanding the intended system and its context of use, and provides a separate “Context Exploration Process” for this task (IEEE, 2021). This process is highly aligned with the state of the practice and particularly concentrates on the formulation of a ConOps (cf. IEEE, 2021; Sommerville, 2016). Tasks during this dedicated process include describing the context of use, identifying and evaluating the SOS, and conducting several feasibility studies (IEEE, 2021). This VOF expands the state of the practice to include additional social, legal, and environmental feasibility studies, providing a more comprehensive and holistic ConOps and context of use understanding (IEEE, 2021). The results of these feasibility studies can serve as the basis for management’s decision to abandon a project that is socially, legally, and environmentally unfeasible (IEEE, 2021). Compared to VSD, the decision not to build a system can thus be justified through additional feasibility studies. Knowledge of potential social, legal and environmental risks can have a positive impact on the social, economic and environmental sustainability of the resulting requirements or prevent the further development of a potentially harmful system in the first place.

To examine the use context, IEEE Std. 7000 recommends considering “a long time-horizon (i.e., 10 to 20 years),” assuming a “significant market share” and taking into account “those regions of the world in which the SOI is or will be marketed” (IEEE, 2021, p. 36). Compared to VSD, IEEE Std. 7000 focuses on a shorter time frame—20 years versus multiple generations—making predicting the context of use more realistic, but potentially at the expense of less positive impacts on dimensions of sustainability. Consideration of a significant market share and multiple world regions forces the assumption that the system being developed is pervasive, which could help make potential negative effects more apparent. If we consider, for example, the consequences of the higher energy consumption of various word processors, they only become significant when we consider that these programs are used for many hours in millions of offices worldwide (see Section 3.1.4 *“Environmental Sustainability”*).

The IEEE Std. 7000 framework has a unique and special focus on SOS in that it identifies and evaluates the controllability (using the RACI matrix) of all subsystems of the product being developed (IEEE, 2021). It is explicitly stated: “Aggregate the SOS elements potentially relevant for the concept” (p. 36) and “Obtain access to the enabling systems or services to be used” (p .37) (IEEE, 2021). Thereby the framework seeks to mitigate risks or issues from subsystems impacting the system under development as early as possible (IEEE, 2021). This is in line with the SE communities’ view that the complexity of modern SOS can lead to unpredictable harms (Sommerville, 2016). For example, a system design that includes a VISA payment system as a subsystem could violate users’ privacy now or in the future if system engineers do not have the necessary control over them (see Section 2.3 *“Origins of Harmful Information Systems”*).

While this could be a reasonable solution to managing complexity and establishing control of SOS, this approach might potentially be dangerous. Choosing a necessary subsystem—such as the VISA payment system—is an activity that should occur during *system design* in accordance with previously specified system requirements—not during project initialization (Sommerville, 2016). While IEEE Std. 7000 does not mandate or select a subsystem at this point, analysis and documentation of the controllability of a potential subsystem could accidentally lead to early inclusion of that subsystem. Practitioners of IEEE Std. 7000 should therefore be careful not to fall into problem-solution inversion or violate the implementation freeness of requirements, as this can lead to the specification of harmful IS (see Section 2.3 *“Origins of Harmful Information Systems”*). However, in later SE iterations, when a *system design* based on system requirements points to a particular subsystem, it seems highly advisable to assess controllability to avoid undesirable harms. This is envisioned in IEEE Std. 7000 during the “Ethical Risk-Based Design Process” (IEEE, 2021). Similarly, but more specific than VSD, IEEE Std. 7000 envisions constant iterations “… to [be] modified to accommodate changing contexts, different value priorities, or changes in technical needs…” (IEEE, 2021, p. 49). This could seriously help address malicious use cases if they arise and can mitigate malicious use as a suspected source of harmful IS (see Section 2.3 *“Origins of Harmful Information Systems”*).

In addition to feasibility studies, IEEE Std. 7000 refers to market research to gain knowledge on existing use cases or contexts (IEEE, 2021). This VOF is considered “...most applicable to organizations that are building a system for a known context or at least know typical use cases for the products, services, and systems they build” (IEEE, 2021, p. 14). Although not explicitly mentioned in IEEE Std. 7000, ethnographic methods can provide additional insight and are generally considered very useful for discovering and understanding unknown or untypical use cases, in particular (Mariampolski, 1999).

Both VOFs—IEEE Std. 7000 and VSD—recognize, consistent with mediation theory, that context of use can be dynamic and unpredictable. Therefore, both frameworks rightly recommend constant iterations and improvement of context of use understanding (Friedman & Hendry, 2019; IEEE, 2021). Iterative development seems to be a good way to deal with unexpected or unanticipated effects that may become apparent only when a system is in use.

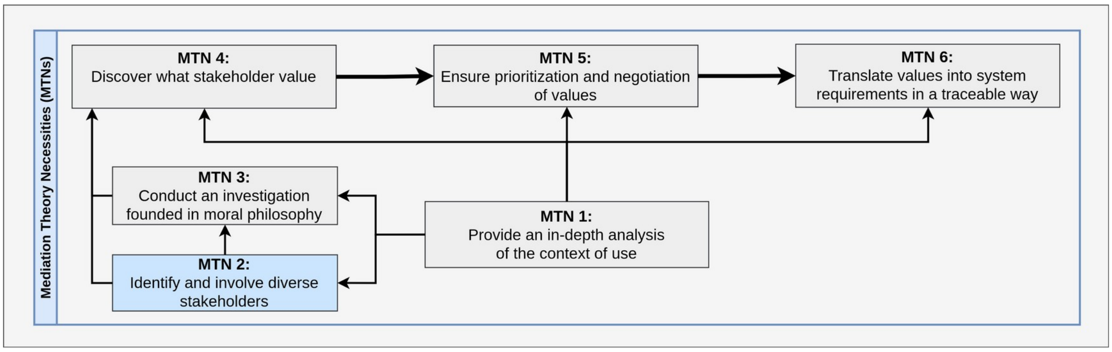
Since VSD is a high-level design framework not strictly tied to engineering, it does not focus on providing a ConOps. In contrast, IEEE Std. 7000, which is more SE-based, places a particular emphasis on extending current ConOps practices and focuses on controlling system complexity. While the unique theoretical perspective of IEEE Std. 7000 (significant market share and multiple markets) may provide an advantage in facilitating the development of ethical IS, the longer time horizon of VSD (multi-lifespan perspective) is also well-suited to this stated aim. In general, both VOFs have the theoretical and methodology commitment (see Figure 17, B) necessary to provide an in-depth analysis of the context of use (MTN 1). Following the VOF EvalCon (Section 5), the next section discusses MTN 2 and the need to identify and subsequently involve stakeholders.

6.2 Stakeholder Identification

Identifying stakeholders is a necessary prerequisite for involving them and discovering their system expectations—either as needs, goals, or values. Without identifying and then involving stakeholders, neither VSD nor IEEE Std. 7000 practitioners are able to discover relevant stakeholder expectations in the form of values (MTN 4). Therefore, proper stakeholder identification is essential for gaining necessary knowledge and insight into stakeholder expectations (RED 1). Achieving proper stakeholder identification is only possible if the context of use of a system is known in advance (MTN 1). Without the context of use acting as a constraint, it would be easy to include too many or the wrong stakeholders, or to ignore important ones. Since mediation theory recommends stakeholder analysis as a way of moral consideration that allows for the perspective of all stakeholders to be taken (Verbeek, 2011), identifying stakeholders is also a necessary prerequisite for conducting a moral investigation (MTN 3). Excluding stakeholders and thus failing to consider their values is an especially huge risk for VOFs that claim to facilitate the development of ethical IS. Furthermore, many successful innovations in recent decades have largely been the result of the identification and subsequent involvement of stakeholders (Bradonjic et al., 2019). This makes it clear that identifying the right stakeholders is essential for facilitating the development of innovative and ethical IS.

Whereas in the early days of SE, the focus was solely on users as a stakeholder group, today the general goal is to include as many stakeholders as possible (ISO, 2011b). It is the goal to gain a "...representative cross-section of stakeholders…" which is deemed "...necessary to provide the true picture of the 'problem to be solved,'" and by that avoid biased insights from a single perspective (ISO, 2011b, p. 20). This goal is consistent with the general engineering belief that understanding and grasping the right problem to solve is essential to a successful system (Norman, 2013; Sharma & Pandey, 2013; De Lucia & Qusef, 2010; Breitman et al., 1999). According to ISO 15288 (2015), stakeholders are all people who have “a legitimate right, share, claim, influence or interest in a system” (p. 10). At first glance, it appears that by-the-book SE practices are aware that stakeholder identification is important and that their exclusion could lead to bias. However, in the industry practice, stakeholder identification is largely underdeveloped and taken too lightly (Pacheco & Garcia, 2012). The following section discusses the theoretical foundations and methodology of VSD and IEEE Std. 7000 for stakeholder identification (MTN 2), which are shown in Figure 18 (A) within the VOF EvalCon.

A) Situationality



B) Commitment

VSD	IEEE P7000
Theoretical: Stakeholder Roles, Multi-lifespan Perspective, Non-humans, Stakeholder Mapping	**Theoretical:** Classes
Methodological: Stakeholder Analysis, Stakeholder Tokens, Brainstorming, Literature Review, Interviews	**Methodological:** Feasibility Studies

Figure 18: *MTN 2 within the VOF EvalCon (A), and VOF commitments (B)*

Robust stakeholder identification and analysis is an essential feature of VSD and is considered vital for any project using this framework (Friedman & Hendry, 2019). In VSD, a stakeholder is understood as a role, with a dynamic, contextual identity and relationship to a system, rather than an entity (Friedman & Hendry, 2019). One and the same person may therefore hold several stakeholder roles, which may vary depending on the time frame or situation; that is, depending on the context (Friedman & Hendry, 2019). Seeing a stakeholder as a role could provide the opportunity to identify stakeholders comprehensively and contextually and to understand values. By considering stakeholders in terms of "roles," it is possible to obtain a grasp on the dynamic stakeholder-system relation, as well as "...provid[ing] a means for legitimating stakeholders" (Friedman & Hendry, 2019, p. 40). For example, a person who uses a piece of software in one context by watching YouTube videos may act as a creator or differentiator in other contexts by uploading or rating videos. Because it is the same person but with different roles, these can bring different perspectives to the system.

From the SE perspective, VSD brings several new stakeholder role concepts. First is the distinction between direct and indirect stakeholder roles (Friedman & Hendry, 2019). A direct stakeholder is anyone who interacts directly with a system, while indirect stakeholders "never or rarely interact with the system as end users, [but] are nevertheless affected by the system" (Friedman & Hendry, 2019, p. 38). Considering stakeholders who are "only" affected by a system but have no intention of using it can have the potential to discover system consequences not normally considered in SE. For example, if one is not—perhaps intentionally—a user of social media, the impact on social fragmentation or one's child's body image is still an issue that should be considered. The indirect stakeholder role might enable such consideration, which in this particular case might have a positive impact on individual and social sustainability (see Section 3.1.1 and Section 3.1.2).

VSD additionally suggests distinguishing between targeted roles (expected) and non-targeted (atypical) roles and proposes to consider groups, communities, organizations, society, and previous generations as unique roles (Nathan et al., 2008; Friedman & Hendry, 2019). It can be assumed that, for example, consideration of organizations such as schools or hospitals could facilitate the specification of system requirements, with a positive impact on individual sustainability. Since it is known that particularly addictive applications hinder educational success and affect health—both relevant to individual sustainability—such schools or hospitals would provide unique stakeholder expectations (see Section 3.1.1 *"Individual Sustainability"*).

Furthermore, VSD also suggests a pro-social role for each stakeholder, referring to "when and why people act to help others, often seemingly voluntarily and without obvious benefit to themselves" (Friedman & Hendry, 2019, p. 41). Understanding the reasons for pro-social behavior—represented as a stakeholder role—might facilitate the development of systems with social sustainability. It is also recommended to identify and consider stigmatized stakeholders, such as representatives of vulnerable groups or minorities (Friedman & Hendry, 2019). Since these stakeholders are particularly vulnerable to system effects, identifying and considering these might help to prevent the development of harmful IS.

Recognizing the implications beyond humans, VSD also aims to include non-human entities such as non-human species, super-organisms, Earth, history or sacred sites and social robots (Friedman & Hendry, 2019). In addition, in the spirit of the multi-lifespan commitment, future stakeholders or generations should also be included (Friedman & Nathan, 2010; Friedman & Hendry, 2019). In particular, the consideration of non-human entities, as well as future generations, is in line with the ethical foundations of sustainability, which could have a positive impact on system specification (see Section 4.1 *"Ethical Potential"*).

From a methodological perspective, VSD scholars propose "stakeholder analysis" or "stakeholder tokens" as methods for identifying and mapping the interaction between stakeholders and in relation to the system (Friedman & Hendry, 2019; Yoo, 2021). The "stakeholder tokens" method, in particular, makes it possible both to understand the contextual identity, tasks, circumstances, and dynamic relationships involved, and to distinguish between central and peripheral stakeholders, as well as supporting the identification of vulnerable or stigmatized stakeholders (Yoo, 2021). Other methods have been used by VSD scholars in the past to identify stakeholders, including brainstorming, literature review, interviews, or mapping of interaction roles with the proposed technology (cf. Winkler & Spiekermann, 2018).

Building on the VSD heritage, IEEE Std. 7000 also aims to consider and identify direct and indirect stakeholders, as these are considered critical to the goal of "… applying values to engineering design" (IEEE, 2021, p. 17). All necessary direct and indirect stakeholder classes are identified early on during the IEEE Std. 7000 unique "Context Exploration Process" (IEEE, 2021). Recognizing the importance and seeking to identify indirect stakeholders works well towards facilitating the development of ethical IS.

Additionally, IEEE Std. 7000 provides extensive lists of potential stakeholder classes, including "...the general public at large, both current and future users, and vulnerable populations, such as those unable to read, children, the aged, and people of different abilities" as well as "...competitors; cybersecurity hackers; or opponents of the development organization, system owner, or customer" (IEEE, 2021, p. 27f). Also mentioned are "[g]overnment regulators and external advocacy groups…Third-party assessors, data brokers, and independent verification and validation (IV&V) contractors" (IEEE, 2021, p. 28). Additionally, this VOF seeks to identify "organizational representatives driving the innovation effort," "stakeholder advocates for indirect stakeholders," "professionals who understand the social context of the SOI," "professionals who understand the technical capabilities of the SOI," "… end-users from the market or world regions in which the system is or will be deployed," "institutions that are affected…", and "civil society and legal advocates..." (IEEE Std. 7000, p. 37).

More than half of the stakeholders listed above are experts who can contribute important knowledge—for instance, in technical, ethical or legal terms—to the development process. Furthermore, consulting stakeholders such as competitors, cybersecurity hackers or opponents in general could provide insights into malicious use cases and thus help mitigate this suspected origin of harmful IS (see Section 2.3 *"Origins of Harmful Information Systems"*). In addition, IEEE Std. 7000 aims to identify stakeholders that drive innovation and future users, which demonstrates an awareness of the importance of stakeholders to innovation (cf. Bradonjic et al., 2019). In addition, consideration of vulnerable stakeholders could help prevent harm and promote the development of ethical IS.

Despite this extensive list of potential stakeholder classes, IEEE Std. P7000 does not suggest a methodology for identifying these. It might be unclear to practitioners whether stakeholders are identified as the result of brainstorming, feasibility studies or any other viable method. While not explicitly mentioned, one could assume that a limited list of relevant stakeholders is the result of the foreseen legal, social and environmental feasibility studies (cf. IEEE, 2021). Therefore, I would like to recommend to IEEE Std. 7000 scholars to make it clear how these stakeholders are identified and how the dynamics between the different stakeholders and also their relationship to the system should be mapped. In practice, not mapping such relationships could be problematic since the discovered expectations of a corporate adversary or hacker—which may be misleading or hostile—must be interpreted in light of their system relationship. Considering that the majority of listed stakeholder are experts, I would like to recommend to IEEE Std. 7000 practitioners not to overestimate the experts' findings and to truly appreciate the viewpoint of direct, indirect, at-risk, current, and future stakeholders. Various biases are known in psychology, such as the "Dunning-Kruger Effect," the "Authority Bias" or even the "Bandwagon Effect," which all caution against overconfidence in expertise or expert opinion (Dunning, 2011; Baybutt, 2018).

A theoretical challenge of both VOFs is that these provide no limit to the number of potential stakeholders. This can turn the identification of stakeholders into an ambiguous and frustrating task. Although this challenge is recognized by VSD, to date this framework does not provide an indicator of when this critical task has been sufficiently accomplished (Friedman & Hendry, 2019). Although both frameworks provide the option that stakeholders may be represented, I would encourage practitioners to do so only when necessary (cf. Friedman & Hendry, 2019; IEEE, 2021). Pure representation may limit the quality of the knowledge and insights gained, but may be necessary for practical reasons. While in many cases—the Earth, interest groups or non-humans—representation is unavoidable, it is considered best practice in SE to directly "[i]dentify and consult with the stakeholders of the system" (Pacheco & Garcia, 2012, p. 2178). Framework practitioners should directly engage indirect, at-risk, and innovation stakeholders in particular to meet the claim of developing innovative and ethical IS. The IEEE Std. 7000 framework recognizes that merely representing stakeholders—with the persona method—and not involving stakeholders risks subsequent RE steps being based on implicit assumptions, which can lead to bias (IEEE, 2021).

Compared to the state of practice in SE, both frameworks—IEEE Std. 7000 and VSD—provide a valid extension to stakeholder identification that might contribute to the development of innovative or ethical IS. Both frameworks provide the theoretical foundation for comprehensive stakeholder identification. While VSD's concept of stakeholders as roles might be a useful extension to IEEE Std. 7000, both frameworks provide extensive lists of who or what might be relevant stakeholders. On a methodological level, IEEE Std. 7000 does not, however, suggest a specific methodology for identifying or mapping relevant stakeholders. In general, both VOFs have the theoretical commitment (see: Figure 18, B) necessary to identify diverse stakeholders (MTN 2) but IEEE Std. 7000's methods should be extended.

Following the VOF EvalCon (Section 5), the next section takes a wider perspective on stakeholder expectation types, including needs, goals, VSD's human values and IEEE Std. 7000's material values. It is discussed how values are discovered (MTN 4) without ethical framing but also with the help of moral investigations (MTN 3).

6.3 Stakeholder Expectations

Any form of stakeholder expectations, especially values, must be determined with existing knowledge of the context of use (MTN 1). Without knowledge of context, the insights gained may be only spontaneous thoughts, biased, mainstream, or may not be understandable (Spiekermann, 2015; Pommeranz et al., 2012). This step usually involves stakeholders, who must first be identified for this purpose (MTN 2). Only together with stakeholders is it possible to gain knowledge and insight into stakeholder expectations (RED 1). Achieving this first RE deliverable is of tremendous importance to subsequent deliverables and thus to the success of software development. The knowledge and insights gained should serve the stated purpose of a framework used to facilitate RE (see Section 2.2 *"Requirements Engineering"*).

Frameworks that are common in RE, such as GDD, GORE, NFR, or DT, aim to provide insights to achieve high usability, meet stakeholder goals, address non-functional aspects, or deliver innovative solutions (cf. Cooper et al., 2014; Van Lamsweerde, 2001; Chung et al., 2000; Brown, 2008). These frameworks typically use goals or needs as a stakeholder expectation type, which are introduced and described in Section 6.3.1 ("*State of Practice: Goals or Needs*"). On the other hand, VSD and IEEE Std. 7000 aim to provide insights that help facilitate the development of innovative and ethical IS (cf. Friedman & Hendry, 2019; IEEE, 2021). Consistent with the value-laden nature of systems, these VOFs focus on discovering and understanding values in order to meet framework claims (Verbeek, 2011; Friedman & Hendry, 2019; IEEE, 2021). These stakeholder expectations, which are novel from an SE perspective, are introduced in Section 6.3.2 (*"Novel to SE: Value Flavors"*) and their different theoretical foundations are discussed and described in Section 6.3.2.1 (*"Human Values"*) for the human value concept of VSD and in Section 6.3.2.2 (*"Material Values"*) for the material value concept of IEEE Std. 7000. The summary descriptions for each type of stakeholder expectation are intentionally kept simple to be understandable to participants in the empirical study (Section 7 *"Empirical Investigation"*). After these considerations, Section 6.3.3 (*"Expectation Discovery"*) is concerned with how these can be discovered from stakeholders (MTN 4) without an ethical framing (Section 6.3.3.1) or through moral investigations (Section 6.3.3.2).

6.3.1 State of Practice: Goals or Needs

The discovery of stakeholder expectations is performed in the first *discovery and understanding* step as part of the first requirements *elicitation and analysis* activity (see: Section 2.21 *"Insights into Stakeholder Expectations"*). During the *discovery and understanding* step, framework-specific methods are used to gather knowledge on stakeholder expectations, typically either as goals or needs (Sommerville, 2016). When these are analyzed and understood—often referred to as conceptualization—they are then considered to be more formal stakeholder requirements.

Using a goal as an expectation type is the de facto standard in many RE frameworks such as Goal-directed Design (GDD) or Goal-oriented Requirements Engineering (GORE, Kavakli, 2002; Cooper et al., 2014; Van Lamsweerde, 2001). Goals are a condition, objective or state a stakeholder would like to achieve, which can be directly linked to functional aspects of a system that enables goal achievement (Regev & Wegmann, 2005). Furthermore, it could be shown that goals-oriented approaches are also well suited to capturing non-functional aspects (coined as soft-goals) of a system (Chung et al., 2000; Chung & do Prado Leite, 2009). Goals are highly related to specific actions—they guide behavior—but do not explain the reasons for specific behavior, for which values are considered useful (Arieli et al., 2020). The state of practice SE does not question the rational behind goals stated by stakeholders, which could be one of the reasons why ethical issues are introduced (see Section 2.1 *"Anchoring ethical issues"*). As discussed in Section 2.3 (*"Origins of the Harmful Information System"*), the system in SE is often viewed as a neutral tool that produces a result in accordance with inputs and should merely solve a problem. People generally strive to achieve their goals, which gives direction to their behavior and a desired end-state (Austin & Vancouver, 1996). Therefore, SE often works with goals as stakeholder expectations, goals can be described as follows:

- **Description:** "A goal is the idea of a concrete desired result. People often base their actions on goals. Goals define the purpose and direction of human behavior"

From the classical SE perspective, this provides all the necessary knowledge and insight, such as the desired outcomes and the purpose or direction with respect to the end state, the reasons for which are not considered a matter of concern. As discussed in Section 2.4 (*"Implications for Sustainability Dimensions"*), this can and should no longer be the way technology is developed.

Using needs as another type of stakeholder expectation is employed by well-known frameworks such as Design Thinking (Brown, 2008). Furthermore, ISO 12207 also put an emphasis on stakeholder needs by asking for activities such as: "...describe the needs, wants, desires, expectations and perceived constraints of identified stakeholders" (2017, p. 60). The general focus is on needs to be discovered through active stakeholder engagement, which allows us to "… pay attention to the genuine needs of these stakeholders instead of their momentary wants and desires" (Pereira & Baranauskas, 2015, p. 79). In psychology, needs are defined as "psychological nutriment that are essential for ongoing psychological growth, integrity and well-being" (Deci & Ryan, 2000, p. 229). Based on this definition, outlining a relationship between needs and human well-being, one could assume that the satisfaction of needs could also have positive effects on some aspects of the sustainability dimensions, which also focuses on human well-being (see Section 4.1 *"Ethical Potential"*). In addition, needs are also seen suitable for describing constraints and thus for gaining non-functional system aspects (ISO, 2017a).

Therefore in addition to goals SE, often works with need as stakeholder expectations, which can be described as follows:

- **Description:** "Needs describe psychological conditions that are essential for personal development, performance and well-being. In short, needs describe the conditions under which people can best develop their potential. When needs are not met, people focus on meeting them."

Some scholars argue that there is a hierarchical relationship between needs and human values, according to which needs are subservient to values (Jolibert & Baumgartner, 1997). Such a relationship is also implicitly recognized by frameworks such as "Effective Technical and Human Implementation of Computer-based Systems," which focus on need satisfaction argued to emphasize the emergence of value (Hickey et al., 2006). Fuchs (2020) points out that humans have the ability to put aside some needs in order to achieve higher values. This may suggest that stakeholder values are more important and stable than needs in certain circumstances. From an SE perspective this can be beneficial, as the variability of requirements is generally a major challenge (Fowler & Highsmith, 2001; Schmidt, 2016). VOFs aim to mitigate the lack of value consideration from the outset (Spiekermann, 2015; Van den Hoven, 2017). Mediation theory, and thus VSD and IEEE Std. 7000, however, place a great deal of emphasis on the consideration of values and relate their claim of enabling innovative and ethical IS in large part to this type of stakeholder expectation. However, from a practitioner's point of view, the goal of "finding an environmentally friendly route" can easily be expressed as the stakeholders" need for "environmental protection" or the value "environmental consciousness." This raises the question of whether it makes any difference which type of stakeholder expectation—needs, goals or values—is discovered and subsequently investigated. It is this view of practitioners, as well as scholars who see a close connection between goals, needs, and values (see Jolibert & Baumgartner, 1997; Hickey et al., 2006; Fuchs, 2020), that points to the question of whether it makes a difference which type of stakeholder expectation is used in SE. This question is the subject of Section 7 (*"Empirical Investigation"*), for which, however, it is first necessary to understand the differences between goals and needs, as well as human values and material values.

6.3.2 Novel to SE: Value Flavors

In economics, the term "value" is usually associated with money, but that is not what VOFs mean when they consider values as a stakeholder expectation. There is a clear trend in the business world to look at values either as a driver for innovation or to evaluate acclaimed innovations (Nonaka & Takeuchi, 2011; Jobin et al., 2019). The presumed relationship between values and innovation suggests that the use of values can facilitate the development of innovative IS. Scholars assume that values enable normative thinking by providing a starting point for considering what ought to be done in a given context (Gogoll et al., 2021). This indicates that discovering stakeholder values could facilitate the development of ethical IS. From the SE perspective, there is a lot of overlap between non-functional requirements collections and value lists (cf. Mairiza et al., 2010; ISO, 2017a; Winkler & Spiekermann, 2019). For instance, "accountability," "security," and "privacy" are simultaneously non-functional requirements and values. Therefore one might assume that using values can help to specify more non-functional system requirements, which also prevent some ethical issues, as has been pointed out in Section 2.2.3 (*"Validated System Requirements"*). Before such presumed benefits of using "values" to facilitate the development of innovative and ethical IS can come to fruition, VOFs must provide a theoretical understanding of these indeed different types of stakeholder expectations.

Understanding the theoretical foundations of values is vital since even physical concepts—such as temperature—are not sufficient by themselves unless embedded in a network of theories and measurement methods (Kroes & van de Poel, 2015). In psychology, such embedding is required for any theoretical concept and is coined as a "Nomological Network"—*nomological* derived from Greek *nomos*, meaning lawful (Trochim & Donnelly 2001). In a sense, laws need to be established that link the theoretical concepts to each other, that link the theoretical concepts to the measurable properties that should also be linked to each other (Trochim & Donnelly 2001). Only if this is achieved, can one claim construct validity—or in other words make inferences from the observed to the theoretical idea, which applies equally to values as to temperature (Trochim & Donnelly 2001; Kroes & van de Poel, 2015). Temperature is embedded in theories related to fluid volume, air pressure, and related measurements, which should also be achieved for the theoretical conception of values (Kroes & van de Poel, 2015).

In psychology, values are seen as conceptions of desirable behaviors or desirable end states or trans-situational goals (Verplanken & Holland, 2002; Schwartz, 1994). Psychology therefore assumes a close relationship between goals—desirable end states—and values. Others view values as closely related to needs, viewing them as cognitive representations of needs (Schwartz & Bilsky, 1987). Bilsky and Schwartz (1994) characterized values as relatively stable individual preferences that reflect socialization with even some dispositional aspects. Schwatz (1994) even goes so far as to suggest that there are some universal aspects to values. This characterization of values as more stable preferences compared to needs could be beneficial for SE, as it could allow for gaining more stable stakeholder requirements.

As discussed in Section 3.2 (*"Mediation Theory"*), an important emphasis of mediation theory is that technology embodies values that need to be discovered (MTN 4), should be explored through moral investigation (MTN 3), and must be considered in SE. Putting these and other emphases into practice, as required by VOFs such as VSD and IEEE Std. 7000, could represent a paradigm shift in SE toward ethical IS. Since both VOFs have a different theoretical foundation of what values are, the next section—Section 6.3.2.1 (*"Human Values"*)—introduces the VSD concept of human values, and Section 6.3.2.2 (*"Material Values"*) introduces the IEEE Std. 7000 concept of material values.

6.3.2.1 Human Values

Dealing with human values is not easy, as they are often formulated ambiguously, can be interpreted in different ways and thus could produce false norms and actions (Manders-Huits, 2011). Values should be discussed in-depth to explore different interpretations and nuances, which helps to convey and understand the true meaning and grasp the value concepts associated with them (Steen & van de Poel, 2012; Pommeranz et al., 2012). Differences in the meaning of a value arise inter- and intra-culturally depending on the general and specific context of use of a system (Burmeister, 2016). For example, if we consider the value of "security," it has a different meaning for a security expert than for a manager in a system, even though both might be part of the same culture. While a security expert considers data integrity essential, a manager has an understanding biased toward confidentiality with an eye toward potential leaks. The same applies to the specific context of use; for example, a publicly accessible system entails a different security conception and understanding compared to a system used in a private context. This ambiguity in meaning and contextuality must be taken into account in the value discovery process discussed in Section 6.3.3 (*"Value Discovery"*), since misunderstandings can lead to incorrect norms and ultimately to incorrect system design. From an SE perspective this is not new, however, since it is common knowledge that taking into account the context and cultural environment of stakeholders is crucial in any engineering effort (Le Dantec et al., 2009; Reijers & Gordijn, 2019; Pereira & Baranauskas, 2015). In other words, stakeholders give meaning to human values and its larger value concept depending on their personal perspective and within a context. A depiction of this can be seen in Figure 19.

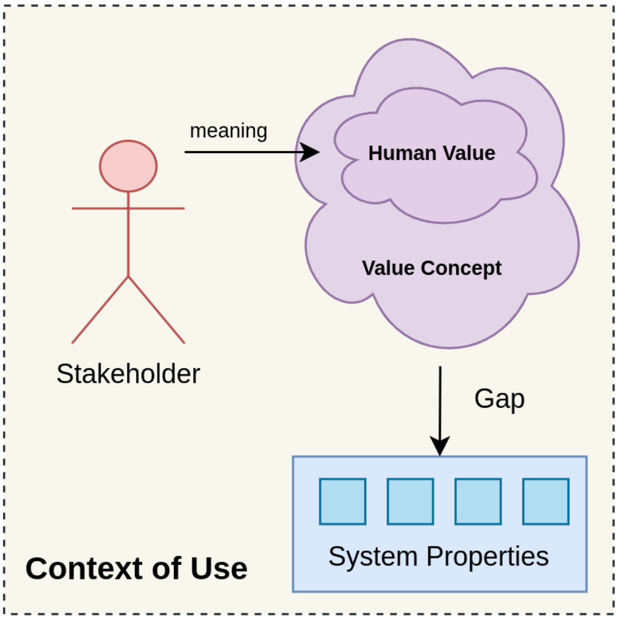


Figure 19: *VSD's human value concept with theoretical gap*

According to Friedman and Hendry (2019), VSD builds on a working definition of values as "what is important to people in their lives, with a focus on ethics and morality" (p. 24), which are explicitly coined as "human values" (p. 22). Therefore, a description of human values in accordance with VSD could be the following:

- **Description:** "Values reflect what is important to a person in life and often have an emphasis on ethics and morals. Human activities or actions often reflect their values."

Aside from the working definition's verbal commitment to focus on morality and ethics, scholars have criticized the lack of ethical justification within the VSD framework (Jacobs & Huldtgren, 2021; Manders-Huits, 2011; Reijers & Gordijn, 2019). Whether VSD offers further ethical justification will be discussed in Section 6.3.3 (*"Value Discovery"*); whether such verbal commitment to morality and ethics is enough to have a measurable impact is topic of Section 7 (*"Empirical Investigation"*).

The VSD conception of human values is clearly connected to people and assumes that values are culturally shared, weighted differently by individuals, and mediated through interaction (Pereira & Baranauskas, 2015; Verplanken & Holland, 2002; David & Nathan, 2015). Since human values are learned by culture also, "[p]arents, peer groups, professional milieus, and culture in general may all serve as sources of values" (Verplanke & Holland, 2002, p. 444). According to Friedman et al. (2013) human values "… depend substantively on the interests and desires of human beings within a cultural milieu" (p. 57). Human values should not be confused with facts, which would be naturalistic fallacy: simply because a value is considered important by an individual does not mean it should be important (Friedman et al. 2013). Therefore, during conceptual investigation (see Section 3.1.2 *"Value Sensitive Design"*), VSD practitioners must not only discover values, but also what the stakeholder's conceptions of those values include (Friedman & Hendry, 2019).

Human values are mutually dependent—for example, security is essential to privacy—and are considered of varying importance by stakeholders, with the value tension shifting accordingly (Friedman & Hendry, 2019). According to VSD, "...in the complexity of human relations and society, values sit in a delicate balance with each other" (Friedman & Hendry, 2019, p. 25). For example, without confidentiality—an essential aspect of security—a system cannot provide privacy by sending data in this case in an encrypted manner. Edward Snowden's revelations about the U.S. government's surveillance activities have prompted society and companies to place a higher importance on security, thereby strengthening privacy, prompting Apple and Google to enable encryption on their phones by default (Sanger & Chen, 2014). This means that not only is the meaning of values highly dependent on the context and culture of an individual stakeholder, but also that importance can vary, leading to tensions as discussed in Section 6.4 (*"Prioritization and Negotiation"*).

From a theoretical point of view, there is a gap in the human value concept of VSD that lies between the human value concept and the intended system and its properties themselves (see Figure 19). In other words, the nomological network of the human value concept lacks a link (cf. Trochim & Donnelly 2001), as there is no "law" or theoretical consideration that connects a value concept to the properties of a system to be incorporated during SE. While this may not be a problem for established values in SE such as security, for which it is clear to most that encryption is a necessary system property, it could be a devastating problem for other values. Ethically relevant values such as autonomy, freedom, or human well-being, for which no established system properties are known, may be more difficult to achieve. This missing link risks the inability to properly translate human values into system requirements (a description of system properties) and therefore might make this framework incapable of facilitating the development of ethical IS. The traceable translation of values into system requirements is a mediation theory necessity (MTN 6) that is discussed in Section 6.5 (*"Translation of Values into System Requirements"*). The material value concept of IEEE Std. 7000 sets out to fill this theoretical gap, which I will discuss below.

6.3.2.2 Material Values

IEEE Std. 7000 uses a concept of values based on a material value ethics, according to which values do not depend on human sensemaking, but are independent phenomena that people perceive and appreciate (IEEE, 2021; Kelly, 2011). According to Scheler (1973) "… the ego is neither the point of departure for the apprehension nor the producer of essences" (p. 77). In other words, stakeholders do not ascribe meaning—the essence—to material values, which is in stark contrast to other forms of stakeholder expectations such as human values, goals or needs.

Material values are regarded as ideal ought-principles which are supra-temporal (transcend time) and whose essence or meaning is given a priori (Kelly, 2011). Thus, unlike human values, the meaning of material values is not given by the parties involved, but is timeless and therefore more than just a preference. As Kluckhohn (1962) puts it: "A value is not just a preference but is a preference which is felt and/or considered to be justified—'morally' or by reasoning or by aesthetic judgments, usually by two or three of these" (p. 396). Material values are therefore a phenomenon that is perceived as morally justified, which already points to the ethical relevance of this concept of value.

Material values are ideal principles that have a form of being that is ontologically objective (Kelly, 2011). According to Scheler (1973), values provide orientation to humans' striving for sense and meaning creation. Compared to human values, material values seem to be objective—a fact—having universal validity, to some extent. Material values are defined as an explicit or implicit representation of something "...desirable which influences the selection from available modes, means and ends of action" (Kluckhohn, 1962, p. 395). Therefore, values influence people and their choices of means and goals. This may illustrate why it is important to consider material values instead of goals in SE, as they are the reasons for stated goals. Understanding such rationales for goals can lead to uncovering ethical issues early on in SE (see Section 2.1 *"Anchoring Ethical Issues"*). In this way, the conception of material values provides a theoretical foundation for the claim of facilitating the development of ethical IS.

In contrast to human values, material values can also be carried by objects, relationships, situations and activities, which are all potential value bearers (Scheler, 1973). As Kelly (2001) puts it, material values are … "experientially present 'on' the physical objects, acts, and persons we encounter..." (p. 19). The material value concept is thereby clearly in line with mediation theory (see Section 3.2 *"Mediation Theory"*), according to which objects *embody* values and thereby influence human behavior or activities, the context or situation, and social practices or relationships (cf. Verbeek, 2011; Scheler, 1973). Like mediation theory, material value ethics does not limit the discovery of values to stakeholders, but also focuses on technology, context, behavior, and social practices.

According to IEEE (2021), a core value is "...a value that is identified as central in the context of a system of interest…" (p. 17). For example, for a system this could be the core value of "security." A value quality (also called "value demonstrator"), furthermore, is a "...potential manifestation of a core value, which is either instrumental to the core value or undermines it" (IEEE, 2021, p. 23). The core value of "security" is supported, for example, by value qualities such "confidentiality" and "data integrity." A value quality has a respective value disposition built into a system as a system property and is an "… enabler or inhibitor for one or more values" (IEEE, 2021, p. 23). A value disposition is a "… characteristic that is an enabler or inhibitor for one or more values" (IEEE, 2021, p. 23). In SE, terms such as value disposition could, for instance, be an "encryption algorithm" or a "cryptographic hash function."

Physical objects, such as technology, acts and persons, do not have material values; however, they can "carry" them—as a potential—if they have the right "value disposition" (Scheler, 1973, p. 79). To truly "carry" or embody "security," a system must have an appropriate property embedded—for instance, an encryption algorithm—which is a value disposition with a respective value potential. This disposition has the potential to enable a value quality such as "confidentiality," which is instrumental to "security". The material values concept allows us to close the theoretical gap between values and system properties, as can be seen in Figure 20. In this way, the theoretical foundations of material value ethics provide the missing link for establishing a complete nomological network (cf. Trochim & Donnelly 2001). This could be impactful for the upward traceability of system requirements (describing system properties) to its source, in this case material values. In practice, understanding this concept and its associated terminology may be the only way to truly consider values in SE. In familiarizing themselves with this concept, practitioners should pay attention to terminology, for what material value ethics calls "value qualities," IEEE Std. 7000 calls "demonstrated values," just as material value ethics refers to "core value" as "ideal values" (cf. Scheler, 1973; IEEE, 2021). This should not be a source of confusion.

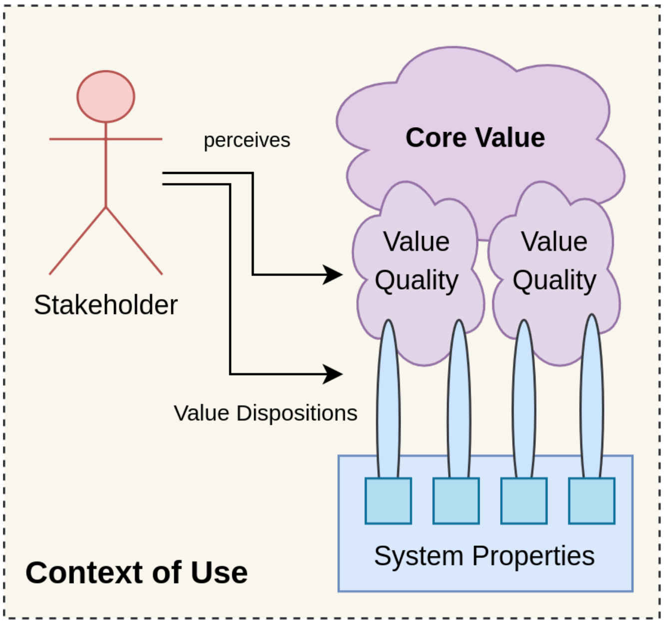


Figure 20: *IEEE Std. 7000's material value concept*

Another important difference from the human value concept of VSD is that material values can be positive or negative (Kelly, 2011). Based on the previous considerations about material values, a general description for use during an experiment (Section 7 *"Empirical Investigation"*) could be:

- **Description:** "Values are clear objects of thought that influence the actions of people. Positive values are perceived as something fundamentally desirable and influence the choice of available paths, means and goals. People, things, relationships and activities are carriers of values in a given situation. Values can be positive or negative, whereby positive values are intuitively perceived as attractive and negative values as repulsive."

Scheler (1973) formulated axioms that describe the relationships between positive and negative values and thereby provide a link between values and ethics. As based on Scheler (1973) and cited in IEEE Std. 7000, "a) The existence of a positive value is itself a positive value," while b) "The non-existence of a positive value is itself a negative value" (IEEE, 2021, p. 56). For practitioners, this means that it is good to build a system that carries positive values such as "privacy," "security," "transparency," and "accountability," while it is bad (or even evil) to omit one of these values. Likewise, the other way around, "c) The existence of a negative value is itself a negative value," while "d) The non-existence of a negative value is itself a positive value" (IEEE, 2021, p. 56). Thus, if a system bears a negative value such as "dishonesty" or "prejudice," this is bad, while the absence of such values is considered good.

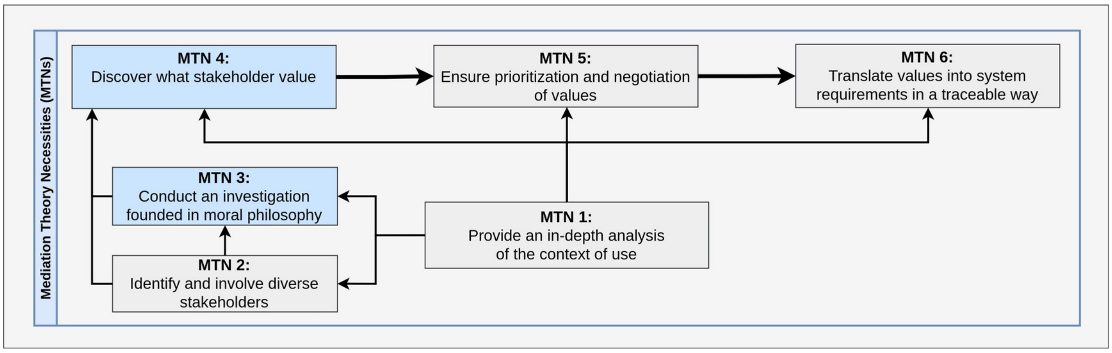
These axioms have several implications: First, they enable ethical judgment—what is good or bad—and second, they make it clear that each value is important, which in turn affects prioritization, as discussed in Section 6.4 (*"Prioritization and Negotiation"*). Omitting a positive value because of a prioritization method would be ethically bad or even evil from the perspective of material value ethics. With this axiom—the linking of positive and negative values—the material concept of value itself has a theoretical foundation in ethics. On this basis, practitioners can decide what to do, which is not the case with the concept of human values, or in other words, assess stakeholders' expectations, which is not possible in the current state of practice in SE (see Section 2.1 *"Anchoring Ethical Issues"*). One could even go so far as to use only material values without moral investigations (Section 6.3.3 *"Determining Values"*), which is, however, not recommendable.

6.3.3 Value Discovery

Regardless of the type of stakeholder expectations used—goals, needs, human values, or material values—stakeholders must first be identified (MTN 2) and afterwards involved in value discovery. Although certain phrases within IEEE Std. 7000, such as "Identify benefits for individual stakeholders …," or "… activities can benefit from close co-operation with stakeholders …" (IEEE, 2021, p. 40) could be misunderstood, practitioners should engage stakeholders with a view to gaining knowledge and insights into stakeholder expectations (RED 1). According to the SE state of practice, a multitude of methodologies can be used to discover stakeholder expectations, such as traditional (interviews, questionnaires or surveys), collaborative (focus groups, prototyping, workshops, storyboards, modeling, use case, scenarios), cognitive (card sorting or laddering) and observational (ethnography) (Tiwari et al., 2012). It should be noted that none of these methods includes an ethical framework, which reinforces the observation that the state of the practice is unable to distinguish between good and bad stakeholder expectations (see Section 2.1 *"Anchoring Ethical Issues"*). This is something that VSD and IEEE Std. 7000 seek to change, which should be achieved not only by discovering values (MTN 4), but also by conducting a moral investigation (MTN 3).

Value discovery and moral investigation can only be conducted if the context has been analyzed (MTN 1) and understood in advance (see Section 6.1 *"Context of Use"*) but the context of use also must be made graspable to stakeholders. In the past, ConOps documents have been criticized as being too technical, unreadable, and bureaucratic to adequately communicate the context of use, and it has been suggested that they could be improved by, for instance, scenarios or storyboards (Mostashari et al., 2012). To address this criticism, IEEE Std. 7000 not only relies on a description of the context of use, but also recommends the selection of scenarios or actual use cases to illustrate and raise awareness of social, legal, and environmental issues with potential impact on value (IEEE, 2021). Similarly, VSD proposes to use value scenarios to make explicit human and technical aspects of a proposed system in a particular context (Friedman & Hendry, 2019). While developing meaningful scenarios is far from easy, they help anticipate the context of use and connect it to the planned system (Verbeek, 2011). Manders-Huits (2011) warns that questions and stimulus materials such as scenarios may bias people's opinions and beliefs. For example, if stakeholders are presented with polemical scenarios entailing a hidden agenda, their opinions will be distorted. To gain in-depth insights—not discussing banal cases—IEEE Std. 7000 recommends that "… the choice of scenario should be guided by those social, legal, and environmental issues that turn out most problematic …" (IEEE, 2021, p. 38). If practitioners exercise due diligence in making this choice, it can help ensure that they bring forward relevant values in their discovery and thereby facilitate the development of ethical IS. Figure 21 shows the situationality of MTN 3 and MTN 4 within the VOF EvalCon (Figure 21, A) and summarizes key commitment (Figure 21, B), which will now be discussed in more detail.

A) Situationality



B) Commitment

VSD	IEEE P7000
Theoretical: Human Values, Implicit Utilitarian	**Theoretical:** Material Values, Utilitarian Ethics, Virtue Ethics, Duty Ethics, Global Ethics
Methodological: Context Scenarios Multi-modal	**Methodological:** Context Scenarios Moral Investigations

Figure 21: *MTN 3-4 within the VOF EvalCon (A), and VOF commitments (B)*

The VSD framework has been criticized for not recommending specific moral investigations, lacking a commitment to ethics and for not prescribing specific methods in general (Jacobs & Huldtgren, 2021; Manders-Huits, 2011; Reijers & Gordijn, 2019, Le Dantec et al., 2009). Instead VSD, as does the state of practice SE, relies on a broad set of methods from social science such as observations, interviews, surveys, experiments, user behavior measurements, and brainstorming to discover values (Friedman & Hendry, 2019; Winkler & Spiekermann, 2018). In addition, VSD recommends unique methods—value scenarios, value sketch, value-oriented semi-structured interview, scalable assessments of information dimensions, value-oriented mock-up, prototype or field deployment and value sensitive action reflection model—which, however, have no ethical framing (Friedman & Hendry, 2019). All these methods can help to discover, examine and discuss value interpretation and even promote a multi-model reflection—logic, linguistic, interpersonal or physical—but do not allow for giving human values ethical relevance (Steen & van de Poel, 2012; Pommeranz et al. 2012). This is a severe problem for VSD and its claim to facilitate the development of ethical IS. As an example of a provocation, stakeholders might say the value of "privacy" is important in relation to "location protection" for a GIS. While VSD methods might show that this value is considered important because stakeholders do not want to be caught cheating, stalking, stealing or organizing a government overthrow without an ethical framework, how should an engineer judge the goodness of the value and related concepts? The question of whether a GIS should protect the privacy of individuals against a repressive regime must be asked and answered, otherwise one runs the risk of having the same problems as the state of practice in SE.

According to Friedman and Hendry (2019), VSD explicitly abstains from imposing any moral investigation, since "… the complexity of social life, the technological development process, the commitments of designers, and the unresolved nature of debates on morality…" (p. 24) requires an adequate balance. This inherent flexibility is consistent with Palm and Hansson's (2006) recommendation of not committing to a particular moral theory, but instead being open to different perspectives, interests, and solutions. It is recommended that during VSD's conceptual investigation, potential harms or benefits and appropriate ethical or cultural justification frameworks are identified (Friedman & Hendry, 2019). I would recommend that VSD practitioners take this recommendation seriously, because without any ethical or cultural framework of justification, the discovery of values—especially human values (see Section 6.3.2.1 *"Human Values"*)—is a mere discovery of individual preferences without ethical or moral framing (Reijers & Gordijn, 2019). Although it is only a recommendation, when VSD practitioners think about possible harms or benefits, they implicitly follow a form of utilitarian ethics (Manders-Huits, 2011). However, such implicit utilitarian ethics is not sufficient to fulfill the claim of facilitating the development of ethical IS.

There is an ongoing debate in VSD about the appropriateness of using lists of values to help identify important values with ethical relevance, or protect values that should never by omitted, particularly in an industrial setting (Borning & Muller, 2012; van de Poel 2009; Le Dantec et al., 2009). In theory value lists collected as an outcome of moral considerations could be helpful, such as lists related to sustainability (see Appendix A) or for AI development (cf. Winkler & Spiekermann, 2020; Jobin et al., 2019), however, their moral foundations are questionable (Mittelstadt, 2019). It is especially critical that such lists are made with a top-down approach—neglecting stakeholders—and cannot account for use-context-dependency of values and technology (Le Dantec et al., 2009; Reijers & Gordijn, 2019). The use of value lists is not a way out of the fact that only moral investigation can help distinguish between mere stakeholder expectations expressed as values and values that are good or right and should be considered in SE. In this sense, VSD seems to lack the necessary moral foundations (Manders-Huits, 2011; Reijers & Gordijn 2019).

Early work in VSD community discussed three moral theories that could provide such foundations, but these never made it into the literature canon of this VOF (cf. Friedman & Kahn, 2007; Friedman & Hendry, 2019). These moral theories—utilitarian, virtue and duty—inspired scholars and are a vital part of IEEE Std. 7000 (Spiekermann, 2015; IEEE, 2021). A key difference between these is that utilitarian and duty ethics are theories of law that are often viewed as obligations, while virtue ethics is a theory of the good that leaves much room for personal discretion (Friedman & Kahn, 2007). Bednar and Spiekermann (2020) show that investigations based on these theories lead to considerable value discovery and consideration of potential harms and increased creativity (originality) in the benefits considered. This already suggests a potential benefit of using these moral investigations for the claim of facilitating the development of innovative and ethical IS (see Section 4 *"Novel Quality Metrics for System Requirements"*).

The IEEE Std. 7000 framework applies these three moral investigations—utilitarian-, virtue- and duty-ethics—to discover ethical values in the service of facilitating the development of ethical IS (IEEE, 2021). In addition, this VOF also asks for a global—that is, culturally relevant—moral investigation, thereby also being open to different ethical traditions, interests, and solutions (cf. IEEE, 2021; Palm & Hansson, 2006). Thus, the framework takes an additional stance for ethics, alongside the commitment to an ethics of material values.

First, according to IEEE Std. 7000, a benefit-harm analysis of the proposed system—a utilitarian analysis—is first conducted based on the question, "What benefits or harms would arise if everyone were to build and/or deploy the SOI in the way we envision it?" (IEEE, 2021, p. 40). Utilitarian ethics holds that a choice "...is right if and only if it brings about at least as much net happiness as any other action the agent could have performed; otherwise it's wrong" (Shaw, 1998, p. 10). Or in more general terms, utilitarian ethics seeks to maximize good for the greatest number of people (Frankena, 1973). In other words, according to IEEE Std. 7000 (2021) the benefits of an IS, should outweigh the harms "… if everyone were to build and/or deploy…" (p. 40) it. Especially with the part that focuses on anyone building and deploying an IS, this VOF reinforces its pervasive focus on context of use (see Section 6.1 *"Context of Use"*).

Second, a virtue ethical investigation examines in detail how a proposed system might affect the character of the individual—undermining virtue and developing vice. This is achieved by asking stakeholders the question, "What are the effects of the respective SOI for the virtues of stakeholders affecting their community behavior?" (IEEE, 2021, p. 30). This question already suggests that virtues are tied to a stakeholder, but are also relevant to their community.

The term "virtue," which comes from ancient Greek, is linked to the term "arête," meaning "excellence," and in a broader sense, virtues refer to "… any stable trait that allows its possessor to excel in fulfilling its distinctive function" (Vallor, 2016, p. 17). Virtue ethics emphasizes the moral excellence of character rather than consequences (utilitarian ethics) or obligations (duty ethics). A virtuous person has an alignment of beliefs, desires, and perceptions that are appropriate to the practical context in which actions are performed (Vallor, 2016). A virtuous person acts in a certain way not because it has the best consequences or is a duty, but because he or she possesses stable virtues such as "kindness" or "compassion." These virtues are vital to the flourishing and stability of a small community as well as an entire society. Therefore, when considering and promoting virtues during SE, one could assume a positive impact on social sustainability (see Section 2.4.2 *"Social Sustainability"*).

According to IEEE Std. 7000, while not all values are virtues, each virtue is a value that describes the character traits of a person who is characterized by balanced behavior with the golden mean (IEEE, 2021). IEEE Std. 7000 defines virtues as the "positive value of human conduct" (IEEE, 2021, p. 24), which is based on an understanding of virtues as moral values carried by persons (Kelly, 2011). By including a virtue ethics investigation, IEEE Std. 7000 greatly expands the number of values that can be recognized. While a utilitarian or even duty ethics inquiry would not consider "kindness" or "compassion" as values because they are not associated with consequences or obligations—such values would not be at issue—virtue ethics, however, considers them essential to a person's excellence and morality (Vallor, 2016; Friedman & Kahn, 2007). This makes clear why Bednar and Spiekermann (2020) could show that virtue ethical investigation is "…the main driver of … significantly higher originality… " (p. 14) of value discovered. The study of virtue ethics expands the number of possible values that can occur compared to other investigations, which automatically makes them rarer or more original, which in turn could have a positive effect on the innovative potential of the system requirements (see Section 4.2 *"Innovative Potential"*).

Third, IEEE Std. 7000 moral investigation focuses on the potential challenges an intended system poses for the ethical duties (potential value maxims fostered or harmed) of the stakeholders (IEEE, 2021). This duty ethical investigation asks, "What are the potential personal value maxims that can be undermined or fostered by the respective system?" (IEEE, 2021, p. 30). The IEEE Std. 7000 framework assumes that "[a]ll personal principles are values, but not all values are personal maxims" (IEEE, 2021, p. 40). According to Kant, a moral obligation (categorical imperative) can only be justified by something that is itself a universal principle (Kant, 2010). Following this logic, he famously formulated the following: "Act only in accordance with that maxim through which you can at the same time will that it become a universal law" (Kant, 2010, p. 583). Although the categorical imperative is applicable to any situation or context, Vallor (2016) questions whether it is applicable to a dynamic technological context. This may indeed be a challenge, but only underscores the importance of an in-depth analysis of the context of use (MTN 1) and its appropriate communication to stakeholders, as foreseen by IEEE Std. 7000.

A biased use of Kant's categorical imperative can lead to a subjective and paternalistic interpretation of what is good for humanity—bad actions might be legitimized when problematic universal values are misused as a maxim (MacIntyre, 2007). Most famously, Eichmann convinced himself to abide to the categorical imperative, while in fact he didn't consider that "...the legislator is the moral self, and all people are legislators" (Arendt & Krohl, 1964, p. 136). Instead, Eichmann allowed the politics and ideology of the time to dictate what the universal law was, thereby embracing cruelty and evil. This example points to several implications: first, people need to be trained in moral investigation, and second, the market-driven development context of SE (see Section 2.3 *"Origins of Harmful Information Systems"*) should not define what universal law is. These aspects are further covered in Section 6.7 (*"Development Context"*).

IEEE Std. 7000 articulates the task to conduct a duty ethical investigation as follows: "Conduct a detailed and critical analysis of how the SOI or features within the SOI potentially challenge the perceived ethical duties of the stakeholders…" (IEEE, 2021, p. 40). This might confuse SE practitioners, since especially in a first iteration there are no features yet, but only a rough outline of the SOI described in the ConOps document (ISO, 2011b). A system can only have features, functions, or subsystems when the RE and subsequent system design and implementation are complete (see Section 2.1 *"Anchoring Ethical Issues"*). However, RE and also SE in general is typically performed as a continuous and iterative cycle, with engineers gaining a better understanding at each pass (Sommerville, 2016; ISO, 2011b). I therefore recommend that IEEE Std. 7000 practitioners follow the iterative conduct envisioned in this VOF and repeat moral investigations in every cycle.

Putting complex ethical theories into practice is anything but easy. While research has shown that IEEE Std. 7000 is succeeding in discovering ethically and morally relevant values (cf. Bednar & Spiekermann, 2022), it is still unclear whether the posed ethical questions reflect the entire ethical theories. To convincingly demonstrate that these questions are a reflection of ethical theories—content validity—future research could, for example, use expert raters to create clarity (Trochim & Donnelly, 2001). It is also questionable whether all vulnerable stakeholders "… such as those unable to read, children, the aged, and people of different abilities" can answer the questions of these moral investigations (IEEE, 2021, p. 27f). In these cases, it seems advisable to either find other appropriate methods or to resort to stakeholder representation as foreseen in IEEE Std. 7000 (IEEE, 2021).

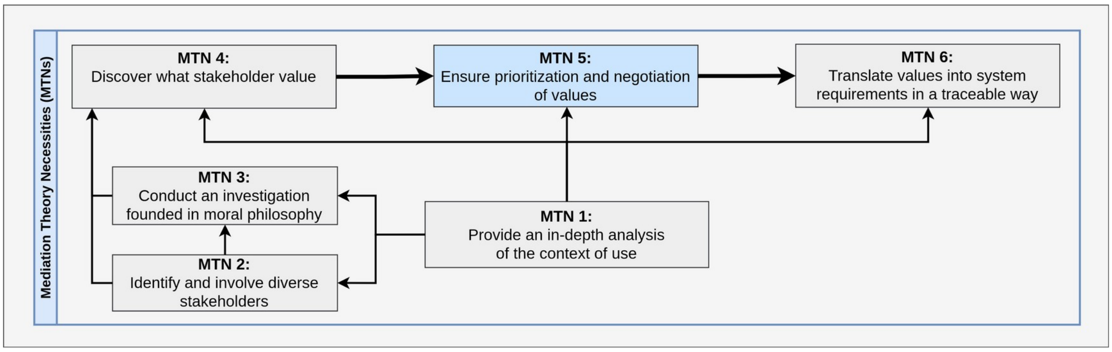
According to IEEE Std. 7000, "[n]ot all values are identified as the result of interactive activities with stakeholders"; instead some can also originate from "… regulations or other social-responsibility frameworks" (IEEE, 2021, p. 32). Despite the fact that these values stem from regulation and social responsibility, which might lead some to believe that such values are harmless, I would recommend to practitioners to make them the subject of context-specific moral inquiry as well. Despite minor uncertainties, IEEE Std. 7000 has explicit theoretical foundations and methodology for conducting moral investigations that, compared to VSD, make the claim to facilitate the development of ethical IS with respect to the third and fourth mediation theories necessity valid (see Section 3.2 *“Mediation Theory”*). In the following section, another important aspect for successful SE is covered, namely, the prioritization and negotiation of stakeholder requirements.

6.4 Prioritization and Negotiation

According to the state of practice, conflicts and contradictions should be resolved during *prioritization and negotiation* as part of the *a) elicitation and discovery* step (Sommerville, 2016). Only if this is achieved can the second RE deliverable, a coherent, prioritized, and consistent set of stakeholder requirements, be achieved (RED 2). Understood stakeholder expectations (goals, needs, or values) are stakeholder requirements that should become system requirements only if they do not conflict (see Section 2.2.2 *“Coherent Set of Stakeholder Requirements”*). Prioritizing and negotiating ambiguous or conflicting stakeholder requirements (understood goals, needs or values) can trigger ethical reflection, and finding trade-offs among these have clear ethical implications (Van Gorp & van de Poel, 2001).

For appropriate prioritization and negotiation, the context of use must be known (MTN 1), stakeholders must be identified and selected (MTN 2), and what stakeholders value should be determined (MTN 4), ideally with the help of an investigation founded in moral philosophy (MTN 3). As a reminder, according to van den Hoven et al. (2012), attempting to fulfill too many value commitments might lead to moral overload. VSD and IEEE Std. 7000 handle this particular SE step and the necessity of mediation theory very differently. This is mainly due to the differences between the concept of human values and material values (see Section 6.3.2 *“Novel to SE: Value Flavors”*). Figure 22 shows the situationality of MTN 5 within the VOF EvalCon (Figure 22, A) and summarizes the key commitments of VSD and IEEE Std. 7000 (Figure 22, B), which will now be discussed in more detail.

A) Situationality



B) Commitment

VSD	IEEE P7000
Theoretical: Values in Balance Value Tension	**Theoretical:** All Values are Important Value Hierarchy
Methodological: Value Dams and Flows, Burmeister Method, Quantitative and Qualitative Methods	**Methodological:** Emotion Value Assessment, Seven Ethical Criteria, Five Principles

Figure 22: *MTN 5 within the VOF EvalCon (A), and VOF commitments (B)*

VSD's understanding of human values, assumes that values do not exist in isolation but are interdependent and in a delicate balance (Friedman & Hendry, 2019). According to Friedman and Hendry (2019), value tensions can occur in various combinations—between individuals, within a single individual or between groups—depending on the context, situation, personality or society. For instance, there might be tensions between parents putting an emphasis on their children's "health" and "safety," while teenagers have preferences for values like "autonomy" or "independence." With GIS development, parents might see "safety" in being able to find their children's locations on a map, which is very much at odds with what a typical teenager values. A high-level solution must be found for this tension, otherwise no system design (technical solution) is conceivable.

The VSD term value tension is intended to convey that values are "... potentially in opposition but allows for solutions that balance each value in relation to the others, such that the adjudication of the tension holds each value intact" (Friedman & Hendry, 2019, p. 45). During VSD's empirical investigation, competing values are prioritized and a solution to potential value tension must be found (Friedman & Hendry, 2019; Davis & Nathan, 2015).

Prioritizing values is not an easy task, as the relative importance of a value depends on a person's culture and socioeconomic status, the practical context in which a value is mentioned and additionally, the fact that value importance might change over time (Flanagan et al., 2005; Verplanke & Holland, 2002; Friedman & Hendry, 2019). While none of the 17 core VSD methods mentioned by Friedman and Hendry (2019) are explicitly focused on how to prioritize values, the "Value Dams and Flows" method could be useful here (Winkler & Spiekermann, 2018). By excluding objectionable design options (value dams) or including appealing options (value flows), the associated values can be implicitly prioritized (Miller et al., 2007; Friedman & Hendry, 2019). Note that this is not a system design method, but a high-level design activity performed during RE. For example, a design solution where teenagers' location is always displayed on a map could be seen as both a value dam of their autonomy and a value flow for safety from a parent's perspective. A compromise could be reached in which the location would not be announced until the teenagers had given their approval, which would keep the values of both stakeholder groups more or less in balance. VSD emphasizes that discussing such value tension could lead to creative or even innovative design solutions (Friedman & Hendry, 2019). Competing values among stakeholders are often a problem due to differing perceptions of the same value and its value concepts (Dignum et al., 2016). VSD practitioners should therefore discuss and explore value concepts in detail together with all stakeholders. According to van den Hoven et al. (2012), finding innovative solutions can be a way to resolve conflicts and overcome moral overload. Seeking innovations can be part of a stepwise approach that first establishes minimum thresholds for moral obligations, then searches for innovations to meet the relevant values, and finally makes a decision between acceptable options using various other methods (Van de Poel, 2015).

Emotions can lead to awareness of what is important to users and can therefore help prioritize values (Desmet & Roeser, 2015). People are generally more emotional when it comes to issues or values they consider important. Along this line, material value ethics assumes that emotions are a response to values carried by objects, situations, people and relationships (Scheler, 1973). The "Burmeister method" achieves a prioritization of values by considering the frequency and emotional intensity with which values are expressed (Burmeister, 2016). Although not intended as part of IEEE Standard 7000, researchers have developed a similar method that not only considers frequency and emotional intensity, but also differentiates between the value carrier and the source of the emotion, calling it "Emotion Value Assessment" (Görnemann & Spiekermann, 2022). Both qualitative methods can be useful for prioritizing the perceived importance of values by stakeholders in accordance with the value concept of a given VOF.

Due to the openness of VSD to any kind of quantitative and qualitative methods, all established methods such as laddering interviews, card sorting ("Values Q-sort"), ranking, Likert scaling can be used (Friedman & Hendry, 2019; Hussain et al., 2020; Breidert et al., 2006). Value tensions should always be resolved based on empirical results or analytical reasoning of stakeholders or reasoning drawing upon "moral or ethical frameworks" (Friedman & Hendry, 2019, p. 48). While the "best-worst method", a cost-benefit analysis or discrete choice analysis—both from socioeconomics—have been criticized for reducing human values to utility, their pairwise comparison approach circumvents the challenge in multi-criteria decision making (Van de Kaa et al., 2020; Van de Poel, 2015; Breidert et al., 2006). Prioritizing values is essentially a multi-criteria decision problem, as many aspects influence their perceived importance, including system context, emotions, number of values, individual understanding of values, estimated consequences, and more. By simply comparing values pairwise for a given context repeatedly, best-worst methods for determining their importance, weight, or utility can facilitate prioritization.

For VSD's concept of human values, it makes sense that any type of quantitative or qualitative method is applicable, as the stakeholder here is the object of study that gives meaning to the values and their concepts (see 6.3.2.1 *"Human Values"*). However, some prioritization questions remain, such as whether "… the interests of an indirect stakeholder trump the interests of a direct stakeholder" (Friedman & Hendry, 2019, p. 43f).

A different methodological approach is possible for the concept of material value, where stakeholders are not the meaning-givers and, according to Scheler's axioms, any value is important (Kelly, 2011; Scheler, 1973). It is important to recognize that, unlike human values, there are no conflicts between material values according to their theoretical foundations, but only ".... conflicts about value priorities..." (IEEE Std. 7000, p. 42), since there is a natural hierarchy of material values (Scheler, 1973). In principle, all core values are considered important, but the IEEE Std. 7000 "Ethical Values Elicitation and Prioritization Process" provides seven ethical criteria and five—natural hierarchy—principles to guide development priority (IEEE, 2021). Due to the concept of material values (see Section 6.3.2.2 *"Material Values"*), it would ultimately be ideal if all positive values were taken into account and the materialization of all negative values was prevented during development. However, experience must show whether practitioners will be morally overburdened by committing to all of the values of IEEE Std. 7000, as suggested by van den Hoven et al. (2012). By not committing to conflict resolution, one might argue that IEEE Std. 7000 could avoid introducing ethical problems through “lazy” compromises by watering down requirements as often done in the state of practice (cf. Van Gorp & van de Poel, 2001).

The first ethical criterion for setting development priorities is to let “[s]takeholders agree that the SOI is good for [s]ociety and avoids unnecessary harm” (IEEE, 2021, p. 41). While this is an important criterion from an ethical perspective, it is unclear how it helps prioritize individual core values discovered for a system. Moreover, “good for society” and “avoids unnecessary harm” can be highly subjective criteria for prioritization in practice. Some stakeholders might view a GIS that violates “location privacy” as good for society and preventing unnecessary harm by limiting the misuse of a system and enabling the apprehension of criminals; others might clearly view it as harmful. According to the second criterion, stakeholders shall not be used “… merely as a means to some end” (IEEE, 2021, p. 41). From an ethical perspective, this might prevent systems with, for instance, addictive design elements and thus promote individual sustainability (see Section 2.4.1 *“Individual Sustainability”*). Third criterion, management should be able to take responsibility for prioritized values in accordance with their own personal maxims (IEEE, 2021). It is necessary to be able to take responsibility for an intended system, which is discussed further in Section 6.6 (*“Transparency and Traceability”*). Fourth, the prioritization should respect the companies’ ethical principles if there are any (IEEE, 2021). This prioritization criterion might be a good opportunity to choose adequate ethical principles or code of conduct, which might not necessarily exist in a company. Fifth, value priorities should be aligned with the business mission of the company (IEEE, 2021). For the fourth and fifth criteria, one could argue that corporate reality should be aligned with the lofty claims of their code of conduct or business mission in order to give substance to ethical branding (Fan, 2005). Google’s code of conduct was preceded in the past by the phrase “Don't Be Evil,” which has been moved to a less prominent place in the most recent version (Montti, 2018). Considering that Google’s Android and “Google Play Services” are known for constant privacy violations (Leith, 2021), cynics might think that the reverse is true, that they are adapting the code of conduct to corporate reality. The sixth criterion enjoins that “the environment is maximally preserved” (IEEE, 2021, p. 42). If this prioritization criterion is met, one could expect a significant positive impact on environmental sustainability. Seventh, the company should compare their value priorities with existing external ethical and legal frameworks (IEEE, 2021). From an ethical perspective, this is a good idea, but it is difficult to implement in practice, given the amount of existing ethical and legal frameworks.

While all of the above criteria can help facilitate the development of ethical IS, they may not be clear-cut in practice for setting development priorities. For such cases, IEEE Std. 7000, recommends five criteria based on the natural hierarchy of material values (Scheler, 1973). According to Scheler (1973), there can be no ethical dilemmas that would require compromise; instead, material values are in a natural hierarchy, and ethical behavior is the choice and realization of higher values over lower ones. Consistent with Scheler, IEEE Std. 7000 (2021) considers those values to be higher, relative to others, that are 1. more enduring, 2. less extensible or divisible, 3. more intrinsic (opposed to instrumental), 4. lead to relatively higher satisfaction, and 5. are relatively less dependent of the value-bearer. For guidance to practitioners, IEEE Std. 7000 (2021) includes a table of examples, which can be seen in Table 3.

Table 3: *Value prioritization with examples according to IEEE Std. 7000 (2021, p. 57)*

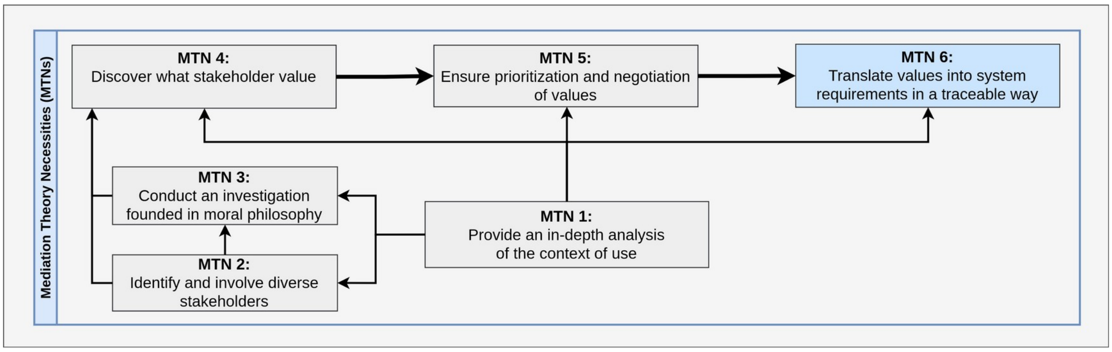
Values are higher…	IEEE Std. 7000 Examples
… the more they endure (persistence and eternality)	Happiness is higher than convenience
… the less they are extensible or divisible	Beauty is higher than an attractiveness
…the less they are founded through other values (more intrinsic)	Dignity is higher than amusing
… the deeper the satisfaction	Life satisfaction is higher than feeling happy
…the less dependent on the existence of a specific bearer	Fairness is higher than convenience

With these five criteria, IEEE Std. 7000 aims to provide concrete guidance for setting development priorities according to material value ethics. In addition, despite the theoretical absence of ethical dilemmas, it is stated that it might be easier to solve these "… by distinguishing between system defaults and system exceptions" (IEEE, 2021, p. 57). In summary, both VSD and IEEE Std. 7000 have the necessary theoretical foundation and methodology to deliver prioritized values (MTN 5) and achieve a coherent, prioritized, and consistent set of stakeholder requirements (RED 2). However, this section has shown how impactful a different theoretical conception of values can be (see Section 6.3.2 *"Novel to SE: Value Flavors"*). While material values do not need to be negotiated, human values must be negotiated at length between stakeholders to resolve value tensions, conflicts that do not exist according to material value ethics. One might assume that the ethical foundations of IEEE Std. 7000 could be of use, but in this case, probably only practical application can show which concept—human values or material values—can better promote the development of ethical IS. Moreover, the translation of values into system requirements is highly influenced by the theoretical foundations of these, which will be discussed below.

6.5 Translation of Values into System Requirements

According to the state of practice, knowledge and insights gathered during a) *elicitation and analysis* based on stakeholder expectations (RED 1) are decomposed during b) *specification* into concrete functional and non-functional system requirements (Sommerville, 2016). These system requirements must be upwardly traceable "… to specific documented stakeholder statement(s) of need, higher tier requirement, or other source…" (ISO, 2011b, p. 11). In other words, a logical chain should be established from a specific system requirement to stakeholder expectations—as needs, goals, material values, or human values. Especially since values are a novel and relatively "fuzzy" concept from an SE perspective, VSD and IEEE Std. 7000 must provide the means to translate these into system requirements (MTN 6). This translation should be based on prioritized and negotiated values (MTN 5), as there is no point in specifying them and going into detail if you do not know whether they are relevant or correct. Since system requirements are context-dependent (Briand et al., 2017), these can only be understood and specified if the context of use is known (MTN 1). Obtained system requirements should also be validated (Sommerville, 2016) and reflect the desired ethical and innovative potentials (see Section 4.1 *"Ethical Potential"* and Section 4.2 *"Innovative Potential"*). VSD and IEEE Std. 7000 should be able to establish system requirements consistent with their stated purpose, which may result in a system design for innovative and ethical IS. This is the last step necessary for achieving a set of validated functional- and non-functional system requirements (RED 3) for starting with system design. Figure 23 shows the situationality of MTN 6 within the VOF EvalCon (Figure 23, A) and summarizes key commitments of VSD and IEEE Std. 7000 (Figure 23, B), which will now be discussed in more detail.

A) Situationality



B) Commitment

VSD	IEEE P7000
Theoretical: Three-tiered Hierarchy **Methodological**: Regulations Historical Reports Design Activities	**Theoretical:** Material Values **Methodological:** IEEE Std. 7000 Method

Figure 23: *MTN 6 within the VOF EvalCon (A), and commitments (B)*

According to the state of SE practice, analyzing stakeholder expectations can help understand their concepts—often referred to as conceptualization—thereby allowing more formal stakeholder requirements to be gained. Subsequently, stakeholder requirements are specified in technical terms as system requirements. Both requirement essential types—functional and non-functional system requirements—must be gained, since a system which does not provide the right functionality is not useful and a lack of non-functional requirements leads to low software quality, dissatisfied stakeholder expectations and high costs (Mairiza et al., 2010; Chung et al., 2000; Chung & do Prado Leite, 2009). A simple example: a GIS that does not have a map or cannot provide directions because there have been no system requirements for this is probably useless. The same is true for a GIS that provides incorrect directions because non-functional system requirements for “location correctness” or “location accuracy” have not been specified.

Engineers are always tempted to go into detail too quickly and specify system requirements too early, before understanding the stakeholder requirements that express the problem to be solved (Hull et al., 2005). System requirements indicate on a technical level “...what the system must do to solve the problems posed by the stakeholders” (Hull et al., 2005, p. 111). Hasty system decisions are known to hinder creativity and the development of innovative solutions

(Hull et al., 2005). Furthermore, such kinds of decisions might be an origin of harmful IS, through problem-solution inversion (see Section 2.3 *"Origins of Harmful Information Systems"*).

Dealing with particularly human values is not easy, as they are often formulated ambiguously, can be interpreted in different ways and thus could produce false norms and actions (Manders-Huits, 2011). VSD should therefore not view values as predetermined or stable entities that exist in a form ready for reflection and consideration; one should not ignore the hermeneutic work required to determine what values are or mean in practice (Boenink & Kudina 2020). Gaining a hermeneutic understanding (exploring of meaning and implications) is important moral labor (Boenink & Kudina, 2020). This hermeneutic work is done in VSD during its conceptual investigation, during which a definition, analysis or description of a discovered value and its entailed concepts provides its meaning (Friedman & Hendry, 2019; Van de Poel, 2021). For example, when teenagers value their "autonomy" or "independence," it is first necessary to understand what they mean by this, even in contrast to a textbook definition. When using GIS that can be controlled by their parents, are they afraid of losing their self-determination through monitoring, or are they more afraid that their secrets will be exposed? Only after the meaning of a human value is understood, can one hope to specify system requirements.

Following this hermeneutic work, the VSD framework aims at specifying the system requirements during the technical investigation, for which it proposes three different paths (Friedman & Hendry, 2019). The first path is to specify system requirements according to the concrete demands of policies, laws, or regulations (Friedman & Hendry, 2019). This is a typical approach in RE, which works well for known established values like "security" or "privacy." The ISO 27001 (2022b) standard, for example, defines specific requirements that a system must meet to ensure security and data protection. It is questionable whether this is possible for less familiar values in SE such as "freedom" or "autonomy," for which there are no standards. The second path is to analyze whether historical "technological properties and underlying mechanisms support or hinder human values" (Friedman & Hendry, 2019, p. 34). This can also be a viable path if technological properties can be found that already contain the discovered values. The third VSD path is to aim for a proactive "design of systems to support values identified in a conceptual investigation" (Friedman & Hendry, 2019, p. 34). This is also a common approach in SE, where one develops a high-level design as a prototype or mockup, verifies that it meets stakeholder expectations, and then analyzes it to derive the system requirements needed for a system design. This approach should be done with diligence however, as it risks breaking the logical chain (upward traceability) from stakeholder expectations, such as human values, to system requirements (see Section 2.2.3 *"Validated Functional and Non-functional System Requirements"*).

Most notably, Ibo van de Poel (2013) proposes a hierarchical relationship between values, end-norms, and associated design requirements, which he exemplifies for aviary (chicken farming) design. End-norms can also include objectives, goals, and constraints (Van de Poel, 2013), which might be confusing in practice. From an SE perspective, the mentioned design requirements are not yet system requirements, since these do not describe specifically what the system should do (functional system requirement), nor in which way or under what constraints (non-functional system requirement). For specifying system requirements, practitioners should therefore incorporate the RE methods (cf. Hull et al., 2005) to achieve a translation of human values. For example, according to the NFR framework, stakeholder requirements—equivalent to van de Poel's (2013) design requirements—are soft goals relevant to norms, goals, objectives, and constraints and can be specified into functional and non-functional system requirements (Chung et al., 2000). Thereby one could view VSD's methodology of translating values into system requirements as a hybrid approach between the conceptual and technical investigations of VSD and the RE methodology. This is shown in Figure 24 for the following example.

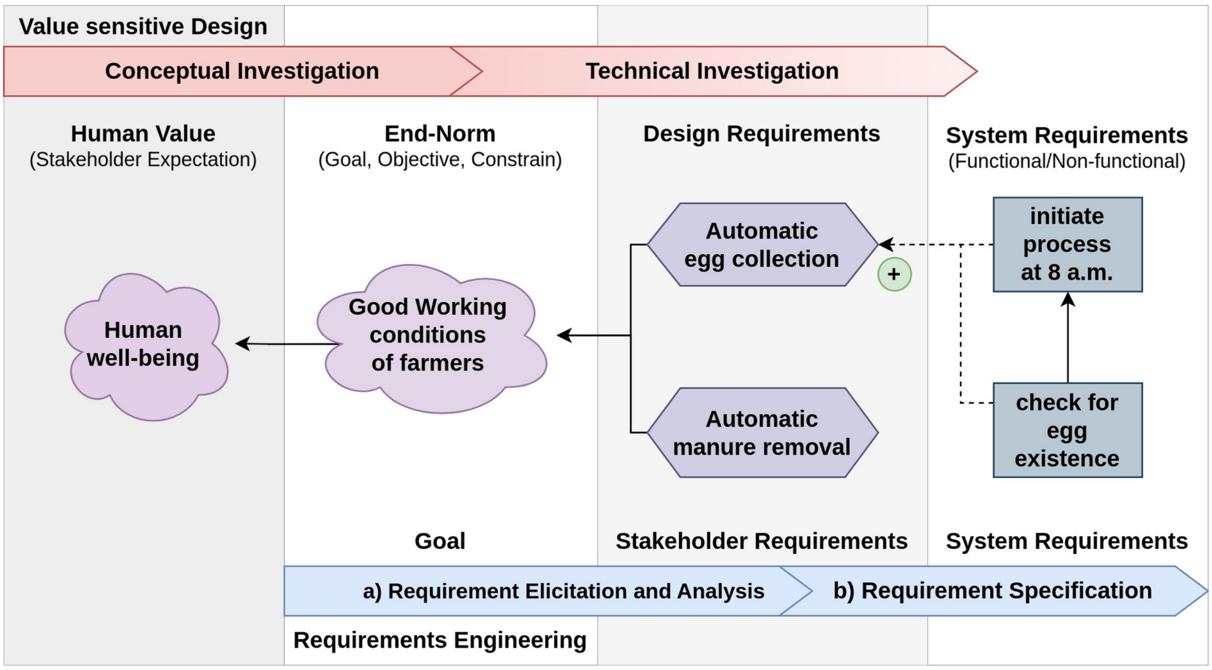


Figure 24: *Hybrid translation approach VSD and RE (based on: Van de Poel, 2013).*

According to this relationship, for a value such as “Human well-being,” the norm “Working conditions of farmers” must be met, which entails supporting design requirements to have “Automatic egg collection” and “Automatic manure removal” (Van de Poel, 2013, p. 258). However, an engineer would fail to design a system based on these design requirements because more specific system requirements are needed. For “Automatic egg collection,” system requirements related to “initiate process at 8 a.m.” or “check for egg existence” would be needed. Therefore, design requirements need further specification, which seems only possible with the help of established RE methods. Interestingly, from an SE perspective, VSD introduces an additional level to the hierarchy in the form of human values, which requires more hermeneutic and conceptual work. State of the practice in SE, might have come up with the goal or objective (stakeholder expectation) to ensure good “Working conditions of farmers” but would not relate it to a higher construct. This shows four things: first, it is possible to translate human values into system requirements, but second, this can only be possible as a combination of VSD and RE. Third, because of the confusing fact that end-norms can include objectives, goals, and constraints (Van de Poel, 2013), and that VSD’s design requirements are related to stakeholder requirements or soft goals, much care is needed to avoid confusion. Participants must be careful not to confuse these terms or the levels in the hierarchy of these, or they risk failure of the project. Lastly, compared to the state of practice, VSD starts with human values at a higher-level.

The IEEE Std. 7000 framework takes its own approach to specifying system requirements, which is only possible through its unique conception of material values and the terminology provided (see Section 6.3.2.2 *“Material Values”*). Based on gained insights—especially during the moral investigations (see Section 6.3.3 *“Value Discovery”*)—“… core values are identified which are then described in the form of value clusters including the ethical issues, values, and potentials raised in the form of value demonstrators” (IEEE, 2021, p. 39). This is essentially the hermeneutic or conceptual work necessary to understand a core value. According to IEEE Std. 7000, a value demonstrator can support or undermine a core value and “… reflect a result valued by the stakeholder that the system should achieve” (IEEE, 2021, p. 29). This definition suggests that the value demonstrator could be linked to goals that also reflect the results valued by stakeholders. Next, during the “Ethical Requirements Definition Process,” ethical value requirements (EVRs) “...and value-based system requirements that define how the prioritized core values and their value demonstrators are reflected in the SOI” (IEEE, 2021, p. 43). An EVR is defined by IEEE Std. 7000 (2021), as an “...organizational or technical requirement catering to values that stakeholders and conceptual value analysis identified as relevant for the SOI” (p. 18).

The IEEE Std. 7000 framework states that "[v]alue demonstrators are rendered as engineering targets in the form of EVRs, which are expressed in technical terms as value-based system requirements" (IEEE, 2021, p. 29).

Taken together, IEEE Std. 7000 forms a clear path going from the core values to the value demonstrator to the EVRs and finally to the value-based system requirements. Practitioners who are not yet familiar with this VOF should not be confused by the unique terminology. An EVR is essentially a particular form of stakeholder requirement that is based on ethical (E) considerations, takes into account values (V), and results in requirements (R). Similarly, value-based system requirements can be functional or non-functional, like system requirements in SE, but they are based on value considerations, hence value-based (IEEE, 2021). The IEEE Std. 7000 hierarchy from core values to value-based system requirements and associated processes is shown in Figure 25 for the following example.

IEEE Std. 7000 includes an example of the development of a full-body scanner at an airport where privacy was identified as a core value. Privacy requires, for instance, a value demonstrator of "avoidance of exposure of passengers' figures" and the related value "confidentiality" with the value demonstrator "avoiding exposure of individuals' data to other passengers" (IEEE, 2021, p. 55). It is reasonable to assume that all previously mentioned value demonstrators and values are instrumental, therefore Figure 26 shows a plus sign. The example continues: "If the organization accepts privacy as a high-ranking core value for the system, it should be formulated in an EVR, e.g., 'The system shall protect the privacy of body images of scanned passengers.' The EVR can then be translated into explicit value-based systems requirements, e.g., 'The system shall display images of suspected contraband metal, plastic, ceramic, and explosive items positioned on a generic body outline'" (IEEE, 2021, p. 55). The IEEE Std. 7000 approach to translating core values into system requirements should be viewed more as an onion model, with the core value in the middle, followed by the "value demonstrator and value" layer, then the EVR layer, and finally the "value-based system requirements" layer. From an SE perspective, the value-based system requirement examples is too broad—not formulated specific enough. In this case, for example, individual system requirements are needed that specifies the quantity of metal (there are also different types of metal) above which the system should consider it as "contraband." Nevertheless, IEEE Std. 7000 provides its own approach to determining system requirements that is able to account for the supporting and undermining nature of values and value demonstrators. In addition, a logical chain is visible, which allows tracing upwards from system requirements to value clusters.

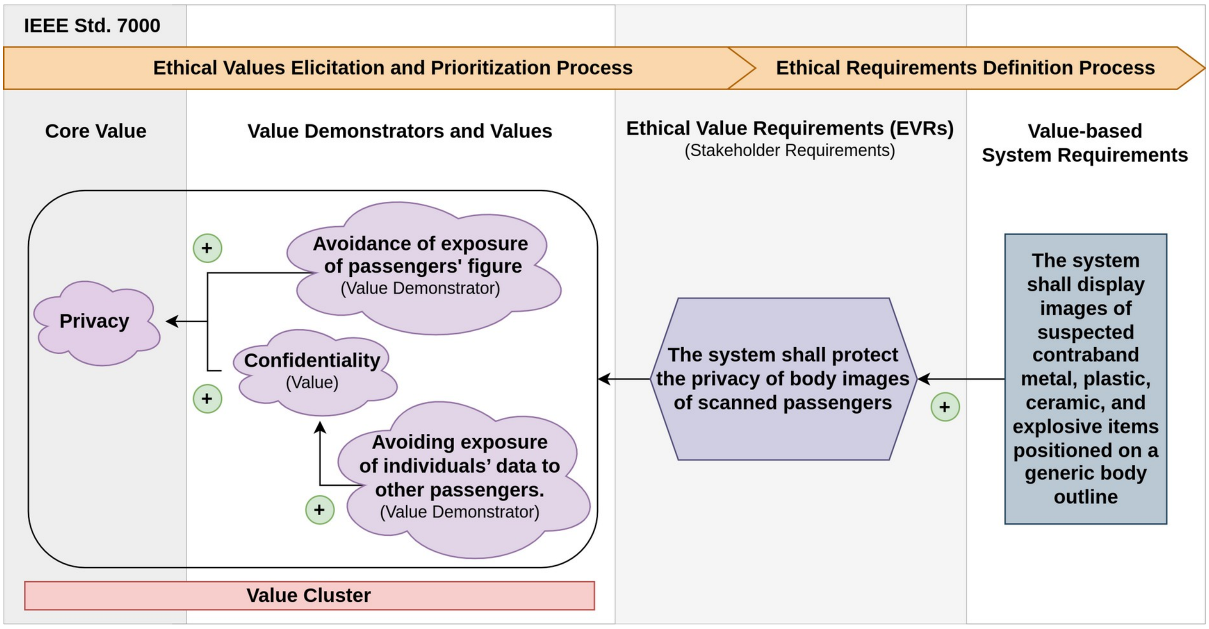


Figure 25: *IEEE Std. 7000 translation approach (based on: IEEE, 2021).*

Translating normative theories or principle into practice is a known challenge, which often means that "[d]evelopers are left to translate principles and specify essentially contested concepts as they see fit, without a clear roadmap for unified implementation" (Mittelstadt, 2019, p. 6). This is a problem that practitioners might encounter with a VSD hybrid approach, which requires them to justify each translation and specification step independently (Mittelstadt, 2019). IEEE Std. 7000 provides a consistent methodology, but understanding and implementing it may still require training and experience, which is the topic of Section 6.7 (*"Development Context"*). In practice, it could certainly be beneficial to rely on a uniform method, such as that provided in IEEE Standard 7000, to meet the requirement of facilitating the development of ethical IS.

6.6 Transparency and Traceability

Enabling transparency and traceability is what the first hygiene necessity (HN 1) which has an impact on all other steps. It is important that the findings and decisions made during the system and context of use analysis (MTN 1), stakeholder identification and involvment (MTN 2), moral investigation (MTN 3), discovery of values (MTN 4), their prioritization and negotiation (MTN 5), as well as a translation of values into system requirements (MTN 6) are made transparent and traceable. This is especially necessary because consciously aiming for a design to influence people's perceptions and behavior is an invasive act that could further shift power away from users to engineers (Verbeek, 2011). In the worst case, such design could lead to the introduction of affordances or value dispositions that nudge users, which is an act of paternalism (Thaler & Sunstein, 2009). However, even without paternalistic intent, unintended consequences or ethical issues may have been overlooked and should be made transparent (Verbeek, 2011). A proper transparency process could also help mitigate or at least make visible some of the suspected origins of harmful IS (see Section 2.3 *"Origins of Harmful Information Systems"*). For example, a transparency document could help highlight malicious use cases, make system complexity more tangible, make the problem-solution inversion visible, and clarify whether values were considered from the beginning. First and foremost, transparency and traceability allows practitioners to take responsibility for their product (see Section 3.2.2 *"Hygiene Necessities"*). Table 4 summarizes the key ethical and methodological commitments of VSD and IEEE Std. 7000 related to transparency and traceability, which are discussed below.

Table 4: *Key commitments towards transparency and traceability (HN 1)*

VSD	IEEE P7000
Theoretical: Make Values Explicit Power Relations	**Theoretical:** Habermasian Discourse Ethics Management Decision
Methodological: None	**Methodological:** Transparency Management Process Value Register Case for Ethics

The VSD framework encourages practitioners to make the values of project sponsors (management) and engineers explicit and transparent throughout the project (Friedman & Hendry, 2019). By nature, there is a strong power imbalance within a project, as typically management and engineers are in the privileged role to capture, interpret and report the values and knowledge gained (Borning & Muller, 2012). This imbalance of power makes it necessary to be transparent about what values are being considered to ensure that it is not just the values of the project sponsors or engineers that are being considered (Friedman et al., 2021; Borning & Muller, 2012). To enforce this, the facilitating role of the "values advocate," is charged with "… safeguarding and monitoring of the process of incorporating moral values into design …" (Manders-Huits, 2011, p. 285). The role of the "value advocate" and its IEEE Std. 7000 counterpart will be discussed in detail in Section 6.7.2 ("*Facilitating Roles*"). In part because such a "value advocate" would be part of the engineering team, VSD sees resolving power imbalances as an open challenge (Friedman et al., 2021). The VSD framework does not appear to provide a clear methodology for what should be documented other than the values of the project sponsors and engineers. I would recommend VSD practitioners to note all insights gained—context of use, identified stakeholders, etc.—and document them as transparently as possible. There does not appear to be a specific methodology to make the process transparent or traceable.

The IEEE Std. 7000 framework proposes a "Transparency Management Process," that aims to share "… how the developer has addressed ethical concerns during SOI design" (IEEE, 2021, p. 50). This process is a refined implementation based on established ISO standards with the aim of communicating as openly as possible with relevant stakeholders (IEEE, 2021). The process aims to make available most of the knowledge gained and decisions made during the other processes. For ConOps development, this includes a representation of each likely context of use, the identified stakeholders, and the results of the feasibility study (IEEE, 2021). For the result of the utilitarian- and virtue-ethical investigation, potential harms and benefits should be considered, and underlying values and harms to the character of individual stakeholders should be shared (IEEE, 2021).

For the duty-ethical investigation, project team members' personal maxims that might be undermined or fostered should be documented as part of the transparency process (IEEE, 2021). While this aligns well with VSD's emphasis on making values of project sponsors and team members transparent (Friedman & Hendry, 2019), it is unclear why other stakeholders' personal maxims are not included as part of the transparency process. Other information that should be included is EVRs and value-based system requirements, value dispositions in design, and risks and their treatments (IEEE, 2021). All information should be presented in a "Value Register" and a "Case for Ethics" document (IEEE, 2021).

In line with Habermasian discourse ethics, the transparency management process aims to set an ideal speech situation to ensure that stakeholders can participate in the discourse on an equal footing, ask questions or make statements, and freely express their own attitudes, wishes and needs (IEEE, 2021; Mingers & Walsham, 2010). This is a very important commitment that might lead to the discovery of additional ethical issues or make mistakes apparent (see Section 3.2.2 *"Hygiene Necessities"*). IEEE Std. 7000 practitioners should extend this commitment to discourse ethics to all other processes and activities involving stakeholders. Of concern, however, is that the information shall be available "… consistent with identified stakeholders' interest and need to know," and that "… information to be shared shall be approved by the managers who are directly responsible for the activities of the project that produced the information" (IEEE, 2021, p. 50). One might assume that this is well-intentioned to ensure that stakeholders are not overwhelmed with unnecessary information, but the "need to know" or "explainability" principle that this framework applies could be an invitation to abuse or bad faith behavior (IEEE Std. 7000, p. 28). Having managers responsible for project activities agree to the information shared aims to ensure commitment and accountability, but also puts them in a position of even greater power. Since managers responsible for producing information must approve (or indeed can censor) what is shared, this is also indicative of a potential power imbalance within IEEE Std. 7000.

Transparency and traceability should not be seen as an obligation, but as an opportunity to gain additional knowledge and improve the SE process and the resulting product. For example, making clear which malicious use cases were considered could bring additional insights. If done in good faith, ensuring transparency through a "Values Register" and a "Case for Ethics" could be a good way to demonstrate responsibility for the system developed (see Section 3.2.2 *"Hygiene Necessities"*).

Since the amount of documentation required can be overwhelming, especially for large projects, and the imbalance of power seems to be an open challenge for both VOFs, future research might focus on automatically generating machine-readable documents to facilitate this process (cf. Bednar & Winkler, 2020). Although ensuring transparency can be very beneficial, this is not a lived practice in the current development context and especially in agile development, which deliberately avoids time-consuming documentation (Fowler & Highsmith, 2001; Schmidt, 2016). Also, for this reason, VSD and IEEE Std. 7000 should, for example, provide an appropriate development context that allows time for proper documentation.

6.7 Development Context

The developmental context is seen not only as an origin of harmful IS, but also as a hygienic necessity (HN 1) for mediation theory (see Section 5 *"Concept for Value-oriented Framework Evaluation"*). As Mittelstadt (2019) has correctly recognized, implementing ethics in practice involves work and incurs costs, for instance, by involving stakeholders, bringing the necessary knowledge (from ethicists, for example) to development teams, and resolving conflicts. Taking into account the insights from the previous chapters, it is easy to see that other activities such as in-depth analysis of the context of use (MTN 1) or value discovery and moral investigation (MTN 3 and MTN 4) also require additional time, money, and expertise. Learning and correctly applying a new methodology, resolving ethical issues, and understanding the nuances and differing interpretations of values takes time (Steen & van de Poel, 2012; van de Poel & van Gorp, 2006). In general, developing a good product requires the right development context that provides time, ethical guidance and good working conditions (Berenbach & Broy, 2009). Mittelstadt (2019) goes even so far as to doubt that VOFs "… will be meaningfully implemented in commercial processes that value efficiency, speed, and profit" (p. 7). Creating an appropriate development context is certainly a challenge that can lead to failure if not mitigated. Therefore, VSD and IEEE Std. 7000 should at least provide a way to address how they aim to create the right development context (Section 6.7.1 *"Organizational Conditions"*), bring in the necessary expertise (Section 6.7.2 *"Competence"*), and address the agile practices that emphasize efficiency and speed as opposed to what is necessary (Section 6.7.3 *"Agile Practices"*). Table 5 summarizes the aspects explained below.

Table 5: *Establishing an adequate development context (HN 2)*

VSD	IEEE P7000
Organizational Conditions: Not Specified	**Organizational Conditions:** Five Commitments
Competency: Value Advocate	**Competency:** Value Lead Team Competencies
Agile Practices: Adaptations Exist	**Agile Practices:** No Adaptation Available

6.7.1 Organizational Conditions

The IEEE Std. 7000 framework explicitly defines five organizational aspects deemed necessary to successfully develop innovative and ethical IS. The first is a general willingness to "… include a wide group of stakeholders in the engineering effort" (IEEE, 2021, p. 9). When companies truly embrace this willingness, it facilitates quality outcomes, particularly in stakeholder identification and involvement (MTN 2) and participation in value discovery (MTN 4). The second aspect demands an "... open, transparent and inclusive project culture" (IEEE, 2021, p. 9). This aspect is a commitment to transparency and traceability (HR 2), which could mitigate a further shift of power to engineers and the associated risk of technocracy (Verbeek, 2011). The third aspect is the desire to have "a commitment to quality" (IEEE, 2021, p. 9). This is generally a good idea, but it is unclear what the framework means by quality. It could be understood as a departure from fast-paced SE practices, a rigorous commitment to a framework's theory and methodology, or a general aim for software quality. I would recommend that IEEE Std. 7000 scholars make clear what is understood as a commitment to quality. The fourth aspect is a call for managements to commit "… to ethical values from the top of the organization" (IEEE, 2021, p. 9). Such commitment can greatly facilitate the development of innovative and ethical IS because of the involvement of management during *project initialization*, when a ConOps could introduce problematic business goals or values and therefore introduce ethical issues in the process (see Section 2.1 *"Anchoring Ethical Issues"*). Whether founders or management, in a top-down process these "...infuse their values into the organization, influencing the organization and their employees" (Arieli et al., 2020, p. 253). This also allows founders of startups—known for ignoring SE practices—to influence them and promote the best way to develop software (cf. Coleman & O'Connor, 2008), such as using VOFs. Management involvement in general could also help reduce the disconnect or communication problems between management and engineering, which could reduce the tendency for problem-solution inversion and weak organizational norms (see Section 2.3 *"Origins of Harmful Information Systems"*). IEEE Std. 7000 further reinforces this commitment by stating that "...organizational leaders and top management are involved in and assume responsibility for the products and services created" (IEEE, 2021, p. 9). In order to be able to take responsibility for a product, moral investigations must be carried out (MTN 3). As mentioned in Section 3.2 (*"Mediation Theory"*), every engineering decision inevitably has moral consequences, therefore responsibility should be equally divided between engineering and management (Verbeek, 2011). The fifth aspect is a commitment to provide time and resources "… for ethical requirements definition" (IEEE, 2021, p. 9). It is unclear whether this is a commitment to allocate time and resources to all key activities or "only" to defining the ethical requirements. Since all activities should be conducted with due diligence and time, I would recommend practitioners to take this commitment as a general call to provide the necessary time and resources.

These stated commitments clearly show that IEEE Std. 7000 considers the organizational conditions necessary to develop innovative and ethical IS. This is something that, to my knowledge, is currently missing from the VSD framework. The fact that the development context is simultaneously a source of harmful IS and a hygiene requirement for mediation theory should highlight the importance of such considerations. IEEE Std. 7000 limits its own responsibility by stating that it "… cannot guarantee that the system as designed and subsequently built is ethical…" because the final system will depend to a large degree "…on the moral capabilities and choices…" of those applying the framework (IEEE, 2021, p. 13). Such a limitation of one's claim is very reasonable, since it is indeed the moral capabilities, choices and general competency that determine the outcome of a project. However, it should be made clear what such competencies are and where these are supposed to come from.

6.7.2 Competence

Clearly, the employing of VOFs—both VSD and IEEE Std. 7000—requires training and knowledge in specific theoretical considerations, methods, or an entire framework. Providing such knowledge is highly relevant, since "[i]t certainly is unethical … for people to make decisions when they know they lack the knowledge needed to make sound professional decisions" (Berenbach & Broy, 2009, p. 75).

The IEEE Std. 7000 framework defines several team competencies required for successful implementation of this framework. A team should have empirical and academic expertise, contextual application experience, adaptability to changing situations, and the ability to perform tasks in an efficient and waste-minimizing manner, as well as "… appropriate behaviors, such as teamwork, leadership, and compliance with professional codes" (IEEE, 2021, p. 35). While all of these capabilities are highly desirable, it is unclear from a practitioner's perspective where such a team would come from or how to transform an existing team. Future work should focus on the conceptualization of training that enables the acquisition of such competencies and skills, as well as on measurement scales to assess the outcomes of such training. Moral sensitivity and well-developed emotional skills also seem important for such a team (Roeser, 2012). According to IEEE Std. 7000 a team should also have "… the ability to sense what is desired and to consistently deliver high quality to the satisfaction of the end client(s)" (IEEE, 2021, p. 35). Whether such a "feeling" is related to the previously mentioned moral sensitivity and emotional abilities, or what this means, remains unclear. From a practical point of view, it seems this framework should only be implemented by sophisticated development teams.

Both frameworks suggest identifying "project sponsors" or a "top management champion" as a separate stakeholder role (cf. Friedman & Hendry, 2019; IEEE, 2021). On top of this, IEEE Std. 7000 specifies seven additional facilitating roles, including "system expert," "value lead," "risk lead," "user advocate," "senior product manager," "moderator," and "transparency manager" (IEEE, 2021). Although all of these roles are essential to project success, I will focus here primarily on the "value lead" and its VSD equivalent, the "value advocate," as these bring much-needed expertise to an organization.

According to the IEEE Std. 7000 framework, the task of a “value lead” is to “… [focus] on the identification, analysis, and prioritization of ethical values and their incorporation in the system design” (IEEE, 2021, p. 33f). Already this brief job description makes it clear how important this role is, because he or she seems to be essential—or at least involved in nearly all relevant activities. A “value lead” should provide “… subject matter expertise and facilitative skills, bridging gaps between engineering, management, and ethical values in a constructive way.” (IEEE, 2021, p. 33f). This means that a “value lead” should not only have knowledge of engineering, management, IEEE Std. 7000 and ethics, but also soft skills. As with team competencies, it is yet unclear where such a highly skilled employee would come from or how they could be trained.

All human decision-making is susceptible to cognitive biases, including risk and harm considerations as envisioned in IEEE Std. 7000 (IEEE, 2021). Besides mentioned knowledge and soft skills, a “value lead” must also possess the knowledge of and ability to self-reflect on such biases. For example, the framework’s particular emphasis on expert involvement could lead to “authority bias” and thus a tendency to give expert opinions more weight than they deserve (Baybutt, 2018). Nobody can be expert in everything—poor performers face a double burden in that “… deficits in their expertise would lead them to make many mistakes,” and secondly, the “… same deficits would lead them to be unable to recognize when they were making mistakes and when other people choosing more wisely” (Dunning, 2011, p. 260f). This is known as the “Dunning-Kruger effect,” which means that a value lead must also be able to recognize when his or her level of expertise is exceeded. Baybutt (2018) recommends that knowledge about biases, use of concrete information, healthy skepticism, devil’s advocate, outside perspective, and aiming to falsify—not proof—one’s option serve as ways to mitigate cognitive biases.

The role of “value lead” is not only critical for project success, but also very powerful by design or accident. He or she not only supports the identification, analysis and prioritization of ethical values, but also communicates and documents “… ethical and/or value related concepts [and] concerns…” and builds “… compromises through practices like participatory design” (IEEE, 2021, p. 33f). Personally, I consider the multiple combination of execution, communication, negotiation and documentation tasks to be too powerful and therefore dangerous. It certainly requires a high degree of emotional and professional integrity to achieve this, which in turn raises the question of how to get such employees. Future research in the IEEE Std. 7000 domain should focus on formulating and evaluating a curriculum for training the role of “value lead.”

Since a “value lead” is explicitly not responsible for “the ethics” of the product, therefore his or her role should not be confused with McLennan et al.’s (2020) call to permanently hire an ethicist as development team member. While IEEE Std. 7000, considers the involvement of an external ethicist as helpful, it is “… not required to engage an ethics expert to conform with the standard” (IEEE, 2021, p. 26). However, facilitating ethical considerations as envisioned for a “value lead” seems advisable, as engineers typically lack experience in identifying and analyzing ethical issues (Palm & Hansson, 2006).

The “value lead,” while more critical and powerful, has similarities to the proposed “value advocate” role in VSD (Manders-Huits & Zimmer, 2009). A “values advocate” should be part of the development team to ensure and monitor the VSD framework process (Manders-Huits, 2011; Manders-Huits & Zimmer, 2009). He or she should support the identification and choice of stakeholders to involve in the process, make value conflicts and trade-offs explicit and second-guess and evaluate “… choices in light of overall (moral) aims” (Manders-Huits, 2011, p. 285). Manders-Huits and Zimmer (2009), in elaborating on what might be necessary for a “values advocate” to be accepted on a development team, point out that he or she must be perceived as someone with special expertise who makes rational and theoretically justifiable value considerations. This is certainly also necessary for a “value lead,” which puts an even higher emphasis on a solid education based on a well-designed curriculum.

Compared to VSD, IEEE Std. 7000 provides a clear picture of what kind of competencies a development team and value lead should have. While it is certainly difficult to find such employees in practice, this could certainly help to ensure that the use of this VOF promotes the development of ethical IS. In the following, I will explore whether and how VSD and IEEE Std. 7000 are compatible with market-driven agile development practices.

6.7.3 Agile Practices

Agile development practices also involve the performance of all aforementioned SE activities (see Section 2.1 *“Anchoring Ethical Issues”*), but in an interwoven and informal manner (Sommerville, 2016; Schmidt, 2016). Similarly, all necessary RE steps (see Section 2.2 *“Requirements Engineering”*) are performed in agile, but intermixed and integrated throughout the whole development process (Ramesh et al., 2010). Therefore, the theoretical and methodological contributions of VOF could be adapted to the currently popular agile development. It has been shown that the popular Scaled Agile Framework (SAFe) can be further enhanced to support the inclusion of human values (Hussain et al., 2022). The essence of agile development as articulated in the agile manifesto—putting people and interactions above processes and tools, working software above comprehensive documentation, working with customers above contract negotiations, and responding to change above following a plan—could be problematic, however (Fowler & Highsmith, 2001). The development context and demands on the team, the amount of upfront planning, transparency documentation, and extensive ethical investigations seem to be in direct conflict with the ideas of agile development (cf. Schmidt, 2016; Fowler & Highsmith, 2001).

VSD scholars actively aim for an integration into agile frameworks, for which the more flexible nature of VSD seems appropriate (Friedman et al., 2021). Overall, VSD practices appear to integrate seamlessly into an industrial setting, "...including conducting stakeholder analyses, harms and benefits analyses, and an empirical assessment of stakeholder views and values" (Miller et al., 2007, p. 289). Furthermore, one of VSD's key commitments to progress (practice) over perfection is in line with agile ideas (cf. Friedman & Hendry, 2019; Fowler & Highsmith, 2001). Winkler (2020) and others have already suggested possible implementations of VSD methods in agile development practices. However, I would recommend for VSD researchers to make such an adjustment wisely, as it should not come at the expense of developing innovative and ethical IS. Agile development practices rely on rapid software specification and implementation cycles, which can risk causing ethical issues or problems that are difficult to change after the fact (cf. Schmidt, 2016; Spiekermann, 2015). There may be a general disconnect between agile practices and value-oriented development that should be the subject of future research.

While IEEE Std. 7000 claims that it can be integrated into existing practices, "… including iterative and incremental life-cycle models and agile methods" (IEEE, 2021, p. 15), there is no known suggestion on how to do so. While this might—at this point in time—hinder the adaptation of IEEE Std. 7000, it can be interpreted as a true commitment to enable the necessary paradigm shift in SE. In the long run, I would like to call on IEEE Std. 7000 researchers to present a workable agile adaptation of this framework.

6.8 Summary

Considering the assumed origins of harmful IS described in Section 2.3 (*"Origins of Harmful Information Systems"*), unaccounted malicious use cases, lack of value consideration, system complexity, problem-solution inversion, market-driven development, both VOFs propose mitigation strategies. Both IEEE Std. 7000 and VSD are built on a continuous and iterative use of their methodology, which can help mitigate unaddressed malicious use cases and deal with system complexity. In addition, IEEE Std. 7000 aims to include adversary stakeholders who can help identify and subsequently mitigate potential malicious use. This framework also aims to establish control of SOS sub-components, which can help to deal with unpredictable consequences due to system complexity. Using values as a type of stakeholder expectation seems to prolong problem definition because more conceptual, hermeneutical and specifying work is required. This can help avoid problem-solution inversion, as design or solution decisions are made at a later time compared to the state of SE practice. A comprehensive transparency document, as suggested by IEEE Std. 7000, can help to make such problems visible, as it enables us to understand when and for what reasons a decision was made in favor of a particular solution. Because IEEE Std. 7000 methods place a particular emphasis on subsystems, for instance, during context exploration or ethical investigation, practitioners should be careful not to get attached to these too early. Given the market-driven development context, both frameworks recognize that time and expertise are needed to contain this potential source of harmful IS. Both frameworks suggest supporting roles—“value advocate” or “value lead”—to create a better development context. Most importantly, IEEE Std. 7000 suggests additional organizational aspects and team competencies. The VSD framework actively seeks to integrate with agile development, which should be approached with caution, as market-driven practices cannot promote the development of less harmful or ethical IS under the current circumstances.

Following mediation theory, both frameworks attempt to mitigate the lack of value considerations from the beginning of an SE project. As summarized in Section 5 (“*Framework Evaluation Concept*”), VSD and IEEE Std. 7000 should provide RE deliverables (RED) and meet the necessities of mediation theory. The theoretical and methodological commitments of both VOFs with regard to mediation theory necessities are summarized in Table 6.

Table 6: *Summary of mediation theory necessities (MTN) and VOF commitments*

Mediation Theory	VSD	IEEE Std. 7000
MTN 1: “Provide an in-depth analysis of the context of use”	**Theoretical:** Multi-lifespan Perspective, Iterations **Methodological:** Mock-up, Prototype, Field Deployment, Ethnography, Multi-lifespan Methods	**Theoretical:** Long-time frame, Pervasive perspective, ConOps, SOS-Controllability, Iterations **Methodological:** Feasibility Studies, Market Research, RACI Matrix

Mediation Theory	VSD	IEEE Std. 7000
MTN 2: “Identify and involve diverse stakeholders”	**Theoretical:** Stakeholder Roles, Multi-lifespan Perspective, Non-humans, Stakeholder Mapping **Methodological:** Stakeholder Analysis, Stakeholder Tokens, Brainstorming, Literature Review, Interviews	**Theoretical:** Classes **Methodological:** Potentially Feasibility Studies
MTN 3: “Conduct an investigation founded in moral philosophy” **MTN 4:** “Discover what stakeholder value”	**Theoretical:** Human Values, Implicit Utilitarian **Methodological**: Context Scenarios, Multi-modal	**Theoretical:** Material Values, Utilitarian Ethics, Virtue Ethics, Duty Ethics, Global Ethics **Methodological:** Context Scenarios, Moral Investigations
MTN 5: “Ensure prioritization and negotiation of values”	**Theoretical:** Values in Balance, Value Tension **Methodological**: Value Dams and Flows, Burmeister Method, Quantitative and Qualitative Methods	**Theoretical:** All Values are Important, Value Hierarchy **Methodological:** Emotion Value Assessment, Seven Ethical Criteria, Five Principles
MTN 6: “Translate values into system requirements in a traceable way”	**Theoretical:** Three-tiered Hierarchy **Methodological:** Regulations, Historical Reports, Design Activities	**Theoretical:** Material Values **Methodological:** IEEE Std. 7000 Method
HN 1: “Enable transparency and traceability of responsibility”	**Theoretical:** Make Values Explicit, Power Relations **Methodological:** None	**Theoretical:** Habermasian Discourse Ethics, Management Decision **Methodological:** Value Register, Case for Ethics
HN 2: “Establishing of an appropriate development context that ensures time and ethical guidance”	**Organizational Conditions:** Not Specified **Competency:** Value Advocate **Agile Practices:** Adaptations Exist	**Organizational Conditions:** Five Commitments **Competency:** Value Lead, Team Competencies **Agile Practices:** No Adaptation Available

Considering the first necessity to perform an in-depth analysis of the context of use (MTN 1), both provide theoretical foundations and methodology to achieve this. While IEEE Std. 7000 directly focuses on developing a ConOps document, VSD can contribute to it nevertheless. The IEEE Std. 7000's focus on SOS controllability is an attempt to mitigate the risks associated with system complexity. Furthermore, the framework's focus on additional feasibility studies could provide valuable additional insight and necessary rationale for early project abandonment. VSD's multi-lifespan perspective, with its associated methodology might provide a small edge compared to the 20-year time frame of IEEE Std. 7000. On the other hand, the pervasive perspective of IEEE Std. 7000—global with considerable maker-share—could raise ethical considerations.

Given the second necessity of mediation theory to identify and later involve diverse stakeholders (MTN 2), VSD takes a more dynamic approach by viewing stakeholders as roles rather than classes. With an added multi-year perspective, a focus on non-human entities, and mapping of stakeholder relationships, VSD is well equipped for stakeholder identification. Considering that IEEE Std. 7000 lists a variety of potential stakeholders and also experts from different fields, it could be assumed that this VOF can also achieve sufficient stakeholder identification. However, it might be unclear to practitioners which method is best for stakeholder identification. In a departure from the state of SE practice, both VOFs aim to engage indirect stakeholders, which could help provide insights into ethical issues.

There are major differences in the way VSD and IEEE Std. 7000 handle value discovery (MTN 4) and conduct moral investigations (MTN 3), which could potentially have a major impact on achieving the first RE outcome to provide the necessary insights and knowledge about stakeholder expectations (RED 1). According to made claims, both frameworks should deliver the insights and knowledge necessary to facilitate the development of innovative and ethical IS. The assumed relation between mediation theory necessities and RE deliverables can be seen in Figure 26.

The IEEE Std. 7000 conceptualization of values as material values allows the theoretical gap between values and system properties to be closed, providing a logical chain from stakeholder expectations to system requirements. Moreover, the material concept of value is itself theoretically grounded in ethics, though it seems unclear to VSD where the focus of morality and ethics—as part of the human definition of value—lies. The VSD concept of human value seems to be more closely related to SE stakeholder expectations (goals or needs), since in both cases stakeholders are the source of their meaning. Therefore, it makes sense for VSD to use multimodal methods for deeper meaning discovery. Although VSD recommends, it does not propose a particular moral investigation to determine whether a value concept is good or bad in simple ethical terms. It can, however, be assumed that implicitly a utilitarian perspective is taken. In contrast, IEEE Std. 7000 commits to a unique set of moral inquiries based on theories of utilitarianism, virtue ethics, and duty ethics. In addition, the choice of a global, culture-specific ethical theory is recommended. In order to live up to the claim of facilitating the development of ethical IS, a moral investigation should be conducted (MTN 4); in regard to this IEEE Std. 7000 clearly seems to have an edge over VSD.

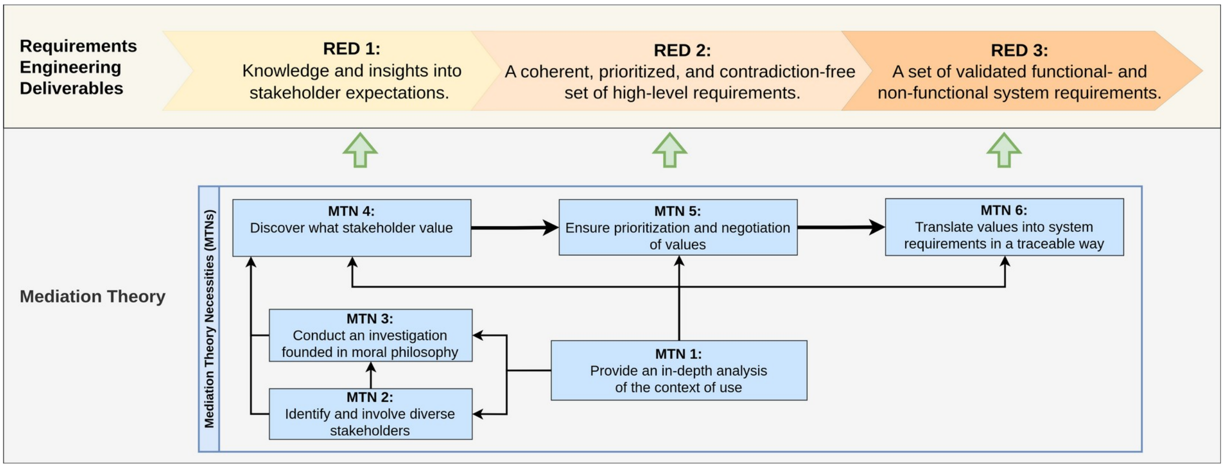


Figure 26: *Mediation theory necessities (MTNs) that impact RE deliverables (RED)*

Current SE practice requires a coherent, prioritized, and consistent set of stakeholder requirements (RED 2), for which values should be prioritized and negotiated (MTN 5). This is where the different value concepts of VSD (see Section 6.3.2.1 *"Human Values"*) and IEEE Std. 7000 (see Section 6.3.2.2 *"Material Values"*) are highly impactful. While material values do not need to be negotiated, human values must be negotiated and discussed at length between stakeholders, for which VSD provides the necessary theoretical foundations and methods. Based on the ethics of material values, IEEE Std. 7000 considers all values to be equally important and merely sets development priorities based on seven ethical criteria and five principles in accordance with the hierarchy of material values. Despite the theoretical foundations and methodology of IEEE Std. 7000, which does not regard that values can be in conflict with each other, practice must show whether it is possible to develop a successful system in this way.

To translate stakeholder requirements into system requirements in a traceable way (MTN 6), VSD practitioners rely in part on methods from the RE field, while the IEEE Std. 7000 framework provides the theoretical underpinnings, based on material value ethics, and the methodology to achieve this. The VSD framework proposes three pathways based on regulations, historical reports, and design activities to elicit the necessary system requirements. Most notably, IEEE Std. 7000 considers potential inhibitors for values, which could work well towards facilitating the development of ethical IS. Theoretically, both VOFs could achieve the specification of system requirements, with IEEE Std. 7000 having the advantage of showing a clear logical chain from system requirements to values, which is in line with necessary upward traceability.

The first hygiene necessity is mostly intended to enable engineers to take responsibility through transparency and traceability (HN 1). To ensure this, IEEE Std. 7000 provides an underlying process with unique methodology such as a value register and a case for ethics. While VSD aims to make values explicit and clarify power relationships, this VOF does not provide a methodology to ensure transparency and traceability. It is unclear, therefore, how VSD practitioners will accept responsibility or demonstrate that they have made efforts to create an ethical IS.

In many ways, it is critical to provide an appropriate development context (HN 2), not only to mitigate the presumed origin of harmful IS, but also to provide the necessary time and expertise to truly promote the development of ethical IS. IEEE Std. 7000 recommends five organizational aspects and several team competencies to ensure an appropriate development context. Both VOFs propose supporting roles either called “value advocate” or “value lead” to introduce the necessary competencies to an organization. However, the role within IEEE Std. 7000 of “value lead” appears to be much more specific and influential. Both VOFs attempt to integrate with the state of the practice of agile development; however, there is no known IEEE Std. 7000 adaptation for this at this time.

Considering the research question of this thesis, namely, to what extend VSD and IEEE Std. 7000 are equipped with the necessary theoretical foundation and methodology to meet the claim of enabling the development of innovative and ethical IS, the answer is yes—but with serious differences. The theoretical underpinnings of IEEE Std. 7000 and its associated methodology appear to have a much deeper foundation in ethics that could give this framework an edge. However, when it comes to a thorough analysis of the context of use and, in particular, the identification of stakeholders, VSD is very sophisticated. For the translation of values into system requirements, VSD practitioners must rely on the state of practice, while IEEE Std. 7000 provides its own theoretical background and methodology. For the necessities with regard to transparency and traceability as well as development context, IEEE Std. 7000 shows a higher commitment on a theoretical and methodological level. Overall, IEEE Std. 7000 appears to be a more streamlined framework, while VSD is much more flexible and open to incorporating methods from other domains. While IEEE Std. 7000 practitioners receive a compilation of all the necessary theoretical principles and methodology, VSD practitioners must include additional components.

In this section it could be shown that the proposed VOF EvalCon can help to systematize such frameworks, which allows us to compare them from a theoretical and methodological point of view. The results from an empirical study, as shown in the following section, will demonstrate how to measure the outcome of these VOFs at the system requirements level without developing a working product.

7. Empirical Investigation

According to SE, system requirements should, for instance, have quality characteristics such as consistency, technical feasibility, and freedom from implementation (see Section 2.2.4 *“Validated System Requirements”*). So far, however, no quality metrics exist that enable us to assess the innovative and ethical potential of system requirements. This is not only a major challenge for SE, as it is not possible to identify whether system requirements with potential ethical issues are incorporated into the system design, but also a challenge for evaluating VSD and IEEE Std. 7000’s claims to facilitate the development of innovative and ethical IS. Currently, only finished software can be roughly evaluated for its innovative or ethical properties using established technology assessment frameworks (cf. Wright, 2011; Grunwald, 2015). Therefore, to compare VSD and IEEE Std. 7000, the same software must be developed in parallel, each based on a different framework, to enable evaluation. Such an endeavor has never been undertaken because it is costly and controlling external factors—such as motivation, skills, and commitment of stakeholders and others—is nearly impossible. So far, VOFs have only been able to demonstrate their quality on the basis of case studies, which are not without limitations, for instance, in terms of the transferability of their findings to an industrial setting (see Section 5 *“Concept for Value-oriented Framework Evaluation”*). To enable assessment within an SE project without the need to develop a finished system, quality metrics for the innovative and ethical potential of system requirements were proposed in Section 4 (*“Novel Quality Metrics for System Requirements”*).

An important motivation for the following empirical study was to demonstrate and test the described quality metrics. In addition, the assumed relationship between needs and values, and the practitioners’ view that stakeholders can express the same expectations interchangeably well as needs, goals, or values, raises the question of whether it makes a difference which stakeholder expectation type is used (see Section 6.3.1 *“State of Practice: Goals or Needs”*). Moreover, the literal definition of human values, which includes an emphasis on morality and ethics, and the definition of material values, which is based on a material value ethic, raises the question of whether these on their own—without moral investigation—have implications for the ethical potential of system requirements (see Section 6.3.1 *“Novel to SE: Value Flavors”*). In addition, values are considered by many to be drivers of innovation (Nonaka & Takeuchi, 2011), which raises the question of whether the use of values leads to a higher innovative potential of system requirements compared to needs or goals. These considerations were formulated as the following research question for this empirical investigation:

- **Research Question:** "To what extend does the use of different stakeholder expectation types (goals, needs, human value or material values) affect the innovative and ethical potential of the resulting system requirements?"

The definitions of the ethical and innovative potential of system requirements defined in Section 4 (*"Novel Quality Metrics for System Requirements"*) are relevant to the formulation of hypotheses accompanying this question. Based on the literature on creativity, it is assumed that a system requirement with innovative potential is statistically rarer than others (original) and should be feasible, with technical maturity (see Section 4.2 *"Innovative Potential"*). The first two hypotheses cover the aspect of originality by considering the number of resulting system requirements (Hypothesis 1) and their originality (Hypothesis 2). The third hypothesis concerns the level of technical maturity (Hypothesis 3).

- **Hypothesis 1:** "The stakeholder expectation type used influences the number of resulting system requirements."
- **Hypothesis 2:** "The stakeholder expectation type used influences the originality of resulting system requirements."
- **Hypothesis 3:** "The stakeholder expectation type used influences the technical maturity of resulting system requirements."

Based on the five sustainability dimensions—individual, social, economic, environmental, and technical—proposed by Penzenstadler and Femmer (2013), the ethical potential of system requirements was defined as ideally having a positive impact on all dimensions (see Section 4.1 *"Ethical Potential"*). As a reminder, one might suspect that because of the importance of values for sustainability, using material values or human values as a form of stakeholder expectations might be advantageous here. However, in order to also be open to the possibility that the relationship between needs and human well-being has an effect (see Section 6.3.1 *"State of Practice: Goals or Needs"*), the fourth hypothesis assumes a general influence on sustainability (Hypothesis 4)

- **Hypothesis 4:** The stakeholder expectation type used influences the impact on sustainability of resulting system requirements.

These hypotheses are part of the research model for this empirical investigation, as shown in Figure 27.

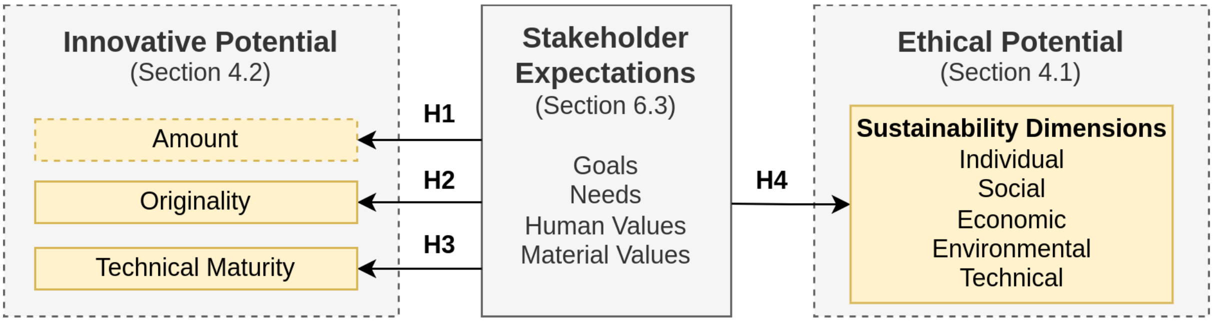


Figure 27: *Research model with hypothesis based in Section 4.1, 4.2 and 6.3*

7.1 Research Design

This research was conducted in three distinct steps: first, a pre-study to improve the research design (Section 7.1.1 *"Improve Research Design"*); second, a main study to gain high-level statements that can be used to obtain system requirements (Section 7.1.2 *"Obtain System Requirements"*); and third, an assessment study to evaluate the obtained system requirements (Section 7.1.3 *"Evaluate Requirements"*) according to their presumed impact on the sustainability dimensions and technical maturity. As a result of the main-study, obtained system requirements can be counted and an originality score calculated, answering hypotheses 1 and 2. The results of the assessment study, allows to answer hypotheses 3 and 4. The flow of the research design can be seen in Figure 28.

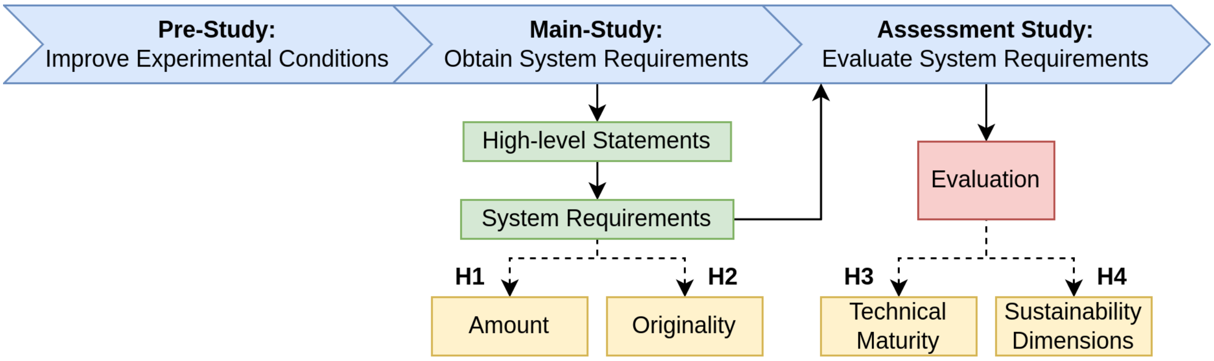


Figure 28: *Flow of research design with hypothesis*

For each study, the same hypothetical development case for a GIS was chosen, that is, systems such as Google Maps, Apple Maps, or OpenStreetMap. This development case was chosen because navigation applications are known to everyone and they offer a large number of possible functions. Furthermore, such systems are prone to bias (Quattrone et al., 2015; Wagner et al., 2021), but this is not discussed with such publicity that obvious answers are the result. Choosing a social media platform, on the other hand, would likely have raised mostly privacy-related requirements. The individual steps of the research design are described below.

7.1.1 Improve Experimental Conditions

The aim of the pre-study was to improve the experimental conditions. To this end, 224 participants were acquired via the university mailing list and took part in an online experiment. Within this experiment, each participant was randomly assigned to one of five conditions: One condition for each stakeholder expectations type—goals, needs, human values and material values—and an additional control condition which directly asked for functional and non-functional aspects of a GIS. Each participant was given the task to come up with high-level statements describing their expectations depending on the assigned condition. In each condition, a different description of stakeholder-type expectations, based on Section 6.3 (*"Stakeholder Expectations"*), was presented as stimulus material. These descriptions have been previously approved by subject matter experts from the Institute for Information Systems and Society.

A scale assessing the understandability of these descriptions showed a statistically significant difference between conditions, $\chi 2(4) = 15.34$, $p = .004$. A Dunns post-hoc test indicated that the user requirement definition ($M = 6.26$, $SD = 2.85$) was perceived as less understandable compared to the needs ($p = .020$, $M = 8.06$, $SD = 2.54$) and human values definition ($p = .004$, $M = 8.50$, $SD = 2.21$). These results and additional participant comments on an open question helped to finalize the user requirement definition to "User requirements describe which services an application should offer the user and under which restrictions the application should be operated." Participants spent on average 117 ($SD = 67$) seconds completing the task, producing an average of 2.94 ($SD = 1.21$) high-level statements.

To avoid superficial statements during the main study (Section 7.1.2 *"Obtain System Requirements"*), a minimum time of three minutes was set for the task, before which participants could not proceed. Furthermore, to maximize the effects of the experimental conditions, the task description was reformulated to "If one assumes that there is only one mobile navigation app on the market. In your opinion, what are [conditional: stakeholder expectation type] that a mobile navigation app should [conditional: expression] that should never be forgotten?”. By framing the task context as there being only one app on the market, the intention is to convey pervasiveness —participants cannot switch to another app. Depending on the assigned condition, the given description—presented to the participants as a definition—was changed, stakeholder expectation type and related expression was condition dependent as well. This is to clarify the differences between the various stakeholder expectations, for example, that goals help to achieve something, while a need is to satisfy something. Figure 29 shows an example stimulus material for the goal condition as used in the main study. All stimulus materials and questionnaires used in the following main-study can be found in Appendix B (*“Experimental Setting”*).

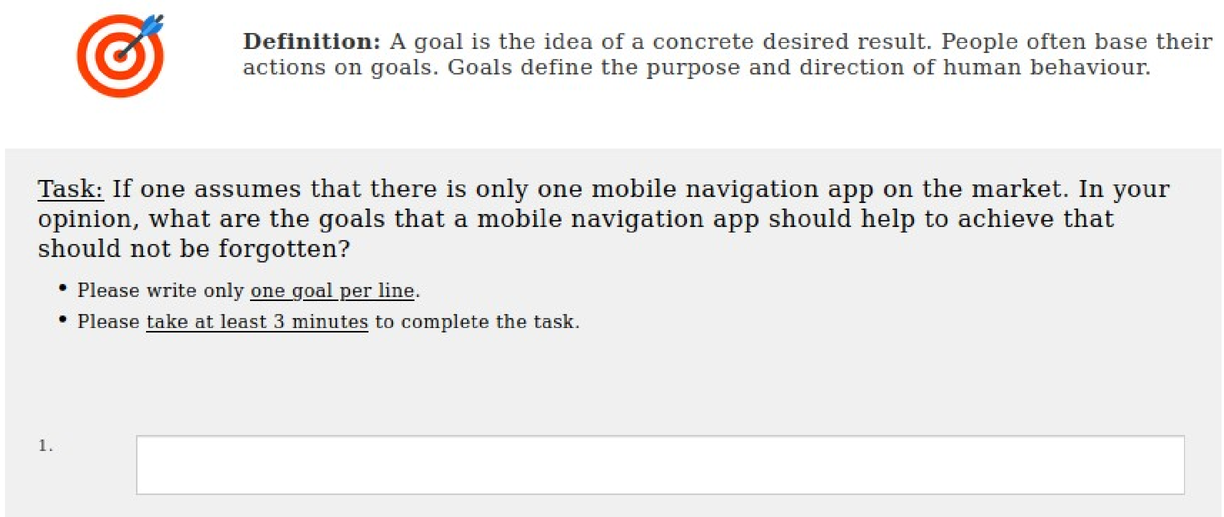


Figure 29: *Stimulus material for the goal condition*

7.1.2 Obtain System Requirements

The goal of the main-study was do gain high-level statements based on different experimental conditions—goals, needs, human values and material values—that would allow system requirements to be coded and thereby obtained. For this purpose, another set of participants was recruited through the university's mailing list and incentivized with a raffle of 20 vouchers worth 15 euros each. In a one-month period between April and May, 2020, 297 participants completed the impoved version of the online experiment base on insight from the pre-study (see Section 7.1.1 *“Improve Experimental Conditions”*). Two items assessing the work and response habits led to the exclusion of 4 participants.

A total of 293 participants, of whom 239 (81.56%) chose the German and the others the English version of the online experiment, were included in the final analysis. Of these 293 participants, 174 (59.39%) identify themselves as female, 116 (39.59%) as male, and the rest as another gender. A majority of participants were students (84.98%) with a mean age of 23.35 (SD = 5.13). All participants reported frequent use of mobile navigation applications—on a scale of 5 from “never” to “all of the time”—and can therefore be considered knowledgeable enough to make the necessary high-level statements. Items assessing participants’ skills related to creativity (verbal ability, reasoning ability, goal-oriented attainment) based on Sternberg’s implicit theory (Sternberg, 1985) and a 4-item creative self-image questionnaire (Trischler et al., 2018) yielded no statistical significance between conditions. Therefore, the differences between the high-level statements gained and the subsequently coded system requirements should not be attributed to a different level of creativity.

Following the same procedure as the pre-study, participants were randomly assigned to one of the five experimental conditions. Each participant was presented with either a description of goals, needs, human values, material values, or user requirements, and was tasked with making high-level statements about what should not be forgotten during development, assuming that there is only one mobile navigation application on the market. The description of the stakeholders' expectations—which were presented to the participants as definitions—and the formulation of the tasks were based on considerations after the pre-study (see Section 7.1.1 “*Improve Experimental Conditions*”). The descriptions and tasks used for each experimental condition are listed in Table 7 and were presented to participants in the same manner as shown in Figure 29. Using the same understandability scale as in the pre-study showed no significant difference between conditions, so the improvement in user requirements descriptive is effective (see Section 7.1.1 “*Improve Experimental Conditions*”). In addition, an open-ended question was asked at the end of the online experiment to test participants' ability to recall the stakeholder expectations presented in their individual condition. Coding these answers as true or false and comparing them did not differ statistically significantly between conditions.

As an improvement over the pre-study, the minimum task time was set at three minutes, which resulted in participants taking an average of 4.9 minutes to produce an overall of 4.39 (SD = 1.59) high-level statements. This minimum task time was established based on the findings of the pre-study (see Section 7.1.1 “*Improve Experimental Conditions*”) to ensure that sufficient, rather than superficial, statements were made to allow for subsequent coding and decomposition into system requirements.

Table 7: *Experimental conditions based on Section 6.3*

Conditions	Presented Description and Task
Goals	• **Definition:** A goal is the idea of a concrete desired result. People often base their actions on goals. Goals define the purpose and direction of human behaviour. ○ **Task:** If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the [goals] that a mobile navigation app should [help to achieve] that should not be forgotten?
Needs	• **Definition:** Needs describe psychological conditions that are essential for personal development, performance and well-being. In short, needs describe the conditions under which people can best develop their potential. When needs are not met, people focus on meeting them. ○ **Task:** If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the [needs] that a mobile navigation app should [satisfy] that should never be forgotten?
Human Values	• **Definition:** Values reflect what is important to a person in life and often have an emphasis on ethics and morals. Human activities or actions often reflect their values. ○ **Task:** If one assumes that there is only one mobile navigation app on the market. In your opinion, what are [values] that a mobile navigation app should [embody] that should never be forgotten?
Material Values	• **Definition:** Values are clear objects of thought that influence the actions of people. Positive values are perceived as something fundamentally desirable and influence the choice of available paths, means and goals. People, things, relationships and activities are carriers of values in a given situation. Values can be positive or negative, whereby positive values are intuitively perceived as attractive and negative values as repulsive. ○ **Task:** If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the [values] that a mobile navigation app should [carry] that should never be forgotten?
User Requirements	• **Definition:** User requirements describe which services an application should offer the user and under which restrictions the application should be operated. ○ **Task:** If one assumes that there is only one mobile navigation app on the market. In your opinion, what are [user requirements] that a mobile navigation app should [meet] that should not be forgotten?

The collected high-level statements were coded by the author of this thesis and decomposed into functional and non-functional system requirements according to the systems and software engineering vocabulary of ISO 24765 (2017b). This was done until the whole meaning of a high-level statement was represented by functional and non-functional system requirements. To ensure that the high-level statements were correctly transformed and are a valid representation of stakeholder expectations (ISO, 2011a), a second coder—student researcher—used the coding manual to also decompose the collected high-level statements. To avoid bias, both coders were blind to the experimental condition from which a high-level statement originated. A Cohen's Kappa inter-coder reliability of $\kappa = 0.79$ for the functional and $\kappa = 0.76$ for the non-functional was requirements was calculated, which indicates a substantial agreement (Landis & Koch, 1977). As proposed by Carey et al. (1996) the inter-coder discrepancies were resolved by the senior researcher, in this case the author of the thesis. This practice resulted in a coding manual containing 40 functional requirements, as can be seen in Appendix C (*"Functional System Requirements"*) and 49 non-functional requirements, as can be seen in Appendix D (*"Non-functional System Requirements"*). In this coding manual, functional aspects are formulated such as "The app should provide the arrival time" under, for instance, the non-functional condition "The app should provide precise times."

Counting the resulting system requirements allows to answer Hypothesis 1 and calculating the originality score allows to answer Hypothesis 2. To test Hypothesis 2, the originality score for each individual functional and non-functional system requirements must be calculated. For each individual requirement the number of occurrences was counted and divided by the total count of a particular requirement type (functional or non-functional), which resulted in a requirement quotient (REQ). To ensure that a high score represents high originality, REQ was subtracted from one, as is customary in creativity research (Jansson & Smith, 1991; Bednar & Spiekermann, 2020). The formula for calculating originality scores for a single requirement type can be seen in Figure 30. Afterwards, two mean originality scores were calculated for each individual participant, one for the functional and the other for the non-functional system requirements, depending on what could be decomposed from her or his high-level statements. In this way, for each type of system requirements—functional and non-functional—a overall mean originality score can be calculated for each experimental condition (goals, needs, human values, material values) and the control condition (user requirements). Thereby, the influence of the individual stakeholder expectation types on the originality of the system requirements can be compared (Hypothesis 2).

$$Originality = \frac{1}{k} \sum_{i=1}^{k} (1 - \mathrm{REQ}_1)$$

Figure 30: *Formula for calculating originality (based on Bednar & Spiekermann, 2020)*

The 89 system requirements (40 functional and 49 non-functional) formulated in the coding manual formed the starting point for the assessment study described below.

7.1.3 Evaluate System Requirements

The goal of the assessment study was for participants to evaluate the formulated system requirements that were gained during the main study (see Section 7.1.2 *"Obtaining System Requirements"*). For this purpose, an additional group of 178 participants was recruited through the university mailing list. For each participant a set of 11 system requirements was randomly drawn from the overall 89 requirements in the coding manual (Appendix C and D). This set of requirements was presented to the participants six times in random order, with a specific evaluation dimension given each time. Five evaluation dimensions for each sub-impact on sustainability—individual, social, economic, environmental, technical—and one for technical maturity were presented (see Section 2.4 *"Impact on Sustainability Dimension"* and Section 4.2 *"Innovative Potential").* The sequence in which the evaluation dimensions were presented was individual (at random) for each participant to avoid order effects. A description of a single dimension was presented, as shown in Figure 32, followed by the set of requirements, along with the question "How would you rate the effect of each requirement (left column) for a navigation app on [conditional: name]?". The name specified in the question was changed depending on the current evaluation dimension.

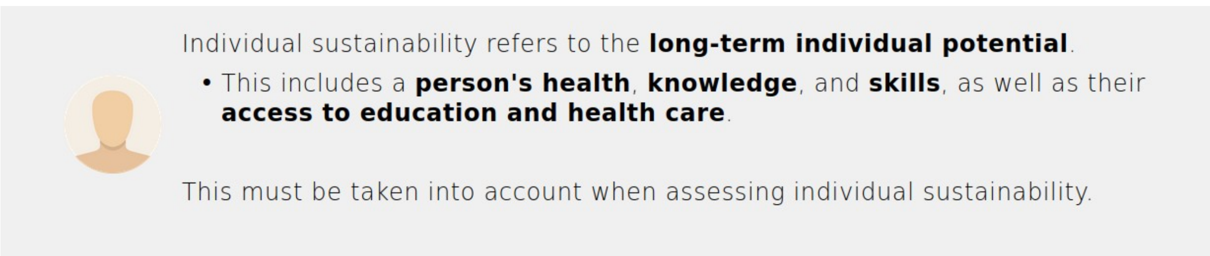


Figure 31: *Description of evaluation required for individual sustainability*

Each participant had to rate individual system requirements according to the expected impact on the currently described dimensions using a 7-point Likert scale ranging from “very negative” to “very positive.” All presented dimension descriptions can be seen in Table 8. Rating results on the level of technical maturity allows to answer Hypothesis 3, while rating results on the five sustainability dimensions allows to answer Hypothesis 4. Participants indicated on a 5-point Likert scale ranging from “not true” to “true” that they had no problems understanding the evaluation dimensions or the presented requirements.

Table 8: *Evaluation Dimensions based on Section 2.4 and Section 4.2*

Name	Presented Description
Individual Sustainability	• Individual sustainability refers to the **long-term individual potential**. ○ This includes a **person's health**, **knowledge**, and **skills**, as well as their **access to education and health care**.
Social Sustainability	• Social sustainability refers to a **long-term stable society based on solidarity**. ○ For this, **shared values**, **equal rights**, **laws** and **information**, as well as **active participation and communication within society** are essential.
Economic Sustainability	• Economic sustainability refers to the **long-term value creation** and **productivity**. ○ To achieve this, **goods**, **time** and **money** must be protected from depletion, and **investments** must be protected from risk.
Environmental Sustainability	• Environmental sustainability refers to the **protection of natural resources** and **ecosystem services**. ○ For this, impact on the environment through **resource consumption** and the **release of emissions or waste** must be considered.
Technical Sustainability	• Technical sustainability refers to the **long-term usage** of an app. ○ Essential for this is the **continuous development (updates)** as well as the **adaptability** of an app.
Technical Maturity	• Technical maturity refers to the **implementation quality** of a requirement placed on the app. ○ This means the absence of **technical obstacles** and **bugs**, as well as the elimination of **inconsistencies** and **difficulties** during development.

Finally, a manipulation check, in which participants were asked to assign relevant aspects of the presented description to a particular dimension, resulted in the exclusion of 16 participants. A total of 162 participants were included in the final analysis, of which 137 (84.57%) chose the German version and the others the English version of the online experiment. Of these 162 participants, 96 (53.63%) identify as female, 62 (34.64%) as male, and the rest as another gender.

The majority of participants are students (86.08%) in the field of business and law (76.44%) with an average age of 23.13 (± 5.68). All further analyses were performed using the programming language R. The results of our hypothesis testing will be presented in the next section.

7.2 Results and Discussion

This empirical investigation serves to demonstrate that system requirements can be evaluated according to their innovative and ethical potential (see Section 4 *"Novel Quality Metrics for System Requirements"*). For the various stakeholder expectations—goals, needs, human values, material values—high-level statements were collected during the main study. It is worth noting that gaining these was not based on any sophisticated VOF discovery methodology, as described in Section 6.3.3 (*"Value Discovery"*). It is therefore merely a test of whether different stakeholder expectation descriptions on their own can result in innovative or ethical potential. For all following analysis, a Kruskal-Wallis H test, robust to deviation from normal distribution and appropriate for count data, followed by a Dunn's post-hoc test with Bonferroni correction, was used.

7.2.1 Innovative Potential

In the main study, participants spent a mean time of 4.9 minutes on producing an average of 4.39 (SD = 1.59) high-level statements. These statements were further decomposed, resulting in an average of 3.17 (SD = 2.26) functional and 3.83 (SD = 1.77) non-functional requirements per participant. To test Hypothesis 1 and its assumption that different stakeholder expectation types influence the number of resulting system requirements, these were counted for each experimental condition. This comparison shows a statistically significant difference for the number of decomposed functional system requirements ($\chi2(4) = 13.21$, $p = .01$). The post-hoc test shows that high-level statements from the material value condition could be decomposed into statistically significant fewer functional system requirements (M = 2.23, SD = 1.84) compared to statements from the goals ($p = .005$, M = 3.44, SD = 2.11) or the control condition ($p = .008$, M = 3.63, SD = 2.60). For the number of decomposed non-functional system requirements, no statistically significant difference could be found. The statistically significant difference in the number of functional system requirements between conditions is shown in Figure 32.

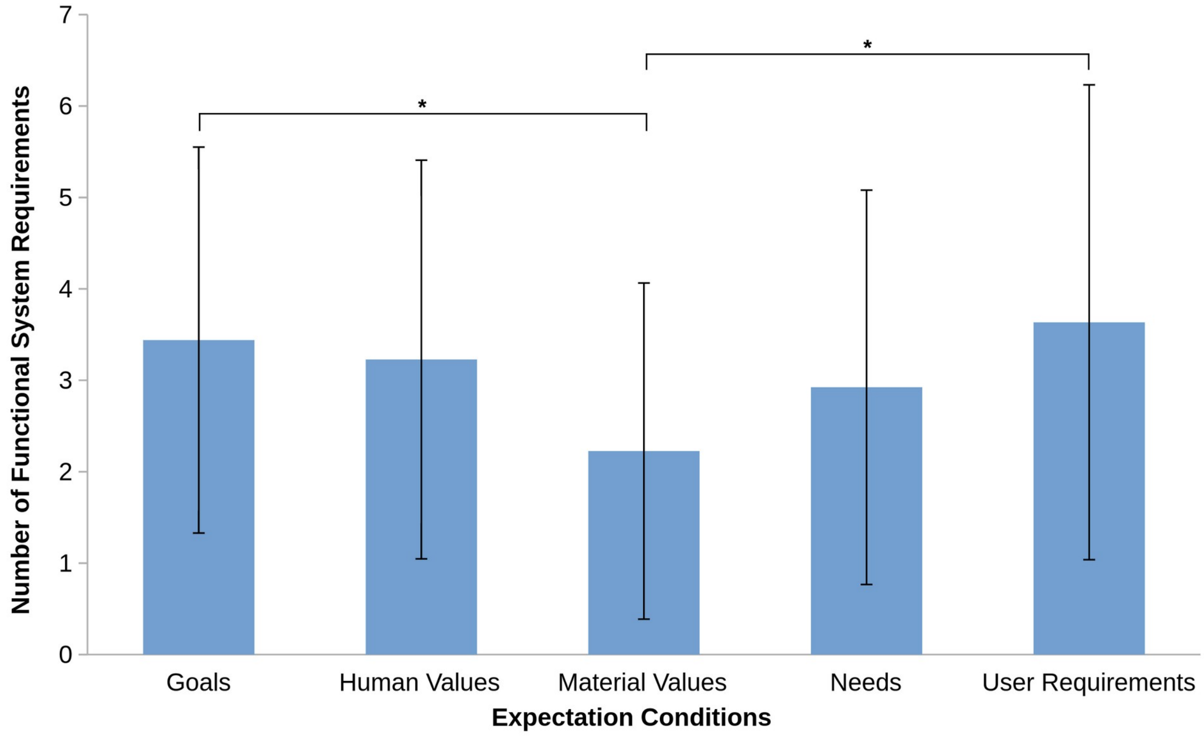


Figure 32: *Material value condition leading to less functional system requirements compared to goals (p = .005) and user requirements (p = .008)*

Since values tend to overlap with the list of non-functional system requirements, one might have expected that these have an advantages in gaining non-functional aspects (cf. Mairiza et al., 2010; Winkler & Spiekermann, 2019). However, this could not be proven here. It could be shown that goals lead to significantly more functional system requirements, which is consistent with the literature, and assumes a direct relationship between goal and functionality (Regev & Wegmann, 2005). It is worth noting that the material value condition yielded a higher proportion of non-functional system requirements than functional system requirements compared to other conditions. In practice, this leads to less functionality with more non-functional constraints and quality demands. This could potentially lead to a more innovative system design (see Section 4.2 *"Innovative Potential"*). The availability of non-functional system requirements should not be underestimated, since a lack of these lead to low software quality, dissatisfied stakeholder expectations and high costs (Mairiza et al., 2010; Chung et al., 2000; Chung & do Prado Leite, 2009).

With respect to Hypothesis 2 and its assumption that different stakeholder expectation types influence the originality of the resulting system requirements, the calculated originality score (see Figure 30 in Section 7.1.2 *“Obtain System Requirements”*) yields a statistically significant difference for non-functional system requirements between conditions ($\chi 2(4) = 10.188$, $p = .037$). The post-hoc test shows that high-level statements from the human value condition resulted in statistically significant higher originality scores ($M = 0.96$, $SD = 0.017$) compared to statements from the control condition ($p = .01$, $M = 0.95$, $SD = 0.017$). No statistically significant difference could be found between conditions for functional system requirements. The result may indicate that it is beneficial to use human values to gain more original non-functional system requirements. Having especially original non-functional system requirements such as, in this case, dealing with “accessibility for elderly,” “consideration of ethical constraints,” or “reliability” and “maintainability” could be beneficial, leading to a more innovative system design.

Considering Hypothesis 3 and the assumed difference on the level of technical maturity of system requirements, a comparison shows a statistically significant difference ($\chi 2(4) = 10.786$, $p = .029$) for non-functional system requirements. The post-hoc test yields requirements based on the material value condition ($M = 5.91$, $SD = 0.27$) have a statistically significant higher positive impact on the technical maturity compared to those of the goal condition ($M = 5.76$, $SD = 0.27$). No statistically significant difference could be found between conditions for functional system requirements. Considering that using goals is state of practice in SE (see Section 6.3.1 *“State of Practice: Goals or Needs”*), which supposedly should focus on achieving technical maturity, this is an astonishing result. Practitioners could benefit from using the material value concept to achieve a system design with technically more mature functionality.

In summary, innovative potential of system requirements was defined in Section 4.2 (*“Innovative Potential”*) as highly original—rarer compared to more popular ones—and capable of solving practical problems by being achievable with a certain degree of technical maturity. Both VOF value types—material values and human values—seem to have a slight influence on the innovative potential of resulting system requirements. In particular, human values produce more original non-functional system requirements, whereas material values seem to be more feasible than functional system requirements based on goals. While this is partially encouraging for the claim of facilitating the development of innovative IS, whether this is sufficient to crown values as a driver of innovation (Nonaka & Takeuchi, 2011) requires further empirical research.

7.2.2 Ethical Potential

Considering Hypothesis 4, by comparing the impact on the five sustainability dimensions (individual, social, economic, environmental and technical), shows a statistically significant difference between conditions for non-functional system requirements on the economic sustainability dimension ($\chi2(4) = 10.786$, $p = .029$). Post-hoc comparison for the economic sustainability dimension shows a statistically significant lower positive impact of the human values condition ($M = 5.61$, $SD = 0.29$) compared to the user requirement condition ($p = .02$, $M = 5.75$, $SD = 0.24$). All other sustainability dimensions showed no significant difference between conditions. Human values seem to have a slightly lower positive influence—one of five dimensions—on the ethical potential of system requirements as was defined in Section 4.1 (*"Ethical Potential"*). This result is by no means sufficient to condemn the human value concept of having less ethical potential. The result might indicate, however, that explicitly stating a project to have "a focus on ethics and morality" (Friedman & Hendry, 2019, p. 4) seems not to be enough to produce requirements with an ethical potential. This underscores the need for appropriate moral investigations, as provided by IEEE Std. 7000. As a reminder, the suggestion that the discovery of values without an ethical frame is merely a representation of individual preferences (Reijers & Gordijn, 2019) seems to be a correct conclusion.

The fact that no real measurable impact on the ethical potential of system requirements has been identified does not necessarily mean that this quality metric does not work. Involving more diverse stakeholders—for instance indirect stakeholders—as foreseen by VOFs (see Section 6.2 *"Stakeholder Identification"*), and encouraging the deeper involvement of stakeholders (compared to an average of just 4.9 minutes), could have led to more measurable ethical potential. Future research should also examine whether experts on sustainability would have rated system requirements differently.

7.3 Summary

This empirical study demonstrated a potential process necessary to validate the innovative and ethical potential of system requirements. The inability to measure the claims made by VSD and IEEE Std. 7000 to facilitate the development of innovative or ethical IS is a gap that should be addressed. While human values produce more original non-functional system requirements and material values seem to be more feasible than functional system requirements based on goals, this is not enough to claim innovative potential. Furthermore, having a slightly lower positive impact on economic sustainability is not enough to assume less ethical potential for human values. The results of this empirical study underscore that the theoretical foundations and methodologies of the frameworks are an orchestrated combination that should not be used independently. It is not enough to simply switch from goals or needs to human values or material values as some SE practitioners might assume.

Although the results of this empirical investigation are inconclusive, the defining and testing of novel quality metrics for system requirements may have long-term benefits. Future research should evaluate the contribution of other VOF-specific theoretical foundations and methodology to innovative and ethical potential.

8. Thesis Conclusion

In advance of the proposed concept of VOF evaluation (Section 5 *“Concept for Value-oriented Framework Evaluation”*), it has been shown that the state of practice in SE is not able to consider or resolve ethical issues during its activities (Section 2.1 *“Anchoring Ethical Issues”*). Such issues seem to be introduced mainly during the initial SE activities and especially during RE. It could also be shown that certain deliverables are required for any VOF that wants to steer SE (Section 2.2 *“Requirements Engineering”*). Furthermore, it has been shown that in addition to the inability to consider and resolve ethical issues, SE has many other problems that are the origin of harmful IS in the modern world (Section 2.3 *“Origins of Harmful Information Systems”*). These origins have serious implications for how IS are engineered, and their impacts can be considered harmful along five different dimensions of sustainability—individual, social, economic, environmental and technical (Section 2.4 *“Impact on Sustainability Dimensions”*). This highlighted the need for a paradigm shift in the way SE is conducted. VOFs have been introduced—notably VSD and IEEE Std. 7000—that promise to put such a paradigm shift into practice by extending the first critical SE activities (Section 3.1 *“Value-oriented Frameworks”*). Mediation theory was then presented as a philosophical perspective that can form the basis for evaluation by outlining certain necessities that VOFs must meet in order to put this theory into practice (Section 3.2 *“Mediation Theory”*). Putting mediation theory into practice could represent a paradigm shift for SE, as it introduces a new perspective on human-technology relationships as being value-laden and with moral significance. As a last aspect of the VOF EvalCon, quality metrics regarding the innovative and ethical potential of system requirements were conceptualized (Section 4 *“Novel Quality Metrics for System Requirements”*). Finally, the VOF EvalCon combines all the desired deliverables from a RE point of view, the necessities for putting mediation theory into practice, and the newly proposed quality metrics.

8.1 Contributions

This thesis provides a synthesis of the assumed origins of harmful IS and their implications for the sustainability of the resulting systems (Section 2.3 *“Origins of Harmful Information Systems”* and Section 2.4 *“Impact on Sustainability Dimensions”*). This contribution aims to raise awareness of the need to change the way SE is practiced and also suggests several ways to mitigate the current situation. Above all, considering values from the outset of a project by putting VOFs into practice is an essential path to more ethical, innovative, and sustainable IS. To this end, Appendix A (*“Values in Relation to Sustainability”*) provides a comprehensive list of values related to sustainability dimensions.

The question of the extent to which VSD and IEEE Std. 7000 are equipped with the necessary theoretical foundation and methodology to meet the claim of enabling the development of innovative and ethical IS was explored. To approach this question, an evaluation concept was formulated (Section 5 *“Concept for Value-oriented Framework Evaluation”*) to systematize and evaluate VSD and IEEE Std. 7000. The proposed VOF EvalCon can also enable the systematization of the other 18 VOFs and enable the identification of their strengths and potential gaps. This can contribute to the further evolution of VOFs. In addition, this concept can help practitioners to select a VOF that has the necessary theoretical foundation and methodology, or to choose a specific VOF aspect for a particular SE task.

In the context of the VOF EvalCon, novel quality metrics were proposed to measure the innovative and ethical potential of system requirements. These quality metrics can help measure the claims made to facilitate the development of innovative and ethical IS without having to develop a final product. From a research perspective, these quality metrics can help further improve VOFs by making their claims measurable. In practice such metrics might prevent the introduction of problematic system requirements or help to identify particularly desirable requirements.

Using the VOF EvalCon, the major theoretical and methodological commitments of VSD and IEEE Std. 7000 were systematically compared (Section 6 *“Theoretical Foundations and Methodology”*). This comparison and the theoretical foundations and methods listed can be a good starting point, especially for novices who want to use these VOFs for the first time. However, the overview presented can also be valuable for experienced VOF practitioners to grasp what theories and methods are available.

Both VSD and IEEE Std. 7000 appear to have the necessary theoretical foundation and methodology to meet the claim of enabling the development of innovative and ethical IS, but with important differences. When considering the context of use, VSD is distinguished by its multi-lifespan perspective, while IEEE St. 7000 demonstrates an important commitment to alignment with the state of SE practice and its pervasive perspective (Section 6.1 *“Context of Use”*). When it comes to stakeholder identification, VSD stands out for its role-based stakeholder concept and associated methodology. Huge differences arise between both VOFs due to different value definitions (Section 6.3.2 *“Novel to SE: Value Flavors”*). The IEEE Std.

7000's material value concept is grounded in ethics and endeavors to close the theoretical gap between values and system properties. On the other hand, VSD's concept of human values seems to be closer to stakeholder expectations in practice and, although it mentions ethics and morality in name, has no theoretical basis in ethics. In addition, IEEE Std. 7000 value discovery includes moral investigations, which is a task that VSD practitioners must solve themselves (Section 6.3.3 *"Value Discovery"*). If this is not resolved by practitioners, it could be a serious challenge to VSD's claim to facilitate the development of ethical IS. Prioritization and negotiation are also severely affected by differences in the theoretical foundations of values. While IEEE Std. 7000, which is based on material value ethics, considers all core values equally important and merely sets development priorities with the appropriate methodology, VSD human values need to be negotiated and discussed at length among stakeholders, as it is the state of practice in SE for goals and needs (Section 6.4 *"Prioritization and Negotiation"*). While this demonstrates the continued commitment of IEEE Std. 7000 to ethics, practice must show whether so many value obligations can be fulfilled. In theory, both VOFs are capable of specifying system requirements. However, while VSD practitioners must work with RE methods, IEEE Std. 7000 practitioners have the advantage of their own method that can provide a logical chain of system requirements to values (Section 6.5 *"Translation of Values into System Requirements"*). Taking into account the situational aspect, which is not directly related to development but is nonetheless important, IEEE Std. 7000 provides a process to ensure transparency and traceability with the appropriate methodology, while VSD is surprisingly vague in this regard (Section 6.6 *"Transparency and Traceability"*). Similarly, IEEE Std. 7000 provides a fairly clear idea of organizational conditions and required competencies, while VSD remains vague in this regard (Section 6.7 *"Development Context"*). However, at this time, there is no known attempt to apply IEEE Std. 7000 to agile development practices, which do exist for VSD.

In summary, the theoretical underpinnings of IEEE Std. 7000 and its associated methodology provide a more explicit ethical foundation compared to VSD. Overall, IEEE Std. 7000 appears to be a more cohesive or streamlined framework, while VSD is much more flexible and open to incorporating methodologies from other fields. In terms of the claim to facilitate the development of innovative and ethical IS, this could be an advantage for IEEE Std. 7000, but when it comes to industry implementation, VSDs could have an edge. Consistent with Hussain's et al. (2020) recommendation to systematically identify activities where values can be considered and then adjust existing practices accordingly, the flexibility and less coherent nature of VSD is convenient.

8.2 Limitations and Future Research

Often it doesn't matter how something is branded, whether as "value sensitive" or "ethically aligned"; what matters is the implementation (Maedche, 2017). Only implementation in industry can really show which framework can meet the claims made. With this in mind, it is clear that an evaluation, as done in this thesis, of the theoretical foundations and methodology of VSD and IEEE Std. 7000 has its limitations. Ultimately, it is important that such theories and methods can be successfully put into practice, which requires flexibility and experience on the part of practitioners. Nevertheless, theories and methods help to gain, structure and communicate knowledge which is essential for the success of any SE project. Especially for beginners who do not yet have the necessary practical experience, I consider a systematization of existing theories and methods to be extremely relevant. At the same time, experienced VOF practitioners and researchers should know what theories and methods exist in their field and what gaps might exist. For example, it became clear in this thesis that neither VSD nor IEEE Std. 7000 provide the theoretical foundation or methodology to meaningfully limit the number of stakeholders to be considered, which could be the subject of future research. Although both VOFs recognize the importance of training, there does not appear to be a curriculum that enables SE teams to acquire the necessary competencies and skills.

The field of VOFs is dynamic and ever-changing, so not all theoretical and methodological commitments of VSD or IEEE Std. 7000 are included in this thesis. While in the past VSD has been criticized for providing limited guidance on implementing certain methods (Burmeister, 2016), this has drastically changed in recent years. Friedmann and Hendry (2019) provide a good overview on necessary theoretical foundations and available methodology. The same goes for IEEE Std. 7000, for which, by the time this thesis is published, a new textbook—*Value-Based Engineering: A Guide to Building Ethical Technology for Humanity*—is available (Spiekermann, 2023). This textbook is providing a working definition of material values as follows: "Values are phenomena disclosing the degree of desirability of something or someone, giving meaning to and motivating the selection of available modes, means and ends of action" (Spiekermann, 2023, p. 47). Furthermore, it also better aligns IEEE Std. 7000 with the terminology of material value ethics and provides ten essential guiding principles.

Based on the presented VOF EvalCon, future research could seek to complete the systematization with as much theoretical foundation and methodology from VSD and IEEE Std. 7000 as possible. Since the concept was formulated in such a way that it can be generalized to other VOFs, it seems reasonable to include them as part of future research. This could provide a comprehensive overview of available theoretical foundations and methods, which would be a good starting point for practitioners and prevent the reintroduction of existing concepts and methods.

The proposed novel quality metrics (Section 4 *“Novel Quality Metrics for System Requirements”*) can help to measure VOF claims without having to develop a final product. Future research in this area should aim to further improve and test these quality metrics. In addition to examining the impact of stakeholder expectation types on the innovative and ethical potential of system requirements (see Section 7, *“Empirical Investigation”*), future research could also assess the impact of other aspects, such as stakeholder identification, moral investigation, value prioritization, and others. Such insights could help improve theory and methods and provide a measurable justification for the use of VOFs in SE practice.

Although the utility of value lists is controversial, such lists can be a helpful starting point for developing sustainable IS. While the comprehensive list attached to this thesis establishes a relationship between values and sustainability (see Appendix A *“Values in Relation to Sustainability”*), future research is needed to substantiate this relationship. Future research could also aim to align values with the United Nations SDGs.

This work was written with practitioners in mind and is intended to provide engineers with a starting point for improving their current SE practices with theoretical foundations and methodology from VSD or IEEE Std. 7000, in particular. Therefore, I would like to conclude this thesis with some recommendations for VOF novices.

8.3 Recommendations

The following list is a synthesis of key recommendations that practitioners should take into account when applying a VOF in practice. These recommendations are based on considerations about VSD and IEEE Std. 7000 made in Section 6 (*“Theoretical Foundations and Methodology”*), but are equally relevant for any VOF.

- An iterative approach is essential to address changing use contexts, emerging malicious use cases, unforeseen effects, and gaining moral insights (see Section 6.1 *“Context of Use”*).

- Early project abandonment may be required, for which adequate justification must be provided (see Section 6.1 *“Context of Use”)*.
- Consideration of pervasive use and a long time frame can help reveal potential ethical issues (see Section 6.1 *“Context of Use”*).
- A subsystem should be selected based on the specified requirements and after assessing its controllability (see Section 6.1 *“Context of Use”*).
- Extending established SE practices can facilitate the implementation of VOFs in practice, but should not come at the expense of developing innovative and ethical IS (see Section 6.1 *“Context of Use”*).
- Understanding stakeholders as dynamic roles with contextual identities can ensure comprehensive identification and contextual understanding of relevant aspects (see Section 6.2 *“Stakeholder Identification”*).
- Consideration of diverse stakeholders, including non-human entities, indirect, future, and stigmatized stakeholders, helps prevent the development of harmful systems (see Section 6.2 *“Stakeholder Identification”*).
- Although stakeholder representation may be necessary in some cases, relying solely on representatives or experts can severely limit the quality of the insights gained (see Section 6.2 *“Stakeholder Identification”*).
- Working with values should be based on a solid theoretical foundation that links values to other relevant concepts (see Section 6.3.2 *“Novel to SE: Value Flavors”*).
- SE should be guided by moral values and not only by the individual preferences of stakeholders, for which conducting moral investigations is essential (see Section 6.3.3 *“Value Discovery”*).
- Moral investigations should be open to diverse perspectives, explicitly conducted, theoretically founded, and require expertise and training (see Section 6.3.3 *“Value Discovery”*).
- A diligent conceptualization of values and a solid theoretical foundation can be a way to resolve conflicts without compromising moral commitments (see Section 6.4 *“Prioritization and Negotiation”*).

- The translation of values into system requirements should be traceable, and based on established methods (see Section 6.5 *"Translation of Values into System Requirements"*)
- All essential insights and decisions should be documented in a transparent and traceable manner and made available to stakeholders (see Section 6.6 *"Transparency and Traceability"*).
- A development context should be created that enables a commitment to quality by providing the necessary time, resources, training, and management support (see Section 6.7 *"Development Context"*).

For each of the above, the referenced sections can be a starting point for VOF practitioners to address these recommendations based on the theoretical foundations and methodology of VSD and IEEE Std. 7000. I see this thesis as my modest contribution to the systematization of VOFs, in the hope of facilitating future research and their relevance in industry. Finally, I hope that the need for a paradigm shift in SE has become apparent and that engineers have been inspired to consider values in their projects in order to build better systems.

References

Adams, G. S., Converse, B. A., Hales, A. H., & Klotz, L. E. (2021). People systematically overlook subtractive changes. *Nature*, *592*(7853), 258-261.

AlAbdulwahab, S. S., Kachanathu, S. J., & AlMotairi, M. S. (2017). Smartphone use addiction can cause neck disability. *Musculoskeletal care*, *15*(1), 10-12.

Aldewereld, H., & Mioch, T. (2021). Values in Design Methodologies for AI. In *International Conference on Advanced Information Systems Engineering* (pp. 139-150). Springer, Cham.

Amabile, T. M. (1997). Motivating creativity in organizations: On doing what you love and loving what you do. *California management review* , *40* (1), 39-58.

Andreessen, M. (2011). Why software is eating the world. *Wall Street Journal*, *20*(2011), C2. Retrieved from: https://www.wsj.com/articles/SB10001424053111903480904576512250915629460 (14.11.2022).

Anderson, S. P. (2011). *Seductive Interaction Design: Creating Playful, Fun, and Effective User Experiences, Portable Document*. Pearson Education.

Anonymous. (2022). ABP Privacy Infra, Long Range Investments [A/C Priv]. Retrieved from: https://s3.documentcloud.org/documents/21716382/facebook-data-lineage-internal-document.pdf (28.06.2022).

Apple. (2019). Environmental Responsibility Report. Retrieved from: https://www.apple.com/environment/pdf/Apple_Environmental_Responsibility_Report_2019.pdf (26.12.2022).

Arendt, H., & Kroh, J. (1964). *Eichmann in Jerusalem* (p. 240). New York: Viking Press.

Arieli, S., Sagiv, L., & Roccas, S. (2020). Values at work: The impact of personal values in organisations. *Applied Psychology*, *69*(2), 230-275.

Austin, J. T., & Vancouver, J. B. (1996). Goal constructs in psychology: Structure, process, and content. *Psychological bulletin*, *120*(3), 338.

Bach, J. (1997). Good enough quality: Beyond the buzzword. *Computer*, *30*(8), 96-98.

Barley, S. R., Meyerson, D. E., & Grodal, S. (2011). E-mail as a source and symbol of stress. Organization Science, 22(4), 887-906.

Batey, M. (2012). The measurement of creativity: From definitional consensus to the introduction of a new heuristic framework. *Creativity Research Journal*, *24*(1), 55-65.

Baybutt, P. (2018). The validity of engineering judgment and expert opinion in hazard and risk analysis: The influence of cognitive biases. *Process safety progress*, *37*(2), 205-210.

Bednar, K., & Spiekermann, S. (2020). On the power of ethics: How value-based thinking fosters creative and sustainable IT innovation.

Bednar, K., & Spiekermann, S. (2022). Eliciting Values for Technology Design with Moral Philosophy: An Empirical Exploration of Effects and Shortcomings. Science, Technology, & Human Values, 01622439221122595.

Bednar, K., & Winkler, T. J. (2020). Ontologies and Knowledge Bases: A New Way to Represent and Communicate Values in Technology Design. In Societal Challenges in the Smart Society (pp. 257-270). Universidad de La Rioja.

Bennett H. (1984). Star Trek III: The Search for Spock. Paramount Pictures.

Berenbach, B., & Broy, M. (2009). Professional and ethical dilemmas in software engineering. *Computer*, *42*(1), 74-80.

Bhatia, A., & Tuli, S. (2018). Sustainability reporting practices in US and UK: An empirical comparison. *International Journal of law and Management*, *60*(4), 1034-1056.

Bilsky, W., & Schwartz, S. H. (1994). Values and personality. *European journal of personality*, *8*(3), 163-181.

Bitcom. (2021). Open Source Monitor, Retrieved from: https://www.bitkom.org/Presse/Presseinformation/Grosse-Mehrheit-der-Unternehmen-setzt-auf-Open-Source, (13.09.2021)

Boenink, M., & Kudina, O. (2020). Values in responsible research and innovation: from entities to practices. *Journal of Responsible Innovation*, *7*(3), 450-470.

Bradonjic, P., Franke, N., & Lüthje, C. (2019). Decision-makers' underestimation of user innovation. *Research Policy*, *48*(6), 1354-1361.

Breidert, C., Hahsler, M., & Reutterer, T. (2006). A review of methods for measuring willingness-to-pay. *Innovative marketing*, *2*(4), 8-32.

Breitman, K. K., Leite, J. C. S., & Finkelstein, A. (1999). The world'sa stage: a survey on requirements engineering using a real-life case study. *Journal of the Brazilian Computer Society*, *6*, 13-37.

Briand, L., Bianculli, D., Nejati, S., Pastore, F., Sabetzadeh, M (2017).: The Case for Context-Driven Software Engineering Research: Generalizability Is Overrated. IEEE Software 34(5):72-75.

Brown, G. R., & Alexandersen, K. (2020). Gender equality and gender gaps in mathematics performance. *Trends in cognitive sciences*, *24*(8), 591-593.

Brooks, F. P., & Bullet, N. S. (1987). Essence and accidents of software engineering. *IEEE computer*, *20*(4), 10-19.

Burmeister, O. K. (2016). The development of assistive dementia technology that accounts for the values of those affected by its use. *Ethics and Information Technology*, *18*(3), 185-198.

BSI (Bundesamt für Sicherheit in der Informationstechnik). (2021). *ID-Wallet: Unterlagen zur Prüfung bzw. Freigabe der Apps*. Retrieved from: https://fragdenstaat.de/dokumente/141932-bmi_idwallet/ (16.06.2022).

Borning, A., & Muller, M. (2012). Next steps for value sensitive design. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 1125-1134).

Brown, T. (2008). Design thinking. *Harvard business review*, *86*(6), 84.

Cadwalladr, C. (2017). "The great British Brexit robbery: how our democracy was hijacked". The Guardian. Retrieved from: https://www.theguardian.com/technology/2017/may/07/the-great-british-brexit-robbery-hijacked-democracy (31.12.2022).

Calienes, G. (2013). Requirements Prioritization Framework for Developing Green and Sustainable Software using ANP-based Decision Making. In *Proceedings of the 27th Conference on Environmental Informatics-Informatics for Environmental Protection, Sustainable Development and Risk Management* . Shaker Verlag.

Calma, J., (2022). "Ethereum just completed The Merge — here's how much energy it's saving". The Verge. Retrieved from: https://www.theverge.com/2022/9/15/23354619/ethereum-cryptocurrency-merge-energy-electricity-greenhouse-gas-emissions-reduction (12.02.2023).

Carey, J. W., Morgan, M., & Oxtoby, M. J. (1996). Intercoder agreement in analysis of responses to open-ended interview questions: Examples from tuberculosis research. CAM Journal, 8(3), 1-5.

Chung, L., & do Prado Leite, J. C. S. (2009). On non-functional requirements in software engineering. In *Conceptual modeling: Foundations and applications* (pp. 363-379). Springer, Berlin, Heidelberg.

Chung, L., Nixon, B. A., Yu, E., & Mylopoulos, J. (2000). „Non-functional requirements in software engineering" Vol. 5. Springer Science & Business Media.

Coleman, G., & O'Connor, R. V. (2008). An investigation into software development process formation in software start-ups. *Journal of Enterprise Information Management*.

Cooper, A., Reimann, R., & Cronin, D. (2014). About Face. *The Essentials of Interaction Design, 3*.

Christl, W., & Spiekermann, S. (2016). Networks of control. *A report on corporate surveillance, digital tracking, big data & privacy. facultas*.

Davis, J., & Nathan, L. P. (2015). Value sensitive design: Applications, adaptations, and critiques. *Handbook of ethics, values, and technological design: Sources, theory, values and application domains*, 11-40.

De Lucia, A., & Qusef, A. (2010). Requirements engineering in agile software development. *Journal of emerging technologies in web intelligence*, *2*(3), 212-220.

de Paula, G. O., & Cavalcanti, R. N. (2000). Ethics: essence for sustainability. *Journal of Cleaner Production*, *8*(2), 109-117.

de Vries, A., & Stoll, C. (2021). Bitcoin's growing e-waste problem. *Resources, Conservation and Recycling*, *175*, 105901.

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological inquiry*, *11*(4), 227-268.

Desmet, P. M., & Roeser, S. (2015). Emotions in design for values. *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, 203-219.

Detweiler, C., & Harbers, M. (2014). Value Stories: Putting Human Values into Requirements Engineering. In *REFSQ Workshops* (pp. 2-11).

Dignum, M., Correljé, A., Cuppen, E., Pesch, U., & Taebi, B. (2016). Contested technologies and design for values: The case of shale gas. *Science and engineering Ethics*, *22*(4), 1171-1191.

Digiconomist. (2022). Bitcoin average energy consumption per transaction compared to that of VISA as of April 25, 2022 (in kilowatt-hours) [Graph]. In Statista. Retrieved from https://www.statista.com/statistics/881541/bitcoin-energy-consumption-transaction-comparison-visa/ (29.08.2022).

Donia, J., & Shaw, J. A. (2021). Co-design and ethical artificial intelligence for health: An agenda for critical research and practice. *Big Data & Society*, *8*(2), 20539517211065248.

Draffin, A. (2010). Methodology vs framework: why waterfall and agile are not methodologies. Retrieved from: *https://morgoth.wordpress.com/2010/04/07/methodology-vs-framework-why-waterfall-and-agile-are-not-methodologies/* (15.12.2022)

Dunning, D. (2011). The Dunning–Kruger effect: On being ignorant of one's own ignorance. In *Advances in experimental social psychology* (Vol. 44, pp. 247-296). Academic Press.

Dwan, K., Altman, D. G., Arnaiz, J. A., Bloom, J., Chan, A. W., Cronin, E., ... & Williamson, P. R. (2008). Systematic review of the empirical evidence of study publication bias and outcome reporting bias. *PloS one*, *3*(8), e3081.

Dwoskin, E., and De Vynck, G. (2022). Facebook's cryptocurrency failure came after internal conflict and regulatory pushback. Wall Street Journal. Retrieved from: https://www.washingtonpost.com/technology/2022/01/28/facebook-cryptocurrency-diem/ (23.12.2022).

Epstein, R., & Robertson, R. E. (2015). The search engine manipulation effect (SEME) and its possible impact on the outcomes of elections. *Proceedings of the National Academy of Sciences*, *112*(33), E4512-E4521.

EuChemS, (2021). The 90 Elements that make up everything. Retrieved from: https://www.euchems.eu/wp-content/uploads/2021/11/2111_Teachers-support-material.pdf (12.02.2022).

European Commission. (2021). Laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain union legislative acts. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52021PC0206 (21.04.2023).

European Parliament. (2022). Regulation (EU) 2022/2065 of the European Parliament and of the Council of 19 October 2022 on a Single Market For Digital Services and amending Directive 2000/31/EC (Digital Services Act). Retrieved from: http://data.europa.eu/eli/reg/2022/2065/oj (21.04.2023).

Engelbrecht, J., Johnston, K. A., & Hooper, V. (2017). The influence of business managers' IT competence on IT project success. *International journal of project management*, *35*(6), 994-1005.

Fan, Y. (2005). Ethical branding and corporate reputation. *Corporate communications: An international journal*.

Fuchs, T. (2020). Values as relational phenomena: a sketch of an enactive theory of value. *Perceiving truth and value: Interdisciplinary discussions on perception as the foundation of ethics*, 23-42.

Friedman, B., Harbers, M., Hendry, D. G., van den Hoven, J., Jonker, C., & Logler, N. (2021). Eight grand challenges for value sensitive design from the 2016 Lorentz workshop. *Ethics and Information Technology*, *23*(1), 5-16.

Friedman, B., & Hendry, D. G. (2019). *Value sensitive design: Shaping technology with moral imagination*. Mit Press.

Friedman, B., Kahn, P. H., Borning, A., & Huldtgren, A. (2013). Value sensitive design and information systems. In *Early engagement and new technologies: Opening up the laboratory* (pp. 55-95). Springer, Dordrecht.

Friedman, B., & Kahn Jr, P. H. (2007). Human values, ethics, and design. In *The human-computer interaction handbook* (pp. 1267-1292). CRC press.

Friedman, B., & Nathan, L. P. (2010). Multi-lifespan information system design: A research initiative for the HCI community. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2243-2246).

Friedman, B., & Nissenbaum, H. (1996). Bias in computer systems. *ACM Transactions on Information Systems (TOIS)*, *14*(3), 330-347.

Fitzgerald, B. (2012). Software Crisis 2.0. *Computer*, *45*(4), 89-91.

Folketing. (2020). Lov om ændring af årsregnskabsloven. Retrieved from: https://kammeradvokaten.dk/media/8051/20191_l124b_som_vedtaget.pdf (14.02.2022).

Fowler, M., & Highsmith, J. (2001). The agile manifesto. Software Development, 9(8), 28-35.

Flanagan, M., Howe, D. C., & Nissenbaum, H. (2008). Embodying values in technology: Theory and practice. Information technology and moral philosophy, 322.

Flanagan, M., Howe, D. C., & Nissenbaum, H. (2005). Values at play: Design tradeoffs in socially-oriented game design. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 751-760).

Floridi, L. (2016). Faultless responsibility: On the nature and allocation of moral responsibility for distributed moral actions. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2083), 20160112.

Frankena, W. (1973), Ethics, 2nd ed., Englewood Cliffs, NJ: Prentice-Hall, Chapter 1.

Geyer, R., & Doctori Blass, V. (2010). The economics of cell phone reuse and recycling. *The International Journal of Advanced Manufacturing Technology*, *47*(5), 515-525.

General Assembly. (2015). A/Res/70/1 Transforming Our World: The 2030 Agenda for Sustainable Development, 21 October 2015.

Gibson, J. J. (2014). *The ecological approach to visual perception: classic edition*. Psychology press.

Gispen, J. (2017). Ethics for Designers: Incorporating ethics into the design process. Retrieved from: https://www.ethicsfordesigners.com/ (25.05.2022).

Glinz, M. (2007). On non-functional requirements. In *15th IEEE international requirements engineering conference (RE 2007)* (pp. 21-26). IEEE.

Gogoll , J., Zuber, N., Kacianka, S., Greger, T., Pretschner, A., & Nida-Rümelin, J. (2021). Ethics in the Software Development Process: from Codes of Conduct to Ethical Deliberation. Philosophy & Technology, 1-24.

Goodland, R. (2002). The biophysical basis of environmental sustainability. *Handbook of environmental and resource economics* , 709-721.

Görnemann, E., & Spiekermann, S. (2022). Emotional responses to human values in technology: The case of conversational agents. *Human–Computer Interaction*, 1-28.

Gregor, S., & Jones, D. (2007). The anatomy of a design theory. Association for Information Systems.

Gröger, J., Köhler, A., Naumann, S., Filler, A., Guldner, A., Kern, E., ... & Maksimov, Y. (2018). Entwicklung und Anwendung von Bewertungsgrundlagen für ressourceneffiziente Software unter Berücksichtigung bestehender Methodik-Abschlussbericht. UBA TEXTE, 105.

Grunwald, A. (2015). Technology assessment and Design for Values. *Handbook of ethics, values, and technological design* , 67-86.

Hansen, H. R., Mendling, J., & Neumann, G. (2019). Wirtschaftsinformatik. In *Wirtschaftsinformatik*. De Gruyter Oldenbourg.

Haase, C., (2016). Software Engineering Totally Better Best Practices for Practical Practicers. Youtube. Retrieved from: https://www.youtube.com/watch?v=qufVyh8RDAg (23.12.2022).

Hauschildt, J., Salomo, S., Kock, A., & Schultz, C. (2016). *Innovationsmanagement*. Vahlen.

Heidegger, M. (1977). The question concerning technology.

Hendry, D. G., Friedman, B., & Ballard, S. (2021). Value sensitive design as a formative framework. *Ethics and Information Technology*, *23*(1), 39-44.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS quarterly*, 75-105.

Hickey, S., Matthies, H., & Mumford, E. (2006). *Designing human systems*. Lulu. com.

Hirschheim, R., & Klein, H. K. (1994). Realizing emancipatory principles in information systems development: the case for ETHICS. *MIS quarterly*, 83-109.

Hofstetter, Y., (2022). Wie KI Innere Führung lernt—Wertebasierte Technik mit IEEE7000TM-2021. Retrieved from: https://defenseai.eu/wp-content/uploads/2023/01/DAIO_Study2206.pdf (04.02.2023).

Hull, E., Jackson, K., & Dick, J. (2005). *Requirements engineering in the solution domain* (pp. 109-129). Springer London.

Hussain, W., Perera, H., Whittle, J., Nurwidyantoro, A., Hoda, R., Shams, R. A., & Oliver, G. (2020). Human values in software engineering: Contrasting case studies of practice. *IEEE Transactions on Software Engineering*.

Hussain, W., Shahin, M., Hoda, R., Whittle, J., Perera, H., Nurwidyantoro, A., ... & Oliver, G. (2022). How can human values be addressed in agilemethods a case study on safe. *IEEE Transactions on Software Engineering*.

Hustinx, P. (2013). EU data protection law: The review of directive 95/46/EC and the proposed general data protection regulation. *Collected courses of the European University Institute's Academy of European Law, 24th Session on European Union Law*, 1-12.

IEEE. (2021). Standard Model Process for Addressing Ethical Concerns during System Design. Retrieved from: https://sagroups.ieee.org/7000/ (12.11.2022).

Ihde, D. (2010). Heidegger's technologies: Postphenomenological perspectives. Fordham University Press.

Ihde, D., & Malafouris, L. (2019). Homo faber revisited: Postphenomenology and material engagement theory. *Philosophy & Technology*, *32*, 195-214.

ISO. (2011a). ISO/IEC TR 24748-3:2011 Systems and software engineering — Life cycle management — Part 3: Guide to the application of ISO/IEC 12207 (Software life cycle processes). International Organization for Standardization.

ISO. (2011b). ISO/IEC/IEEE 29148:2011 Systems and software engineering — Life cycle processes — Requirements engineering. International Organization for Standardization.

ISO. (2017a). ISO/IEC/IEEE 12207:2017 Systems and software engineering — Software life cycle processes. International Organization for Standardization.

ISO. (2017b). ISO/IEC/IEEE 24765:2017 Systems and software engineering — Vocabulary. International Organization for Standardization.

ISO. (2015). ISO/IEC/IEEE 15288:2015 Systems and software engineering — System life cycle processes. International Organization for Standardization.

ISO. (2022a). ISO/IEC/IEEE 24748-7000 Systems and software engineering — Life cycle management — Part 7000: Standard model process for addressing ethical concerns during system design. International Organization for Standardization.

ISO. (2022b). ISO/IEC 27001 Information security management systems. International Organization for Standardization. International Organization for Standardization.

Ivtzan, I., Gardner, H. E., Bernard, I., Sekhon, M., & Hart, R. (2013). Wellbeing through self-fulfilment: Examining developmental aspects of self-actualization. *The Humanistic Psychologist*, *41*(2), 119.

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design studies*, *12*(1), 3-11.

Jacobs, N., & Huldtgren, A. (2021). Why value sensitive design needs ethical commitments. Ethics and information technology, 23(1), 23-26.

Jaspers, K. (1958). Die Atombombe und die Zukunft des Menschen: politisches Bewusstsein in unserer Zeit.

Jobin, A., Ienca, M., & Vayena, E. (2019). The global landscape of AI ethics guidelines. *Nature Machine Intelligence*, *1*(9), 389-399.

Johnson, P., Ekstedt, M., & Jacobson, I. (2012). Where's the theory for software engineering?. *IEEE software*, *29*(5), 96-96.

Johnson, D. G. (2015). Technology with no human responsibility?. *Journal of Business Ethics*, *127*(4), 707-715.

Jolibert, A., & Baumgartner, G. (1997). Values, motivations, and personal goals: Revisited. *Psychology & Marketing*, *14*(7), 675-688.

Kant, E. (2010). Works of Immanuel Kant. Delphi Classics.

Kauppinen, M., Savolainen, J., & Mannisto, T. (2007, October). Requirements engineering as a driver for innovations. In *15th IEEE International Requirements Engineering Conference (RE 2007)* (pp. 15-20). IEEE.

Kavakli, E. (2002). Goal-oriented requirements engineering: A unifying framework. *Requirements Engineering*, 6(4), 237-251.

Kelly, E. (2011). Material Ethics of Value: Max Scheler and Nicolai Hartmann (Vol. 203). Springer Science & Business Media.

Kidder, T. (2011). The soul of a new machine. Hachette UK.

Klenk, M. (2021). How do technological artefacts embody moral values?. *Philosophy & Technology*, 34(3), 525-544.

Klotins, E., Unterkalmsteiner, M., Chatzipetrou, P., Gorschek, T., Prikladnicki, R., Tripathi, N., & Pompermaier, L. B. (2019). A progression model of software engineering goals, challenges, and practices in start-ups. *IEEE Transactions on Software Engineering*, *47*(3), 498-521.

Kluckhohn, C. (1962). 2. Values and value-orientations in the theory of action: An exploration in definition and classification. In *Toward a general theory of action* (pp. 388-433). Harvard university press.

Knight, W. (2021). AI Can Write Code Like Humans—Bugs and All. Wired. Retrieved from: https://www.wired.com/story/ai-write-code-like-humans-bugs/ (11.09.2022).

Knowles, B. (2021). ACM TechBrief: Computing and Climate Change.

Kremer, R. (2018). Explaining Technological Mediation. Retrieved from: https://www.rachelkremer.nl/project/technological-mediation/. (21.11.2022).

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. biometrics, 159-174.

Le Dantec, C. A., Poole, E. S., & Wyche, S. P. (2009). Values as lived experience: evolving value sensitive design in support of value discovery. *In Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1141-1150).

Leith, D. J. (2021). Mobile Handset Privacy: Measuring The Data iOS and Android Send to Apple And Google. *Trinity College Dublin*.

Lengnick-Hall, C. A. (1992). Innovation and competitive advantage: What we know and what we need to learn. *Journal of management*, *18*(2), 399-429.

MacIntyre, A. (2007). After Virtue: A Study in Moral Theory [1981]. *London: Duckworth*.

Maedche, A. (2017). Interview with Prof. Jeroen van den Hoven on “why do ethics and values matter in business and information systems engineering?”. *Business & Information Systems Engineering*, *59*(4), 297-300.

Mairiza, D., Zowghi, D., & Nurmuliani, N. (2010). An investigation into the notion of non-functional requirements. In *Proceedings of the 2010 ACM Symposium on Applied Computing* (pp. 311-317).

Manders-Huits, N. (2011). What values in design? The challenge of incorporating moral values into design. *Science and engineering ethics*, *17*(2), 271-287.

Manders-Huits, N., & Zimmer, M. (2009). Values and pragmatic action: The challenges of introducing ethical intelligence in technical design communities. *The International Review of Information Ethics*, *10*, 37-44.

Maiden, N., & Robertson, S. (2005, August). Integrating creativity into requirements processes: Experiences with an air traffic management system. In *13th IEEE International Conference on Requirements Engineering (RE'05)* (pp. 105-114). IEEE.

Mariampolski, H. (1999). The power of ethnography. *Market Research Society. Journal.*, *41*(1), 1-12.

Maslow, A. H. (1966). The psychology of science a reconnaissance.

Mathur, A., Kshirsagar, M., & Mayer, J. (2021). What makes a dark pattern... dark? design attributes, normative considerations, and measurement methods. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (pp. 1-18).

McGillivray, M. (2007). Human well-being: Issues, concepts and measures. In *Human well-being* (pp. 1-22). Palgrave Macmillan, London.

McGrenere, J., & Ho, W. (2000). Affordances: Clarifying and evolving a concept. In *Graphics interface* (Vol. 2000, pp. 179-186).

McLennan, S., Fiske, A., Celi, L. A., Müller, R., Harder, J., Ritt, K., ... & Buyx, A. (2020). An embedded ethics approach for AI development. *Nature Machine Intelligence* , *2* (9), 488-490.

Meth, H., Brhel, M., & Maedche, A. (2013). The state of the art in automated requirements elicitation. *Information and Software Technology*, *55*(10), 1695-1709.

Miller, B. (2021). Is technology value-neutral?. *Science, Technology, & Human Values*, *46*(1), 53-80.

Miller, J. K., Friedman, B., Jancke, G., & Gill, B. (2007). Value tensions in design: the value sensitive design, development, and appropriation of a corporation's groupware system. In *Proceedings of the 2007 international ACM conference on Supporting group work* (pp. 281-290).

Mingers, J., & Walsham, G. (2010). Toward ethical information systems: The contribution of discourse ethics. *MIS quarterly*, 833-854.

Mittelstadt, B. (2019). Principles alone cannot guarantee ethical AI. *Nature machine intelligence*, *1*(11), 501-507.

Montti, R. (2018). Google's 'Don't be evil'no longer prefaces code of conduct. *Search Engine Journal*, *20*.

Mostashari, A., McComb, S. A., Kennedy, D. M., Cloutier, R., & Korfiatis, P. (2012). Developing a stakeholder-assisted agile CONOPS development process. *Systems Engineering* , *15* (1), 1-13.

Mora, M., Gelman, O., O'Connor, R., Alvarez, F., & Macías-Luévano, J. (2009). An overview of models and standards of processes in the SE, SwE, and IS Disciplines. *Information Communication Technology Standardization for E-Business Sectors: Integrating Supply and Demand Factors*, 236-252.

Mumford, M. D., & Gustafson, S. B. (1988). Creativity syndrome: Integration, application, and innovation. *Psychological bulletin* , *103* (1), 27.

Nathan, L. P., Friedman, B., Klasnja, P., Kane, S. K., & Miller, J. K. (2008). Envisioning systemic effects on persons and society throughout interactive system design. In *Proceedings of the 7th ACM conference on Designing interactive systems* (pp. 1-10).

Nagle, F., Wheeler, D., Lifshitz-Assaf, H., Ham, H., & Hoffman, J. (2020). Report on the 2020 foss contributor survey. *The Linux Foundation Core Infrastructure Initiative*.

Naumann, S., Dick, M., Kern, E., & Johann, T. (2011). The greensoft model: A reference model for green and sustainable software and its engineering. *Sustainable Computing: Informatics and Systems* , *1* (4), 294-304.

Neyman, C. J. (2017). A survey of addictive software design.

Nonaka, I., & Takeuchi, H. (2011). The wise leader. *Harvard business review* , *89* (5), 58-67.

Norman, D. A. (2013). *The design of everyday things* . Basic books.

Olsen, P. (2019). Nearly Half Of All 'AI Startups' Are Cashing In On Hype. *Forbes.* Retrieved from: https://www.forbes.com/sites/parmyolson/2019/03/04/nearly-half-of-all-ai-startups-are-cashing-in-on-hype/#74804801d022, (16.06.2022).

O'Neil, C. (2016). *Weapons of math destruction: How big data increases inequality and threatens democracy* . Crown.

Pacheco, C., & Garcia, I. (2012). A systematic literature review of stakeholder identification methods in requirements elicitation. *Journal of Systems and Software* , *85* (9), 2171-2181.

Palm, E., & Hansson, S. O. (2006). The case for ethical technology assessment (eTA). *Technological forecasting and social change* , *73* (5), 543-558.

Pariser, E. (2011). The filter bubble: What the Internet is hiding from you. Penguin UK.

Penzenstadler, B., & Femmer, H. (2013). A generic model for sustainability with process-and product-specific instances. In *Proceedings of the 2013 workshop on Green in/by software engineering* (pp. 3-8).

Pereira, R., & Baranauskas, M. C. C. (2015). A value-oriented and culturally informed approach to the design of interactive systems. *International Journal of Human-Computer Studies, 80,* 66-82.

Pommeranz, A., Detweiler, C., Wiggers, P., & Jonker, C. (2012). Elicitation of situated values: need for tools to help stakeholders and designers to reflect and communicate. Ethics and Information Technology, 14(4), 285-303.

Praca. (2018). Ethical OS Toolkit, Retrieved from: https://ethicalos.org/wp-content/uploads/2018/08/Ethical-OS-Toolkit-2.pdf (05.05.2022).

Quattrone, G., Capra, L., & De Meo, P. (2015). There's no such thing as the perfect map: Quantifying bias in spatial crowd-sourcing datasets. *In Proceedings of the 18th ACM conference on computer supported cooperative work & social computing* (pp. 1021-1032).

Ramesh, B., Cao, L., & Baskerville, R. (2010). Agile requirements engineering practices and challenges: an empirical study. *Information Systems Journal*, 20(5), 449-480.

Reer, F., & Quandt, T. (2021). Games addiction: a comprehensive overview. *Oxford research encyclopedia of communication*.

Regev, G., & Wegmann, A. (2005). Where do goals come from: the underlying principles of goal-oriented requirements engineering. *In 13th IEEE International Conference on Requirements Engineering (RE'05)* (pp. 353-362). IEEE.

Reijers, W., & Gordijn, B. (2019). Moving from value sensitive design to virtuous practice design. *Journal of information, communication and ethics in society*, *17*(2), 196-209.

Rierson, L. (2017). *Developing safety-critical software: a practical guide for aviation software and DO-178C compliance*. CRC Press.

Roeser, S. (2012). Emotional engineers: Toward morally responsible design. *Science and Engineering Ethics*, 18(1), 103-115.

Rosenthal, S. R., Zhou, J., & Booth, S. T. (2021). Association between mobile phone screen time and depressive symptoms among college students: A threshold effect. *Human Behavior and Emerging Technologies*, 3(3), 432-440.

Rotondo, A., & Freier, N. G. (2010). The problem of defining values for design: a lack of common ground between industry and academia?. *In CHI'10 Extended Abstracts on Human Factors in Computing Systems* (pp. 4183-4188).

Sanger, D. E., & Chen, B. X. (2014). Signaling post-Snowden Era, new iPhone locks out NSA. *New York Times*, *26*. Retrieved from: https://www.nytimes.com/2014/09/27/technology/iphone-locks-out-the-nsa-signaling-a-post-snowden-era-.html (05.03.2023).

Savolainen, J., Kuusela, J., & Vilavaara, A. (2010). Transition to agile development-rediscovery of important requirements engineering practices. *In 2010 18th IEEE International Requirements Engineering Conference* (pp. 289-294). IEEE.

Scheler, M. (1973). *Formalism in ethics and non-formal ethics of values: A new attempt toward the foundation of an ethical personalism*. Northwestern University Press.

Schlosser, E. (2013). *Command and control: Nuclear weapons, the Damascus accident, and the illusion of safety*. Penguin.

Schmidt, C. (2016). *Agile Software Development Teams*. Springer, Cham.

Schuler, H., & Görlich, Y. (2006). *Kreativität: Ursachen, Messung, Förderung und Umsetzung in Innovation*. Hogrefe Verlag.

Schneberger, S. L., & McLean, E. R. (2003). The complexity cross: implications for practice. *Communications of the ACM*, *46*(9), 216-225.

Schwartz, S. H., & Bilsky, W. (1987). Toward a universal psychological structure of human values. *Journal of personality and social psychology*, 53(3), 550.

Schwartz, S. H. (1994). Are there universal aspects in the structure and contents of human values?. *Journal of social issues*, 50(4), 19-45.

Shaw, W. H. (1998). *Contemporary Ethics*. Blackwell Publishers.

Sharma, S., & Pandey, S. K. (2013). Revisiting requirements elicitation techniques. *International Journal of Computer Applications*, 75(12).

Shearman, R. (1990). The meaning and ethics of sustainability. *Environmental management*, 14(1), 1-8.

Shin, Y., Meneely, A., Williams, L., & Osborne, J. A. (2010). Evaluating complexity, code churn, and developer activity metrics as indicators of software vulnerabilities. *IEEE transactions on software engineering*, 37(6), 772-787.

Sjøberg, D. I., Dybå, T., Anda, B. C., & Hannay, J. E. (2008). Building theories in software engineering. *In Guide to advanced empirical software engineering* (pp. 312-336). Springer, London.

Sommerville, I. (2016). „Software Engineering 10 “. *Harlow: Pearson Education Limited*.

Spiekermann, S. (2015). *Ethical IT innovation: A value-based system design approach*. CRC Press.

Spiekermann-Hoff, S., Winkler, T., & Bednar, K. (2019). A telemedicine case study for the early phases of value based engineering.

Spiekermann, S., Korunovska, J., & Langheinrich, M. (2018). Inside the organization: Why privacy and security engineering is a challenge for engineers. *Proceedings of the IEEE*, *107*(3), 600-615.

Spiekermann, S. (2023). Value-Based Engineering: A Guide to Building Ethical Technology for Humanity. DeGruyter.

Statista. (2021). Number of smartphone users from 2016 to 2021. Retrieved from: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (12.02. 2022).

Steen, M., & van de Poel, I. (2012). Making values explicit during the design process. *IEEE Technology and Society Magazine*, 31(4), 63-72.

Sternberg, R. J. (1985). Implicit theories of intelligence, creativity, and wisdom. *Journal of personality and social psychology*, 49(3), 607.

Stolterman, E. (2008). The nature of design practice and implications for interaction design research. *International Journal of Design*, 2(1).

Thaler, R. H., & Sunstein, C. R. (2009). *Nudge: Improving decisions about health, wealth, and happiness*. Penguin.

Thys, E., Sabbe, B., & De Hert, M. (2014). The assessment of creativity in creativity/psychopathology research–a systematic review. *Cognitive neuropsychiatry* , 19 (4), 359-377.

Tiwari, S., Rathore, S. S., & Gupta, A. (2012). Selecting requirement elicitation techniques for software projects. In *2012 CSI Sixth International Conference on Software Engineering (CONSEG)* (pp. 1-10). IEEE.

Törnberg, P., Andersson, C., Lindgren, K., & Banisch, S. (2021). Modeling the emergence of affective polarization in the social media society. *Plos one* , *16* (10), e0258259.

Travis, G. (2019). How the Boeing 737 Max disaster looks to a software developer. *IEEE Spectrum*, *18*.

Trischler, J., Pervan, S. J., Kelly, S. J., & Scott, D. R. (2018). The value of codesign: The effect of customer involvement in service design teams. Journal of Service Research, 21(1), 75-100.

Trochim, W. M., & Donnelly, J. P. (2001). Research methods knowledge base (Vol. 2). Macmillan Publishing Company, New York: Atomic Dog Pub..

Tu, Y. C., Tempero, E., & Thomborson, C. (2016). An experiment on the impact of transparency on the effectiveness of requirements documents. *Empirical Software Engineering*, *21*, 1035-1066.

Twenge, J. M., Joiner, T. E., Rogers, M. L., & Martin, G. N. (2018). Increases in depressive symptoms, suicide-related outcomes, and suicide rates among US adolescents after 2010 and links to increased new media screen time. *Clinical Psychological Science* , *6* (1), 3-17.

Umbrello, S., & Van de Poel, I. (2021). Mapping value sensitive design onto AI for social good principles. *AI and Ethics*, *1*(3), 283-296.

Unknown. (2021). What is Apache Log4J Vulnerability and How to Prevent It?. Retrieved from: https://www.prplbx.com/resources/blog/log4j/ (16.01.2023).

Vallor, S. (2016). *Technology and the virtues: A philosophical guide to a future worth wanting* . Oxford University Press.

Van Den Eede , Y. (2010). In between us: On the transparency and opacity of technological mediation. *Foundations of Science* , *16* (2-3), 139-159.

Van den Hoven, J. (2017). Ethics for the digital age: Where are the moral specs?. In *Informatics in the Future* (pp. 65-76). Springer, Cham.

Van den Hoven, J., Lokhorst, G. J., & Van de Poel, I. (2012). Engineering and the problem of moral overload. *Science and engineering ethics, 18*, 143-155.

Van de Poel, I. (2013). Translating values into design requirements. In *Philosophy and engineering: Reflections on practice, principles and process* (pp. 253-266). Springer, Dordrecht.

Kroes, P., & Van de Poel, I. (2015). Design for values and the definition, specification, and operationalization of values. *Handbook of ethics, values, and technological design: sources, theory, values and application domains*, 151-178.

Van de Poel, I. (2015). Conflicting values in design for values. *Handbook of ethics, values, and technological design: Sources, theory, values and application domains*, 89-116.

Van de Poel, I. (2021). Design for value change. *Ethics and Information Technology*, *23*(1), 27-31.

Van de Poel, I., & van Gorp, A. V. D. (2006). The need for ethical reflection in engineering design: The relevance of type of design and design hierarchy. Science, technology, & human values, 31(3), 333-360.

Van de Kaa, G., Rezaei, J., Taebi, B., van de Poel, I., & Kizhakenath, A. (2020). How to weigh values in value sensitive design: A best worst method approach for the case of smart metering. *Science and engineering ethics*, *26*(1), 475-494.

Van Gorp, A., & van de Poel, I. (2001). Ethical considerations in engineering design processes. *IEEE Technology and Society Magazine*, *20*(3), 15-22.

Van Lamsweerde, A. (2001). Goal-oriented requirements engineering: A guided tour. In *Proceedings fifth ieee international symposium on requirements engineering* (pp. 249-262). IEEE.

Verbeek, P. P. (2011). *Moralizing technology*. University of Chicago Press.

Verplanken, B., & Holland, R. W. (2002). Motivated decision making: effects of activation and self-centrality of values on choices and behavior. *Journal of personality and social psychology*, *82*(3), 434.

Wagner, B., Winkler, T., & Human, S. (2021). Bias in geographic information systems: The case of google maps.

Walker, C. E., Krumhuber, E. G., Dayan, S., & Furnham, A. (2021). Effects of social media use on desire for cosmetic surgery among young women. *Current Psychology*, *40*(7), 3355-3364.

Weiser, M. (1999). The computer for the 21st century. *ACM SIGMOBILE mobile computing and communications review*, *3*(3), 3-11.

Wedenig, J. (2021), Why. Value-based Engineering with ISO/IEC/IEEE 24748-7000. Retrieved from: https://www.wu.ac.at/value-based-engineering/why/ (18.01.2023).

Well, G., Horwitz, J., & Seetharaman, D., (2021). Facebook Knows Instagram Is Toxic for Teen Girls, Company Documents Show. Wall Street Journal. Retrieved from: https://www.wsj.com/articles/facebook-knows-instagram-is-toxic-for-teen-girls-company-documents-show-11631620739 (12.11.2022).

Winkler, T., & Spiekermann, S. (2018). Twenty years of value sensitive design: a review of methodological practices in VSD projects. *Ethics and Information Technology*, 1-5.

Winkler, T., & Spiekermann, S. (2019). Human values as the basis for sustainable information system design. *IEEE Technology and Society Magazine*, *38*(3), 34-43.

Winkler, T. J. (2020). Value sensitive Design and Agile Development: Potential Methods for Value Prioritization. In *Societal Challenges in the Smart Society* (pp. 289-298). Universidad de La Rioja.

Woodhall, M. (1987). Human capital concepts. In *Economics of education* (pp. 21-24). Pergamon.

Wright, D. (2011). A framework for the ethical impact assessment of information technology. *Ethics and information technology* , *13* (3), 199-226.

Yee, A. (2021). You shouldn't buy a TPM for Windows 11. Here's why. PCWorld. Retrieved from: https://www.pcworld.com/article/545941/you-shouldnt-buy-a-tpm-for-windows-11-heres-why.html (07.01.2023).

Yoo, D. (2021). Stakeholder Tokens: a constructive method for value sensitive design stakeholder analysis. *Ethics and Information Technology*, *23*(1), 63-67.

Zuboff, S. (2015). Big other: surveillance capitalism and the prospects of an information civilization. *Journal of information technology*, *30*(1), 75-89.

Appendix A – Values in Relation to Sustainability

Even though it is not recommended to use lists of values, it can still be helpful to know which values exist and where to find further information about them. The following list is therefore intended to provide an overview of overarching values with their specific aspects in relation to the sustainability dimensions. This list and the necessary referencing can be found in Winkler and Spiekermann (2019).

Social Sustainability	
Overarching Value	**Specific Aspects**
Accountability [20, 32, 45, 46, 47, 48, 52]	Accountability in governance [27], Responsibility [37, 48], Liability [48]
Community [42, 48]	Inclusion [23], Participation (social, culture, politics) [21, 23, 27, 33, 34, 42], Partnerships for goals [30], Public interest [25], Shared responsibility [26, 33], Sustainability [27, 30], Socialness [21], Social Order [33], Social Recognition [35], Solidarity [26], Understanding [27], Compassion [27], Love [27], Inclusive growth [52]
Dignity [23, 27]	Courtesy [20], Politeness [35, 15], Protecting the vulnerable [26], Respect [23, 32, 27], Respect for all life [15, 33, 34], Tolerance [26, 27]
Justice [15, 27, 41, 47]	Asylum from persecution [33], Competent and fair [33], Distributive and procedural justice [37], Integrity and independence [25], Innocent until proven guilty [33], Just distribution of goods and evils [36], Strong institutions [30, 26], Fairness [46, 52]
Relationship [39]	Affection and cooperation [36], Fair and supportive [25], Family [33, 39], Friendship [35, 36], Healthy attachments [42], Interdependence [23], Love [35, 36, 39], Marriage [33]
Respect for Norms	Democracy [26, 27], Ethical Behavior [25], Good governance [26], Human Rights [23, 26, 32, 45, 47], International norms and rule of law [32], Value Alignment [46]
Trust [20, 23, 48]	Truth [36], Integrity [48]
Technical Sustainability	
Overarching Value	**Specific Aspects**
Aesthetics [36]	Balance and Form [39], Beauty [15, 35, 36]
Efficiency [19, 24]	Cost [23], Consumption Minimization [19], Performance [22, 24], Waste Reduction [19]
Maintainability [22]	Building on existing framework (energy and material flow) [19], Feasibility [23], Operability [22], Supportability [24], Functional Suitability [22]
Reliability [21, 22]	Dependability [24], Durability [19], Resilience [21, 48], Robustness [47, 52], Redundancy [48]
Reusability [24]	Compatibility [22], Promotion of disassembly [19], Re-configurability [19]
Simplicity	Avoidance of unnecessary capacity or capability [19], Calmness [20], Cleanliness [15, 35], Predictability [24], Reduction of complexity [19]
Usability [20, 24]	Accessibility [24, 21, 48], Design for all [47]
Individual Sustainability	

Overarching Value	Specific Aspects
Autonomy [20, 23, 37, 47, 48]	Independence [35], Mobility and free movement [23, 33, 42], Modifiability [24], Portability [24, 22], Right to change nationality [33], Self-direction [15], Human Oversight of AI [47], Moral Autonomy [48]
Education [30, 31, 33]	Intellectuality [35], Lifelong learning [25], Values and skills for sustainable living [27]
Human Capabilities [35, 42] also referred to as Virtues [40]	Ambition [35, 41], Beneficence [37, 47, 48], Benevolence [15], Broadmindedness [35, 15], Courage [35, 41], Critical Reflection [42], Forgiveness [35], Generosity [41], Gentleness [41], Helpfulness [35], High-mindedness [36, 41], Honesty [35], Humor [41], Imagination [35], Inflatedness [41], Kindness [41], Logic [35], Power and experience of achievement [36, 15, 39], Responsiveness [35], Reminding [23], Self-Actualization [39], Self-control [27, 35], Self-esteem [36, 39], Self-respect [35, 42], Temperance [41], Tradition [15], Transcendence [39], Universalism [15], Veracity and Truthfulness [41], Virtues [36], Obedient [35], Wisdom [15, 35]
Health [27, 29, 30, 36, 42, 48]	Alerting [23], Clean water and sanitation [30, 39], Combat Diseases [31], Emergency help [23], Human life of normal length [33, 34, 42], Maternal health [31], Reduced child mortality [31], Zero hunger [30, 39]
Human Welfare [20]	Comfortable life [35], Contentment and beatitude [36], Inner Harmony [15, 35, 36], Living standard [33], Meaning [39], Salvation [35], Satisfaction [23, 36], Thriving lives and livelihoods [29], Quality of life [23]
Human Well-being [23, 27, 30, 45, 48, 52]	Harmony [36], Life, consciousness and activity [36], Relief/respite [23], Spiritual well-being [27], Quality of patient care [23]
Knowledge [39]	Informed Consent [20, 23, 48], Open exchange of knowledge on sustainability [27], True opinion and understanding [36], Competence [45]
Pleasure [15, 35]	Adventure and novelty [36], Exciting life [15, 35], Happiness [35, 36], Hedonism [15], Cheerfulness [35], Distraction [23], Rest and leisure [33], Playfulness [42]
Property [27, 33]	No poverty [27, 30, 31], Ownership [20, 33, 42]
Economic Sustainability	
Overarching Value	**Specific Aspects**
Human Productivity	Development [26, 31], Desirable work [30, 33], Interest of client and employer [25], Integrity, reputation and high standards [25], Sense of accomplishment [35]
Environmental Sustainability	
Overarching Value	**Specific Aspects**
Environment [26, 15]	Animal Life [30, 42], Biological Diversity [27], Climate [30], Footprint [24], Output pulled rather than Input pushed [19], Precautionary approach [27], Productive ecosystems [29], Renewable material and energy [19, 30, 29], Respect for Nature [26, 27], Responsible consumption and production [30], Sustainability [20, 31]
Social and Individual Sustainability	
Overarching Value	**Specific Aspects**
Equality [15, 26, 27, 30, 31, 33, 35, 42, 48]	Legal Equality [33], Gender Equality [27, 30, 31], Minority and indigenous equality [27]
Freedom [23, 26, 35, 36]	Freedom from: Arbitrary arrest and exile [33], Bias [20], Discrimination [27, 33, 34, 48], Ill- or degrading-treatment [34, 33], Slavery [33, 34], Torture [33], Freedom of: Expression [34, 36], Opinion and information [33], Thought, Belief and Religion [33, 34]
Security & Safety	Family [35], Food and Water [29], National [35], Non-hazardous [19], Non-maleficence

[21, 22, 23, 26, 33, 36, 39, 47, 48, 52]	[37, 47, 48], Personal [33], Protection from the elements [39], Social [33], Awareness of Misuse [45], Data Security [48], Human Security [48]
Privacy [20, 21, 23, 33, 34, 47, 48]	Surveillance [23], Data Agency [45], User Data Rights [46], Data Governance [47], Confidentiality [48]
Social and Technical Sustainability	
Overarching Value	**Specific Aspects**
Transparency [21, 32, 45, 47, 48, 52]	Data Access [21], Transparency in Governance [27], Explainability [46, 52], Explicability [47]
All five Dimensions	
Overarching Value	**Specific Aspects**
Peace [15, 21, 23, 26, 27, 30, 33, 35, 36]	Disarmament [26]

Appendix B – Experimental Settings

All major aspects of the experimental design for the main and assessment study are presented below as they were presented to the participant.

Appendix B.1 – Main Study

B.1.1 Informed Consent

*Dear participant,

Thank for you for taking part in our online survey. While we are asking for some personal information about you, we do not intend to store any information about you in a way that will allow you to be personally identified.

Please be aware that by entering data into this survey, you consent to the processing of your personal data (e.g. academic degree, field of study and occupation) by WU for the purpose of research. The data indicated above will be stored on WU servers of further academic analysis in an aggregate fashion. This consent is given freely.

Do you consent?

- Yes
- No (end survey)

B.1.2 Creativity

I am the kind of person who…

	Very untrue	Untrue	Somewhat untrue	Neutral	Somewhat true	True	Very True
… has the ability to recognize similarities and differences.	○	○	○	○	○	○	○
… tends to obtain and use information for specific purposes.	○	○	○	○	○	○	○
…. attaches importance to well-presented ideas.	○	○	○	○	○	○	○
… has a huge store of information.	○	○	○	○	○	○	○
… has rationality: ability to reason clearly.	○	○	○	○	○	○	○
… attaches importance to ideas.	○	○	○	○	○	○	○
… studies and reads quite a lot.	○	○	○	○	○	○	○
… is able to apply knowledge to particular problems.	○	○	○	○	○	○	○
… seeks out information, especially details.	○	○	○	○	○	○	○
… has demonstrated a good vocabulary.	○	○	○	○	○	○	○
… is able to put old information, theories, and so forth, together in a new way.	○	○	○	○	○	○	○
… possesses ability for high achievement.	○	○	○	○	○	○	○
… is inquisitive.	○	○	○	○	○	○	○
… makes connections and distinctions between ideas and things.	○	○	○	○	○	○	○
… expresses broad concepts concisely.	○	○	○	○	○	○	○
… is good at distinguishing between correct and incorrect answers.	○	○	○	○	○	○	○
… has good problem-solving ability.	○	○	○	○	○	○	○
… can converse on almost any topic.	○	○	○	○	○	○	○
… sees opportunities and knows when to take them.	○	○	○	○	○	○	○
… has a logical mind.	○	○	○	○	○	○	○
… is inquisitive at an early age.	○	○	○	○	○	○	○
… has the unique ability to look at a problem or situation and solve.	○	○	○	○	○	○	○
… is motivated by goals.	○	○	○	○	○	○	○
… has a good command of language.	○	○	○	○	○	○	○
… answers questionnaires very unfocused.	○	○	○	○	○	○	○

B.1.3 Stakeholder Expectations

B.1.3.1 Goals

Definition: A goal is the idea of a concrete desired result. People often base their actions on goals. Goals define the purpose and direction of human behaviour.

Task: If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the goals that a mobile navigation app should help to achieve that should not be forgotten?

- Please write only one goal per line.
- Please take at least 3 minutes to complete the task.

1.

B.1.3.2 Needs

Definition: Needs describe psychological conditions that are essential for personal development, performance and well-being. In short, needs describe the conditions under which people can best develop their potential. When needs are not met, people focus on meeting them.

Task: If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the needs that a mobile navigation app should satisfy that should never be forgotten?

- Please write only one need per line.
- Please take at least 3 minutes to complete the task.

1.

B.1.3.3 Human Values

Definition: Values reflect what is important to a person in life and often have an emphasis on ethics and morals. Human activities or actions often reflect their values.

Task: If one assumes that there is only one mobile navigation app on the market. In your opinion, what are values that a mobile navigation app should embody that should never be forgotten?

- Please write only one value per line.
- Please take at least 3 minutes to complete the task.

1.

B.1.3.4 Material Values

Definition: Values are clear objects of thought that influence the actions of people. Positive values are perceived as something fundamentally desirable and influence the choice of available paths, means and goals. People, things, relationships and activities are carriers of values in a given situation. Values can be positive or negative, whereby positive values are intuitively perceived as attractive and negative values as repulsive.

Task: If one assumes that there is only one mobile navigation app on the market. In your opinion, what are the values that a mobile navigation app should carry that should never be forgotten?

- Please write only one value per line.
- Please take at least 3 minutes to complete the task.

1.

B.1.3.5 User Requirements

Definition: User requirements describe which services an application should offer the user and under which restrictions the application should be operated.

Task: If one assumes that there is only one mobile navigation app on the market. In your opinion, what are user requirements that a mobile navigation app should meet that should not be forgotten?

- Please write only one requirement per line.
- Please take at least 3 minutes to complete the task.

1.

B.1.4 Understandability

The following understandability scale was presented in each experimental condition.

	(5)	(4)	(3)	(2)	(1)	(0)	(1)	(2)	(3)	(4)	(5)	
The definition is hard to understand.	○	○	○	○	○	○	○	○	○	○	○	The definition is easy to understand.
The language of the definition is unclear.	○	○	○	○	○	○	○	○	○	○	○	The language of the definition is clear.
The task was unclear.	○	○	○	○	○	○	○	○	○	○	○	The task was clear.
The task was hard.	○	○	○	○	○	○	○	○	○	○	○	The task was easy.
The symbol is proper.	○	○	○	○	○	○	○	○	○	○	○	The Symbol is improper.

B.1.5 Demographic Information

How often in the past 6 month did you use one of the following Apps to get from one place to another in Vienna?

	never	rarely	sometimes	often	all of the time
Google Maps	●	○	○	○	○
Quando	●	○	○	○	○
ÖBB Scotty	●	○	○	○	○
WienMobil	●	○	○	○	○
VOR AnachB	●	○	○	○	○
Apple Maps	●	○	○	○	○
Uber	●	○	○	○	○
DriveNow	●	○	○	○	○
Wiener Linien Website	●	○	○	○	○
CityBike	●	○	○	○	○
Car2Go	●	○	○	○	○

How old are you?

With which gender identity do you identify the most?

- female
- male
- other

What is the highest level of education that you have completed?

- Compulsory
- Apprenticeship
- High-school
- College, university

What best describes your main professional activity?

- Student
- Transport
- Arts/ Culture/Entertainment
- Manufacture
- Service
- Research
- Public service
- Farming
- Retiree
- Finance/Insurance
- Medicine
- Looking for Job
- IT Sector
- Housewife/Homemaker
- Other:

B.1.5 General Understandability and Recall

The questionnaire was difficult to understand.

- not true
- rather not true
- half and half
- rather true
- true

Please write down briefly in your own words what you have remembered from the definition.

Appendix B.2 – Assessment Study

B.2.1 Informed Consent

*Dear participant,

Thank for you for taking part in our online survey. While we are asking for some personal information about you, we do not intend to store any information about you in a way that will allow you to be personally identified.

Please be aware that by entering data into this survey, you consent to the processing of your personal data (e.g. academic degree, field of study and occupation) by WU for the purpose of research. The data indicated above will be stored on WU servers of further academic analysis in an aggregate fashion. This consent is given freely.

Do you consent?

- Yes
- No (end survey)

B.2.2 Assessment Dimensions

Participants rated a randomly drawn set of requirement, according to following dimensions on a 7-point-Likert-Scale from "very negative" to "very positive" (B.2.2.1 – B.2.2.6). After presenting each dimension, the following question was asked: "How would you rate the effect of each requirement (left column) for a navigation app on <assessment *dimension*>?". Below this question a mixed set of eleven functional and non-functional system requirements were presented.

B.2.2.1 Individual Sustainability

Individual sustainability refers to the **long-term individual potential**.

- This includes a **person's health**, **knowledge**, and **skills**, as well as their **access to education and health care**.

This must be taken into account when assessing individual sustainability.

B.2.2.2 Social Sustainability

Social sustainability refers to a **long-term stable society based on solidarity**.

- For this, **shared values**, **equal rights**, **laws** and **information**, as well as **active participation and communication within society** are essential.

This must be taken into account when assessing social sustainability.

B.2.2.3 Economic Sustainability

Economic sustainability refers to the **long-term value creation** and **productivity**.

- To achieve this, **goods**, **time** and **money** must be protected from depletion, and **investments** must be protected from risk.

This must be taken into account when assessing economic sustainability.

B.2.2.4 Environmental Sustainability

Environmental sustainability refers to the **protection of natural resources** and **ecosystem services**.

- For this, impact on the environment through **resource consumption** and the **release of emissions or waste** must be considered

This must be taken into account when when assessing environmental sustainability.

B.2.2.5 Technical Sustainability

Technical sustainability refers to the **long-term usage** of an app.

- Essential for this is the **continuous development (updates)** as well as the **adaptability** of an app.

This must be taken into account when evaluating technical sustainability.

B.2.2.6 Technical Maturity

Technical maturity refers to the **implementation quality** of a requirement placed on the app.

- This means the absence of **technical obstacles** and **bugs**, as well as the elimination of **inconsistencies** and **difficulties** during development.

This must be taken into account when evaluating technical maturity.

B.2.3 Example: Rating Requirements on Social Sustainability

How would you rate the effect of each requirement (left column) for a navigation app on **social sustainability**?

Potential requirements	very negative	negative	somewhat negative	not existing	somewhat positive	positive	very positive
The app shall provide time information.							
The app shall have a low complexity.							
The app shall include health functions such as a kilocalorie calculator or pedometer.							
The app shall be cost-effective.							
The app shall have a high IT security.							
The app shall be accessible for elderly people.							
The app shall deliver precise results.							
The app shall find a destination without specifying the exact address.							
The app shall auto complete inputs.							
The app shall help the user with orientation.							
The app shall provide information about events.							

B.2.4 Dimension Recall

*For which sustainability dimension are each of the following apects relevant?

a person's **health, knowledge, and skills**	Please choose...
a person's **access to education and health care**	Please choose...
considering the impact on the environment of **resource consumption**	Please choose...
shared values, equal rights, laws and information within society	Please choose...
absence of **technical obstacles and bugs**	Please choose...
considering the impact on the environment from the **release of emissions or waste**	Please choose...
protection of **goods, time and money** from exhaustion	Please choose...
active participation and communication within society	Please choose...
elimination of **inconsistencies and difficulties** during development	Please choose...
continuous further **development** (updates) of an app	Please choose...
adaptability of an app	Please choose...
protection of **investments** from risks	Please choose...

B.2.3 Understandability

*The following terms were difficult to understand.

	not true	rather not true	half and half	rather true	true
...economic sustainability.	○	○	○	○	○
...technical maturity.	○	○	○	○	○
...environmental sustainability.	○	○	○	○	○
...technical sustainability.	○	○	○	○	○
...social sustainability.	○	○	○	○	○
... individual sustainability.	○	○	○	○	○

B.2.4 Demographic Information

How old are you?

With which gender identity do you identify the most?

- ○ female
- ○ male
- ○ other

What is the highest level of education that you have completed?

- ○ Compulsory
- ○ Apprenticeship
- ○ High-school
- ○ College, university

What best describes your main professional activity?

- ○ Student
- ○ Manufacture
- ○ Public service
- ○ Finance/Insurance
- ○ IT Sector
- ○ Transport
- ○ Service
- ○ Farming
- ○ Medicine
- ○ Housewife/Homemaker
- ○ Arts/ Culture/Entertainment
- ○ Research
- ○ Retiree
- ○ Looking for Job
- ○ Other:

Appendix C – Functional System Requirements

The following list includes all functional system requirements in the coding manual with a description as presented in the assessment study. Additionally resulted means with standard deviations are shown for individual sustainability (INS), social sustainability (SOS), economic sustainability (ECS), environmental sustainability (ENV), technical sustainability (TES) and technical maturity (TEM) dimensions.

Categories	Requirement Description	INS	SOS	ECS	ENV	TES	TEM
Provide Information:							
general time	The app shall provide time information.	**5.77** ± 1.15	**5.39** ± 1.12	**5.74** ± 1.09	**5.26** ± 1.24	**5.77** ± 1.14	**5.94** ± 1.12
travel time	The app shall provide the travel time.	**6.25** ± 0.93	**5.81** ± 1.28	**6.06** ± 1.34	**5.50** ± 1.37	**6.50** ± 0.73	**6.25** ± 1.00
arrival time	The app shall provide the arrival time.	**5.47** ± 1.01	**5.65** ± 1.11	**6.29** ± 1.05	**5.53** ± 1.28	**5.82** ± 1.33	**5.71** ± 1.49
departure time	The app shall provide the departure times for public transport.	**6.33** ± 0.96	**6.08** ± 1.02	**5.92** ± 1.44	**6.46** ± 1.06	**6.08** ± 1.18	**5.58** ± 1.84
general information	The app shall provide additional information about locations.	**5.67** ± 1.09	**5.88** ± 1.03	**5.08** ± 1.38	**5.08** ± 0.93	**5.42** ± 1.14	**5.21** ± 1.61
public buildings & places	The app shall provide information about public buildings and places, tourist sights and points of interest.	**5.71** ± 1.27	**5.79** ± 1.63	**4.86** ± 1.51	**5.29** ± 0.99	**5.71** ± 1.14	**5.00** ± 1.36
restaurants, shops	The app shall provide information about restaurants, shops and clubs.	**5.33** ± 0.91	**5.61** ± 1.58	**5.22** ± 1.26	**4.44** ± 1.29	**5.56** ± 1.15	**5.72** 1.02
events	The app shall provide information about events.	**4.84** ± 1.53	**5.39** ± 1.52	**5.39** ± 1.52	**4.32** ± 1.22	**4.60** ± 1.54	**4.77** ± 1.28
public transport station	The app shall provide information about public transport stations.	**6.29** ± 0.92	**6.18** ± 0.88	**5.76** ± 1.39	**6.82** ± 0.53	**5.94** ± 1.30	**5.35** ± 1.80
travel distance	The app shall provide the travel distance to the destination.	**5.94** ± 1.03	**5.94** ± 1.14	**5.88** ± 1.17	**6.29** ± 0.92	**5.76** ± 1.39	**5.88** ± 1.65
STVO	The app shall provide information about traffic regulations.	**6.24** ± 0.90	**6.18** ± 1.01	**5.65** ± 1.22	**5.65** ± 1.27	**5.94** ± 1.39	**5.35** ± 1.90
Provide Orientation:							
general	The app shall help the user with orientation.	**5.44** ± 0.92	**5.44** ± 1.38	**5.00** ± 1.24	**4.78** ± 1.40	**5.61** ± 1.20	**5.56** 1.04
looking direction	The app shall indicate the viewing direction of the user.	**5.68** ± 1.22	**5.04** ± 1.31	**5.24** ± 1.27	**4.84** ± 1.21	**5.64** ± 1.44	**5.36** ± 1.44
location	The application shall provide the current location.						
Provide Navigation:							

general	The app shall accompany the user through the route (navigation).	**5.76** ± 1.20	**5.47** ± 1.01	**5.41** ± 0.87	**5.59** ± 1.00	**5.76** ± 1.20	**5.82** ± 1.51
car	The app shall accompany the user through a car route (car navigation).	**5.50** ± 1.34	**5.61** ± 1.54	**6.06** ± 1.16	**4.78** ± 1.90	**5.94** ± 1.00	**6.00** ± 1.03
walk	The app shall accompany the user through a walking route (foot navigation).	**6.21** ± 0.80	**5.71** ± 1.20	**4.93** ± 1.54	**5.79** ± 1.05	**5.64** ± 1.28	**5.07** ± 1.77
Provide Routes:							
multiple	The app shall provide multiple potential routes or transport modes.	**6.16** ± 0.94	**5.64** ± 1.25	**6.08** ± 1.04	**5.92** ± 1.32	**5.80** ± 1.38	**6.32** ± 1.25
bike	The app shall provide a bike route.	**6.00** ± 0.88	**5.43** ± 1.16	**5.36** ± 1.39	**6.36** ± 1.01	**6.00** ± 1.11	**5.07** ± 1.73
public	The app shall provide a public transport route.	**6.46** ± 0.98	**6.38** ± 0.92	**5.71** ± 1.33	**6.58** ± 1.02	**6.21** ± 1.25	**5.38** ± 1.69
walking	The app shall provide a route for walking.	**6.31** ± 0.79	**5.88** ± 1.09	**6.00** ± 1.15	**6.19** ± 1.11	**6.13** ± 0.72	**5.69** ± 1.25
car	The app shall provide a route for cars.	**5.54** ± 1.38	**4.92** ± 1.41	**5.42** ± 1.35	**3.63** ± 2.06	**5.61** ± 1.37	**5.29** ± 1.52
one	The app shall only provide a single route to the destination.	**3.35** ± 1.66	**3.35** ± 1.32	**3.47** ± 1.62	**3.65** ± 2.12	**3.41** ± 1.42	**3.82** ± 1.74
environmental	The app shall provide an environmental friendly route to the destination.	**6.12** ± 1.11	**5.94** ± 1.09	**5.35** ± 1.50	**6.59** ± 0.71	**5.65** ± 1.00	**4.88** ± 1.58
toll free	The app shall provide a toll-free route to the destination.	**5.65** ± 1.06	**5.76** ± 1.15	**5.82** ± 1.42	**5.53** ± 1.46	**5.47** ± 1.37	**5.18** ± 1.85
Find:							
location/ address	The app shall find the desired location or address.	**6.22** ± 0.73	**6.00** ± 1.46	**5.83** ± 1.38	**5.44** ± 1.58	**6.22** ± 1.06	**6.61** ± 0.78
without address	The app shall find a destination without specifying the exact address.	**5.55** ± 1.23	**5.19** ± 1.11	**5.58** ± 1.23	**5.13** ± 1.34	**5.67** ± 1.24	**5.48** ± 1.43
previous/saved	The app shall enable the user to find previous or saved destinations.	**5.71** ± 1.31	**5.12** ± 1.11	**5.59** ± 0.87	**5.29** ± 1.31	**6.06** ± 1.34	**5.59** ± 1.58
Visualization:							
map	The app shall provide both a road and satellite map.	**5.86** ± 0.95	**5.50** ± 1.16	**4.79** ± 1.48	**5.00** ± 1.41	**5.71** ± 1.20	**5.46** ± 1.98
route	The app shall visualize the route.	**5.57** ± 1.34	**5.36** ± 1.15	**5.14** ± 1.75	**5.29** ± 1.27	**5.64** ± 1.69	**5.50** ± 1.83
pictures	The app shall be able to show pictures of locations.	**4.96** ± 1.49	**4.52** ± 1.36	**4.48** ± 1.19	**4.32** ± 1.60	**4.68** ± 1.38	**5.20** ± 1.50
street view	The app shall provide a street view (real view/ 3D view).	**4.80** ± 1.38	**4.56** ± 1.45	**4.92** ± 1.58	**4.44** ± 1.36	**4.84** ± 1.57	**5.00** ± 1.71
Interaction:							
voice-control	The app shall have a voice-control and output function.	**4.50** ± 1.20	**4.83** ± 1.65	**4.83** ± 1.65	**4.28** ± 1.27	**5.72** ± 1.02	**5.00** ± 1.94

auto-completion	The app shall auto complete inputs.	**5.16** ± 1.29	**5.03** ± 0.96	**5.42** ± 1.18	**4.74** ± 1.15	**5.80** ± 1.10	**5.65** ± 1.23
Provide Extras:							
ticket	The app shall provide the ability to buy public transport tickets.	**5.76** ± 1.09	**6.29** ± 0.77	**6.06** ± 0.97	**6.24** ± 1.09	**5.41** ± 1.42	**5.24** ± 1.86
health metrics/statistics	The app shall include health functions such as a kilocalorie calculator or pedometer.	**5.29** ± 1.60	**4.81** ± 1.49	**4.68** ± 1.35	**4.84** ± 1.13	**4.77** ± 1.41	**4.58** ± 1.34
location rating	The app shall offer an evaluation function for e.g. restaurants, stores and parks.	**5.13** ± 1.06	**5.50** ± 1.46	**5.69** ± 1.20	**5.00** ± 1.21	**5.38** ± 1.36	**5.44** ± 1.09
communication	The app shall make it possible to communicate with other people via Facebook, Twitter or Whatsapp.	**4.22** ± 1.70	**4.78** ± 1.93	**4.39** ± 1.58	**3.72** ± 1.27	**4.56** ± 1.38	**4.00** ± 2.06
planer	The app is supposed to have a route planner, which allows, among other things, stopovers, planning future routes and creating schedules.	**6.00** ± 1.03	**5.63** ± 1.15	**6.00** ± 1.15	**5.44** ± 1.36	**5.88** ± 1.15	**5.56** ± 1.09
advertisement	The app shall not include advertisement.	**5.47** ± 1.33	**5.47** ± 1.37	**4.24** ± 2.28	**4.94** ± 1.30	**5.71** ± 1.49	**5.41** ± 1.42

Appendix D – Non-functional System Requirements

The following list includes all non-functional system requirements in the coding manual with a description as presented in the assessment study. Additionally resulted means with standard deviations are shown for individual sustainability (INS), social sustainability (SOS), economic sustainability (ECS), environmental sustainability (ENV), technical sustainability (TES) and technical maturity (TEM) dimensions.

Categories	Requirement Description	INS	SOS	ECS	ENV	TES	TEM
Accessibility: The extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use (ISO/IEC 25064:2013 as cited in ISO, 2017b).							
general	The app shall be generally accessible and barrier-free.	**6.24** ± 1.01	**6.76** ± 0.52	**5.8** ± 1.2 6	**5.56** ± 1.29	**6.04** ± 0.95	**5.96** ± 1.17
language	The app shall be multilingual.	**6.18** ± 1.29	**6.6 5** ± 0.7	**6.06** ± 0.9	**5.1 9** ± 1.17	**5.88** ± 1.2 2	**5.82** ± 1.59
elderly	The app shall be accessible for elderly people.	**6.03** ± 1.14	**6.6 5** ± 0.66	**5.57** ± 1.38	**5.13** ± 1.18	**5.87** ± 1.04	**5.48** ± 1.21
disabilities	The app shall be accessible for people with physical disabilities.	**6.53** ± 0.87	**6.65** ± 0.86	**5.41** ± 1.33	**5.53** ± 1.28	**5.71** ± 1.36	**5.41** ± 1.54
Acquisition cost: The entire cost to acquire an asset, which includes the purchase price, delivery, installation, and any other costs to put the asset into service (ISO, 2017b).							
free	The app shall be free.	**6.33** ± 1.37	**6.52** ± 1.20	**4.38** ± 2.24	**5.5** ± 1.35	**5.25** ± 1.98	**4.71** ± 1.78
low/fair	The app shall be cost-effective.	**5.77** ± 1.23	**6.06** ± 1.26	**5.26** ± 1.9	**4.81** ± 1.1 7	**5.4** ± 1.54	**5.52** ± 1.48
Correctness: The degree to which a system or component is free from faults in its specification, design, and implementation (ISO, 2017b).							
general	The app shall provide correct results.	**6.35** ± 1.0 6	**5.82** ± 1.1 9	**6.41** ± 0. 8	**6.5 3** ± 0. 8	**6.29** ± 0.9 2	**6** ± 1.32
Effectiveness: The accuracy and completeness with which users achieve specified goals (ISO 25062:2006 as cited in ISO, 2017b).							
general	The app shall be of high quality (be a competent solution).	**5.88** ± 1.1 3	**5.3** ± 1. 4	**6.08** ± 1.19	**5.16** ± 1.2 5	**6.16** ± 1.0 3	**6.4** ± 1.29
Efficiency: The degree to which a system or component performs its designated functions with minimum consumption of resources. Human resources are included as part of efficiency (ISO 16350-2015 as cited in ISO, 2017b).							
general	The app shall be generally efficient.	**5.56** ± 1.26	**5.31** ± 1.25	**6.1 3** ± 0.89	**5.5** ± 1.32	**6.56** ± 0.63	**6.4 4** ± 0.89
human time	The app shall be efficient with human time.	**6.2** ± 0.96	**5.92** ± 0.95	**5.76** ± 1.2	**4.8** ± 1.47	**5.52** ± 1.19	**5.48** ± 1.58
travel distance	The app shall be efficient with the travel distance.	**6.44** ± 0.70	**5.1 7** ± 1.29	**6** ± 0.97	**5.9** ± 1.30	**6.28** ± 0.9 6	**6.28** ± 1.02
travel steps	The app shall be efficient in terms of necessary travel steps.	**6** ± 0.94	**5.59** ± 1.12	**6.1 8** ± 0.88	**5.76** ± 1.21	**5.94** ± 1.0 9	**5.76** ± 1.3
travel costs	The app shall be efficient with regard to the necessary travel	**5.64** ± 0.9 3	**5.7 9** ± 1.05	**4.8 6** ± 1.70	**4.71** ± 1. 9	**5.43** ± 1.34	**5** ± 1.53

	costs.						
hardware usage	The app shall use the device hardware efficiently.	**5.53** ± 1.46	**5.41** ± 1.42	**6.29** ± 1.05	**6.29** ± 1.05	**6.53** ± 1.18	**5.29** ± 2.08
data volume	The app shall focus on optimizing data volume usage.	**5.39** ± 1.04	**5. 8** ± 1.71	**5.89** ± 1.02	**5.72** ± 1.41	**5.78** ± 1.31	**5.89** ± 1.09
Flexibility: The ease with which a system or component can be modified for use in applications or environments other than those for which it was specifically designed (ISO 25010:2011 as cited in ISO, 2017b).							
general	The app shall be flexible and adaptable.	**5.76** ± 1.09	**5.76** ± 1.2	**5.92** ± 1.1 2	**5.08** ± 1.5	**6** ± 1.08	**5.64** ± 1.60
context	The app shall be able to adapt to new traffic situations.	**5.71** ± 1.31	**5.82** ± 1.07	**6.24** ± 1.2	**6.47** ± 0.72	**6.18** ± 1.13	**5.47** ± 2.12
individualization	The app shall be able to be individualized and adapted by the user.	**5.56** ± 0.81	**5.5** ± 1.41	**5.31** ± 1.35	**4.75** ± 1.34	**5.69** ± 1.08	**5.38** ± 1.02
Functional completeness: The degree to which the set of functions covers all the specified tasks and user objectives (ISO 25010:2011 as cited in ISO, 2017b).							
general	The app shall have a rich set of functions from which the user can choose.	**5.5 3** ± 1.37	**5.29** ± 1.16	**5.24** ± 1.3	**4.88** ± 1.22	**5.18** ± 1.38	**5.24** ± 1.82
Interoperability : The degree to which two or more systems, products or components can exchange information and use the information that has been exchanged (ISO 25010:2011 as cited in ISO, 2017b).							
general	The app shall be able to exchange information with other apps and devices.	**5.35** ± 1.77	**5.0 6** ± 1.92	**5.12** ± 1.58	**4.41** ± 1.4 2	**5.88** ± 1.22	**4.82** ± 2.1
Maintainability: The ease with which a software system or component can be modified to change or add capabilities, correct faults or defects, improve performance or other attributes, or adapt to a changed environment (IEEE 14764-2006 as cited in ISO, 2017b).							
general	The app shall receive support for a long period of time.	**5.71** ± 1.12	**5.75** ± 0.99	**5.4 6** ± 1.53	**5.25** ± 1.07	**6.25** ± 1.19	**6.4 2** ± 1.21
updates	The app shall get frequent updates.	**5.67** ± 1.55	**5.83** ± 1.09	**5.58** ± 1.84	**5.3 8** ± 1.24	**6.6 3** ± 0.71	**6.54** ± 1.28
Operability: The degree to which a product or system has attributes that make it easy to operate and control (ISO 25010:2011 as cited in ISO 24765, 2017). Operability corresponds to controllability, (operator) error tolerance, and conformity with user expectations (ISO 9241-110 as cited in ISO, 2017b).							
general	The application is under the control of the user.						
Precision: The degree of exactness or discrimination with which a quantity is stated (PMBOK® Guide as cited in ISO, 2017b).							
general	The app shall deliver precise results.	**5.98** ± 1.08	**5.5 5** ± 1.12	**6.16** ± 0.97	**5.5 5** ± 1.21	**6.1 7** ± 1.15	**6.16** ± 1.24
time	The app shall deliver precise times.	**5.76** ± 1.13	**5.36** ± 1.25	**5.64** ± 1.15	**5.04** ± 1.17	**5.6** ± 1.35	**5.92** ± 1.22
location/map	The app shall deliver precise locations and distances.	**5.7 9** ± 0.8	**5.71** ± 0.99	**5.07** ± 1.73	**5.36** ± 1.22	**6.14** ± 1.17	**5.64** ± 1.6
Reliability: The ability of a system or component to perform its required functions under stated conditions for a specified period of time (ISO 25010:2011 as cited in ISO, 2017b).							
general	The app shall be reliable.	**6.44** ± 0.96	**5.94** ± 1.29	**6.31** ± 1.01	**5.38** ± 1.41	**6.88** ± 0.34	**6.5** ± 0.82

world wide	The app shall work worldwide.	**6** ± 1.3 3	**6.22** ± 1.5 2	**5.72** ± 1.8 1	**5.5** ± 1.82	**6.33** ± 0.84	**5.78** ± 1.66
offline condition	The app shall work without an internet connection.	**5.92** ± 1.22	**5.48** ± 1.39	**5.2** ± 1.7 8	**5.16** ± 1.55	**5.58** ± 1.61	**5.88** ± 1.36
stable	The app shall not crash.	**6.06** ± 1.18	**5.75** ± 1.34	**6.44** ± 0.89	**5.5** ± 1.5 1	**6.8 8** ± 0.34	**6.81** ± 0.54
Response-time: T he elapsed time between the end of an inquiry or command to an interactive computer system and the beginning of the system's response (ISO, 2017b).							
general	The app shall react quickly to user input.	**5.44** ± 1.65	**5.39** ± 1.85	**5.44** ± 1.65	**4.83** ± 1.50	**6.17** ± 1.29	**6.33** ± 0.9 1
traffic-context	The app shall react quickly to new traffic situations.	**6.33** ± 1.01	**5.88** ± 1.03	**5.92** ± 1.28	**5.96** ± 1.16	**6.42** ± 1.14	**5.92** ± 1.72
Satisfaction: The freedom from discomfort and positive attitudes towards the use of the product (ISO 25062:2006 as cited in ISO, 2017b). The user's subjective response when using the product (ISO 26513:2009 as cited in ISO, 2017b).							
comfort	The app shall be comfortable to use.	**6.31** ± 1.08	**6.1 3** ± 1.26	**6** ± 1.1	**5.31** ± 1.35	**6.73** ± 0.59	**6.6 3** ± 0.62
Security: The d egree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization (ISO 25010:2011 as cited in ISO, 2017b).							
general	The app shall have a high IT security.	**5.74** ± 1.26	**6.10** ± 1.08	**5.79** ± 1.11	**4.90** ± 1.25	**6.07** ± 1.34	**6.23** ± 1.06
Simplicity: The degree to which a system or component has a design and implementation that is straightforward and easy to understand. This includes software attributes that provide implementation of functions in the most understandable manner. (ISO, 2017b).							
general	The app shall have a simple and minimalistic design.	**5.12** ± 1.17	**4.88** ± 0.93	**5.29** ± 1.21	**5.41** ± 1.18	**5.53** ± 0.87	**5.41** ± 1.18
clear	The app shall have a clear and straightforward design.	**6.21** ± 1.06	**6.21** ± 1.14	**5.96** ± 1.23	**5.29** ± 1.23	**6.54** ± 0.78	**6.04** ± 1.52
Complexity: The degree to which a system's design or code is difficult to understand because of numerous components or relationships among components (ISO, 2017b).							
general	The app shall have a low complexity.	**5.61** ± 1.26	**6.16** ± 1.00	**5.84** ± 1.07	**5.06** ± 1.31	**6.20** ± 0.96	**6.23** ± 0.88
Transparency: The pro perty of hiding from the user some specific aspects of the system's complexity needed to support distribution (ISO 10746-2:2009 as cited in ISO, 2017b).							
general	The developer shall be transparent and honest about his intentions towards the user.	**6.00** ± 0.89	**6.38** ± 1.09	**5.56** ± 1.41	**5.63** ± 1.15	**5.69** ± 1.25	**5.50** ± 1.03
Dependability : The trustworthiness of a computer system such that reliance can be justifiably placed on the service it delivers (IEEE 982.1-2005 as cited in ISO, 2017b).							
general	The app shall be trustworthy.	**6.14** ± 0.77	**6.43** ± 0.76	**5.43** ± 1.65	**5.71** ± 1.27	**5.93** ± 1.27	**5.93** ± 1.44
Usability : The extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO 25064:2013 as cited in ISO, 2017b).							
general	The app shall be intuitive and easy to use.	**6.36** ± 0.93	**6.29** ± 0.91	**5.64** ± 1.22	**5.71** ± 1.20	**6.50** ± 0.76	**6.29** ± 0.99
satisfaction	The app shall be visually	**5.65**	**5.24**	**5.94**	**5.35**	**5.82**	**5.12**

	appealing.	± 1.22	± 1.25	± 1.20	± 1.32	± 1.42	± 1.93
Constraint: A limitation or implied requirement that constrains the design solution or implementation of the systems engineering process and is not changeable by the enterprise (IEEE 730-2014 as cited in ISO, 2017b). A constraint is a factor that is imposed on the solution by force or compulsion and can limit or modify (ISO, 2017b).							
moral/ethical	The developer shall strive to develop and design the app according to moral and ethical constrains.	**6.11** ± 1.02	**6.17** ± 1.10	**4.67** ± 2.11	**6.00** ± 0.97	**5.33** ± 1.33	**5.78** ± 1.59
environment	The developer shall strive to develop and design the app in a way that protects the environment, for example by reducing CO2 emissions.	**5.72** ± 1.10	**5.68** ± 1.03	**5.44** ± 1.47	**6.56** ± 0.71	**5.28** ± 1.34	**5.08** ± 1.22
privacy	The developer shall strive to develop and design the app in accordance to data protection regulations.	**5.86** ± 1.29	**5.86** ± 1.56	**5.14** ± 1.83	**6.43** ± 1.02	**5.43** ± 1.65	**5.29** ± 1.20
Human-centered design : An approach to system design and development that aims to make interactive systems more usable by focusing on the use of the system; applying human factors, ergonomics and usability knowledge and techniques (ISO 25063:2014 as cited in ISO, 2017b). Usable systems can provide a number of benefits including improved productivity, enhanced user well-being, avoidance of stress, increased accessibility, and reduced risk of harm. (ISO, 2017b).							
general	The developer shall strive to develop and design the app in a human-centered way.	**5.94** ± 1.43	**6.06** ± 1.52	**6.00** ± 1.70	**5.35** ± 1.58	**6.12** ± 1.41	**4.76** ± 2.11
human well-being	The developer shall strive to develop and design the application in terms of safety and risk reduction for the user.	**6.38** ± 0.97	**6.75** ± 0.44	**5.67** ± 1.52	**5.58** ± 1.18	**6.46** ± 0.88	**6.04** ± 1.37
Independence: Is performed by an organization free from control by the supplier, developer, operator, or maintainer (ISO, 2017b).							
general	The developer shall develop the app independently from other companies, such as advertising agencies.	**5.25** ± 1.22	**5.88** ± 1.30	**4.33** ± 1.93	**4.88** ± 1.39	**4.88** ± 1.51	**4.42** ± 1.74
Portability: The ease with which a system or component can be transferred from one hardware or software environment to another (ISO 2382:2015 as cited in ISO, 2017b).							
general	The developer shall develop the app so that it can be used on all platforms including Windows, Apple, Android and others.	**5.71** ± 1.14	**5.93** ± 1.21	**5.07** ± 1.90	**5.07** ± 1.27	**5.57** ± 1.79	**5.43** ± 1.40
Unique function: A function that differs in form and/or logical processing from every other function provided by a certain application (ISO 24570:2005 as cited in ISO, 2017b).							
general	The developer shall strive to be innovative or incorporate unique features that make the app stand out from the competition.	**5.25** ± 1.13	**5.25** ± 1.24	**6.20** ± 0.86	**4.94** ± 1.53	**5.69** ± 1.01	**5.50** ± 1.21