

Defining and Evaluating Prudence and Recklessness of Enterprise Architecture Debt

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Abstract. Enterprise architecture (EA) debt refers to a situation where the quality of an EA declines in exchange for gains in other areas. This situation occurs when sub-optimal architectural decisions are made by the projects contributing to the EA. To prevent the reckless accumulation of EA debt, evaluating the impact of architectural decisions on EA debt and its prudence is crucial. However, due to the wide range of systems and stakeholders involved, there may be different opinions on the prudence or recklessness of EA debt based on the evaluation context. Failure to consider all relevant contexts can result in hasty estimates and justifications for EA debt. Although prudence and recklessness analysis exist in related fields of study such as technical and financial debt, research has not explored how to apply these concepts in EA debt management practices. Therefore, this study proposes a process for evaluating the prudence and recklessness of EA debts based on current insights about these concepts in related fields of study. Additionally, we highlight some open questions and suggest future research directions in this area.

Keywords: Enterprise Architecture · Enterprise Architecture Debt · Prudence · Recklessness.

1 Introduction

Aligning business and IT through enterprise architecture (EA) is a complex task, with misalignment issues being a common challenge. These issues can arise due to problematic organizational behavior (e.g., deficient communication and IT governance) or hasty trade-off decisions (e.g., using outdated systems to speed up project delivery). If left unaddressed, these problems can impede the progress of EA, leading to a concept called EA debt [18].

EA debt refers to "the deviation of the current state of an enterprise from a hypothetical ideal state" [18]. EA debt can cause a decline in architectural quality (e.g., increased complexity and lower maintainability) and can make future changes more difficult and expensive. However, taking on EA debt may be necessary in the short-term to deal with constraints or optimize IT investment returns. Therefore, stakeholders must understand the consequences and take responsibility for their decisions on EA debt.

To make prudent decisions on EA debt, enterprise architects must understand the factors that affect prudence and recklessness in this context. However, evaluating the prudence and recklessness of EA debts can be challenging because stakeholders may have differing views on what is prudent or reckless. This is especially true in complex organizations with diverse interests and conflicting views. To avoid reckless decisions, a collaborative process for evaluating the prudence and recklessness of EA debt is needed.

Although studies on the definition of prudence and recklessness exist in various debt-related contexts, e.g., technical debt (TD) and financial debt (FD), they do not address the evaluation of prudence and recklessness, especially in the context of EA debt. As such, this study aims to gather insights into these concepts and provide answers to the following research questions (RQs):

RQ1 How have prudence and recklessness been defined in debt-related contexts?

RQ2 How can the prudence and recklessness of EA debt be evaluated?

The remainder of this paper is structured as follows: In section 2, we identify research gaps related to prudence and recklessness in debt decision-making. Section 3 outlines the literature review that we performed to collect insights on prudence and recklessness. Based on the analysis of these insights, we propose definitions of prudence and recklessness in EA debt in section 4 and a process for evaluating them in section 5. This process is demonstrated in the sub-section 5.2 using an illustrative problem scenario. Section 6 summarizes the feedback on our results which we gathered through an interview involving EA researchers and practitioners. Section 7 presents the results of analyzing the feedback gathered from the expert interviews. Section 8 discusses the contributions of our study and potential threats to their validity, while section 9 concludes this paper and motivates future research directions in this area.

2 Related work

The prudence and recklessness of debt decisions have been extensively discussed in the fields of TD and FD. Since the theories and practices of these fields have greatly influenced the conceptualization of EA debt, we have conducted a review of existing literature and gathered insights into prudent and reckless debt decisions.

Fowler [16] introduced the understanding of prudent and reckless debt as part of the TD quadrant. Here, one can understand TD as prudent when the "payoff is greater than the costs of paying it off" and as reckless when it "results in crippling interest payments or a long period of paying down the principal." Since then, various studies have considered the concepts of prudence and recklessness. Tsoukalas et al. [43] and Nugroho et al. [31] associate the distinction between the two concepts with awareness. Nugroho et al. define it further by discussing awareness of committing the debt, which is supported by other studies focusing on the stakeholders knowledgeably taking on the debt [37] [38] [44]. Zalewski [51] relates the prudence of a debt to considering the consequences [9] [10] [37]

[38] [44], along with the risks. Silva et al. [38] focus on the strategical approach towards taking a debt, identifying the repayment measures beforehand [6]. Sas and Avgeriou [37] underline the need to document relevant information and validate the decision to take on the debt [6] [15]. There are also several things to note when considering taking on debt. One of them, recognized by Ernst et. al [15] is that a prudent decision is deliberate and correct concerning the knowledge when taking on the debt. Second, the perception of debt might change in time, especially given stakeholder change [6]. Third, reuse of implementation or solutions is not always prudent [44].

Prudence and recklessness have also been considered in the context of FD. In the context of FD, the consideration of risk is most prevalent. Wolf [49] and Denton et al. [12] consider risks in relation to their mitigation strategies. Egorova et al. [14] evaluates risk and cost to assess the loss related to the unpaid FD. Arps and Arps [2] focus on assessing available resources concerning their costs, allowing to inform the relevant stakeholders of the debt cost-benefit analysis, which Wolf [49] also proposed. Similar to the approach proposed for TD, Becha [3] focuses on the analysis and validation of debt.

Despite the insights into what could be considered prudence or recklessness in TD or FD contexts, there is no uniform definition of the two concepts. Furthermore, we could not find such consideration in the context of EA debt. Finally, the approach to evaluating the prudence or recklessness of debt is missing [40].

3 Systematic Literature Review

To define prudence and recklessness in the context of EA debt, one needs to first understand how these concepts have been defined in related fields. We conducted a systematic literature review (SLR) following the guidelines by Kitchenham et al. [23]. The methodological details of the SLR are described in the following.

3.1 Search scope

For the search, the databases proposed by Kitchenham et al. [23] and the *dblp* database were considered. After trial searches were executed, the *El Compendex* database was excluded as it was not freely accessible through the university network. Several other databases (i.e., *SpringerLink*, *CiteSeerX*, *Wiley InterScience*, and *Google Scholar*) were excluded for providing limited filtering options while returning an excessive number of irrelevant search results. Table 1 summarizes the selection and access times of the considered databases.

3.2 Search strategy

As mentioned, multiple trial searches were conducted to improve the accuracy of the results. These searches helped to become familiar with the databases' search engines and refine the search string and selection criteria. To maximize the coverage of the search, the search string was kept as general and inclusive

Table 1: Selection and access times of the considered databases

DB#	Database Name	Included? (Yes/No)	Date of access
DB1	IEEEExplore	Yes	10.12.2020
DB2	ACM Digital Library	Yes	10.12.2020
DB3	Science Direct	Yes	10.12.2020
DB4	Inspec (ISI Web of Science)	Yes	10.12.2020
DB5	SpringerLink	No	-
DB6	Scopus	Yes	10.12.2020
DB7	CiteSeerX	No	-
DB8	Wiley InterScience	No	-
DB9	El Compendex	No	-
DB10	IET Digital Library	Yes	10.12.2020
DB11	dblp	Yes	13.01.2021
DB12	Google Scholar (as extension)	No	-

as possible by searching both the nouns ("prudence" and "recklessness") and adjectives ("prudent" and "reckless") of the searched terms. Furthermore, to ensure that all TD, FD, and EA debt studies are covered, the keyword "debt" was appended to the search string. Lastly, the keyword "decision" was included to indicate how prudence and recklessness affect debt decision-making. The resulting search strings are as follows.

1. ("prudence" OR "prudent") AND "debt" AND "decision"
2. ("recklessness" OR "reckless") AND "debt" AND "decision"

Please note that these search strings had to be slightly adapted for some of the databases to match the databases' specific syntactical rules.

3.3 Study selection criteria

As per the SLR guidelines, inclusion and exclusion criteria were selected as listed in table 2. These criteria were applied to both of the searches for prudence and recklessness to ensure uniform findings. The first criterion, subject areas, limited the search context. The second, article type, and the third, publication stage, ensured a set of complete and peer-reviewed papers. The language criterion was added to accommodate the authors in analyzing the papers.

3.4 Study selection process

The execution of the two search strings over the selected databases resulted in 932 and 61 search results, respectively. After applying the selection criteria, 43 papers on prudence and 10 paper on recklessness were selected, where 44 definitions of prudence and 10 definitions of recklessness were identified. The entire selection process is summarized and represented in Figure 1.

Table 2: Selection criteria applied during the performed SLR

Name of criteria	Values selected
Subject areas/Publication topics/Categories	Decision sciences Economics and finance Business and management Psychology
Article type/Filters applied/Document type	Conferences Research articles Journals Books
Publication stage	Final Complete
Language	English

3.5 Data extraction

During the data extraction phase, the first focus was on finding all definitions of prudence. They were then grouped into three usability categories, namely *exists*, *maybe*, *does not exist*. The definitions in the *maybe* category were then analyzed in detail in order to identify their core idea. Some were then re-categorized into the *exists* category. For each of the papers in the *exists* category, a detailed analysis was performed with the goal of identifying the core idea represented by them. The identified core ideas were then grouped and expanded upon with the help of a mind-mapping tool. The same approach was applied to recklessness search results.

3.6 Data synthesis

The focus of the work was not only on the definitions but also on criteria affecting the categorization of a debt as prudent or reckless. In order to support that, an analysis of all definitions was performed. Those were then categorized by the field, in which they were defined. Only definitions existing in the context of TD, FD, Decision Sciences, Management, and Artificial Intelligence were used as they were closest to EA. Such definitions were then abstracted into eight most common criteria for prudence, and five most common criteria for recklessness.

4 Definition of Prudence and Recklessness in EA Debt

During the SLR, we gathered existing definitions of prudence and recklessness. Each of the found definitions was considered separately, and the authors discussed the applicability of the considered definition. This was performed based on consensus between the authors. If it wasn't reached immediately, the authors argued for their classification by discussing their concerns. This was continued until a consensus was reached. As a result, only the definitions applicable in the context of EA debt were considered.

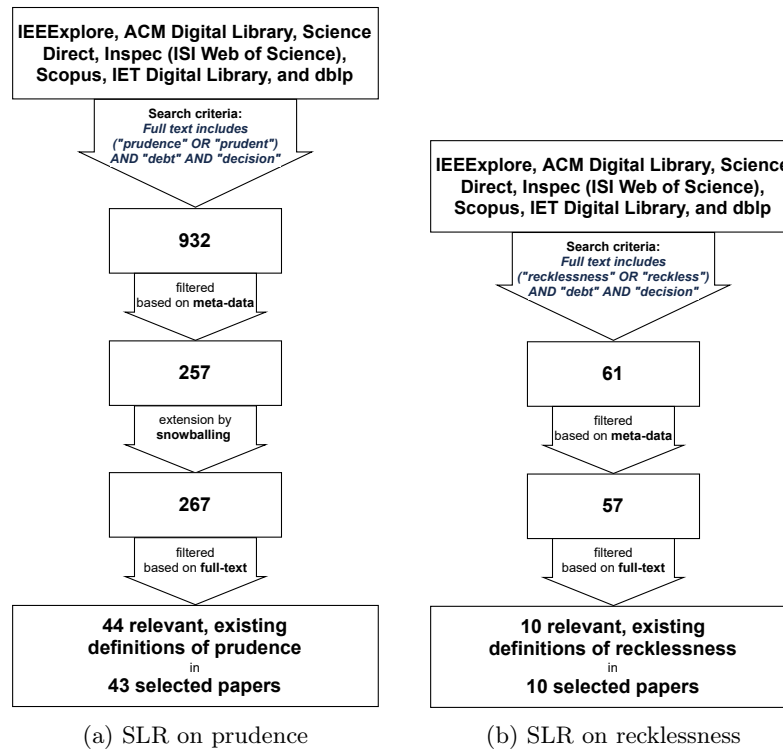


Fig. 1: Steps performed in the SLR. The numbers represent the number of papers included unless stated otherwise.

The chosen definitions were then placed on a mindmap displaying their relation to prudence and recklessness, respectively, from the beginning. Each of the chosen definitions was then carefully analyzed. All additional information from the papers was gathered and listed in addition to the corresponding definition. This allowed us to understand the context in which the given definition was considered by the original authors better. In parallel, the dictionary definitions of prudence and recklessness were considered for comparison.

During the second iteration of work on the mindmap, we focused on identifying the underlying key concepts that could be used to evaluate prudence or recklessness. The key concepts were then gathered and grouped together based on their closeness, resulting in several closely related characteristics. We could observe an inverse relation between the characteristics of prudence and recklessness. The identified characteristics of prudence and recklessness are introduced separately in the next subsections.

4.1 Prudence

The SLR showed that even if one can identify definitions of prudence, they usually pertain to one specifically chosen aspect. There is also a lack of provided information on how the definition was achieved. To make the concept of prudence usable in the context of EA debt, prudence needed to be identified and defined. Although the definition is proposed in the context of EA debts, the general understanding of prudence can be applied to other fields as well. Eight characteristics of prudence have been identified, which are discussed below. Detailed information on these characteristics is given in Table 3.

- C1: **Payoff > cost.** The comparison of payoff and cost means that when making a decision, all potential gains should be considered and related to the respective potential costs. One example would be the consideration of risks as compared to benefits. The decision could only be made if the cost of the decision and the risks together would be lower than the gain related to that decision. This line of argumentation follows Fowler's understanding of prudent debt [16].
- C2: **Consequences considered.** Negative and positive as well as short-term and long-term consequences need to be considered. This means assessing their severity and the probability with which they might occur. The goal is to prioritize the consequences based on their impact and avoid the most problematic ones. Note that long-term consequences require special attention as future uncertainties make it hard to estimate their impact.
- C3: **Mitigation strategies.** As each debt comes with certain risks, some specific to that debt only, it is important to tailor the mitigation strategy. Identification of the risks and consequences is needed to be able to establish mitigation strategies. The larger the risk, the larger the mitigation measures to take. A debt that at first seems unbearable might have its negative consequences identified and appropriately mitigated, leaving mostly the positive consequences with a higher payoff than the cost.
- C4: **Preparation.** To decide whether or not to take on debt, one should gather and consider the available information, such as measures and strategies. Without apriori preparation, even a prudent debt might start causing problems over time. To gather relevant data, one should observe the identified debt over time. This can be supported by using thresholds, which can detect any untypical behavior of the observed data. To ensure a smooth and successful debt restructuring process, norms and protocols should be introduced to support involved stakeholders.
- C5: **Stakeholders informed.** When making a decision, relevant stakeholders need to be involved in the process. Not only might they have previously undocumented information that is relevant to the evaluation, but also they might be able to predict or identify certain risks based on their experience and historical data. Additionally, having been informed, the stakeholders might consider the debt more seriously and might be actively engaged in applying the chosen measures. Finally, as the teams might change, it is nec-

essary to document the stakeholder know-how and proceedings in order to introduce new stakeholders to the process as soon as possible.

- C6: **Goals considered.** The goals of the company and project need to be considered with regard to any decision taken. Each company should have clearly defined goals describing the direction the company is moving. This can be motivating for the stakeholders, making it easier to focus on the direction in which the project needs to be taken. The goals should be prioritized in case the decision needs to be taken between two contradicting objectives.
- C7: **Risk awareness.** When making a decision, another relevant aspect is risk awareness. Similar to a consequence, which discusses the impact of the decision, risk discusses the likelihood with which negative consequences occur. Careful preparation and mitigation of identified risks reduce the probability of unwanted, negative consequences. One special case of risk awareness is being risk-averse. It is an approach where it is better to wait or classify the decision as reckless when in doubt. It also concerns taking more preventive measures in the face of a larger risk.
- C8: **Iterative process.** As the data and available information might change, the evaluation of the decision might change as a result. This indicates the need to re-evaluate. Similarly, the change of context might have a similar effect. This is especially important as re-using previously applied solutions might not always be prudent, even if it was prudent previously.

Based on the SLR results and the identified characteristics, we propose the following definition of prudence.

Definition 1. *Prudence is a characteristic representing a cautious approach towards decision-making, allowing to avoid unexpected, negative consequences of a decision made in the context of EA debt.*

Note: There are certain efforts to be done to exercise prudence:

- Consider the concerns represented by both the enterprise and project
- Seek the common agreement of involved stakeholders
- Consider all identified consequences and their mitigation strategies

This definition is applicable in the context of EA debts as it relates to the concerns and goals of the enterprise and the projects, i.e., it takes into account the company's approach to achieve the hypothetical ideal state of the EA, as defined by Hacks et al. [18].

4.2 Recklessness

Recklessness is typically considered an inverse concept to that of prudence. Due to the lower amount of paper concerning recklessness, fewer characteristics relevant to the definition could be identified than in the case of prudence. Five characteristics of recklessness have been identified. They are as follows:

- C1: **Stakeholders not informed.** Not informing the stakeholders means that the decision is made on limited data. It also means that the awareness of the

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Table 3: Characteristics describing prudence along with the corresponding list of citations and their short descriptions

Characteristic	Key Concepts/References
payoff > cost	<ul style="list-style-type: none"> - prudent as of high quality - cost vs quality [35] - in doubt classify as bad credit rather than a good credit [3] - assessment of risks and costs to mitigate them [12] - prudent risk-taking approach [2] - larger risk requires larger preventive measures [20] - larger risk, makes more patient [46] - prudent - save more in face of risk [8] - inappropriate attributes waste valuable evaluation resources [26] - considering risks in the face of not paying of [14]
consequences considered	<ul style="list-style-type: none"> - foresee little interest probability on the rushed parts [37] - after analyzing the benefits and when to repay it - action plan to repay, and eventually, eliminate it [38] - reusing implementation is not always prudent [44] - consequences are analyzed especially wrt risks [51] - prudent person hypothesis [19] - prudent egoism [50] - preventive focus to reduce vulnerability [21] - prudent compromise - opportunity, competition and deadline to be considered [39] <ul style="list-style-type: none"> - prudent as of high quality - cost vs quality [35] - risk reduction adds value to stakeholders [49] long-term consequences <ul style="list-style-type: none"> - prudent risk-taking approach [2] - considering risks with relation to the impact and future uncertainties [11]
mitigation strategies	<ul style="list-style-type: none"> - after analyzing the benefits and when to repay it - action plan to repay, and eventually, eliminate it [38] - assessment of risks and costs to mitigate them [12] - prevention of risk should be bound by optimal threshold [29] - larger risk requires larger preventive measures [20] - preventive focus to reduce vulnerability [21] - avoid exchange when threshold crossed [33]
preparation	<ul style="list-style-type: none"> - most debt occurs in the "inadvertent/prudent" quadrant [15] - impact and threshold of the risks should be identified and quantified periodically [45] - consequences are analyzed especially w.r.t. risks [51] - considering risks with relation to the impact and future uncertainties [11] - establishing norms and processes for assessing risks [47] - prudent decisions require knowledge and understanding [32] - prevention of risk should be bound by optimal threshold [29] - preventive focus to reduce vulnerability [21] - warning on unusual behavior [1] - inappropriate attributes waste valuable evaluation resources [26] - prudence as informed and context dep. [5] - avoid exchange when threshold crossed [33]
stakeholders informed	<ul style="list-style-type: none"> - foresee little interest probability on the rushed parts [37] - after analyzing the benefits and when to repay it - action plan to repay, and eventually, eliminate it [38] - reusing implementation is not always prudent [44] - documentation of TD is important as the teams can change [6] - project manager optimism in risk taking [25] - consequences are analyzed especially wrt risks [51] - risk reduction adds value to stakeholders [49] - prudent decisions require knowledge and understanding [32] - prudent person hypothesis [19] - prudence as informed and context dep. [5]
goals considered	<ul style="list-style-type: none"> - prudent person principle [4] - prudent egoism [50] - project manager optimism in risk taking [25] - prudent predator [17] - prudence as informed and context dep. [5]
risk awareness	<ul style="list-style-type: none"> - prudent person principle [4] - project manager optimism in risk taking [25] - crucial to analyze awareness (reckless or prudent) and intention [43] - awareness (reckless or prudent) 2 [31] - consequences are analyzed especially wrt risks [51] - assessment of risks and costs to mitigate them [12] - risk reduction adds value to stakeholders [49] - considering risks with relation to the impact and future uncertainties [11] - metric of sensitivity to changes in risk [22] - considering risks in the face of not paying of [14] <ul style="list-style-type: none"> - in doubt classify as bad credit rather than a good credit [3] - prudent risk-taking approach [2] - conservatism in decision making [22] risk-averse <ul style="list-style-type: none"> - larger risk requires larger preventive measures [20] - larger risk, makes more patient [46] - prudent - save more in face of risk [8] - prudence as downside risk aversion [13]
iterative process	<ul style="list-style-type: none"> - impact and threshold of the risks should be identified and quantified periodically [45] - reusing implementation is not always prudent [44] - establishing norms and processes for assessing risks [47] - warning on unusual behavior [1]

debt is not uniform among involved stakeholders. Stakeholders might unconsciously contribute to the debt. Additionally, as a result of team changes, one might create a team that has no information on measures taken.

- C2: **Consequences not considered.** Not considering the consequences means a lack of understanding of the debt. As a result, the consequences no one considered nor prepared for can accumulate new debt. When the consequences are not analyzed, there are no prepared mitigation strategies, meaning the unwanted consequences have a higher chance of happening. Such an approach might also mean that the previously made mistakes are repeated.
- C3: **Lack of risk awareness.** The lack of risk awareness may appear due to a high-risk tolerance or simply a failure to recognize them. It can result in unexpected difficulties in the project, such as unmanaged negative consequences. Being unaware of risks or having too high of an acceptance threshold endangers the project's success.
- C4: **Lack of risk strategies.** The lack of risk strategies is, in fact, a lack of a debt management plan. This in itself might be the cause of multiple negative consequences. The lack of analysis and preparation for the debt makes tracking such debt impossible. As a result, it is increasingly hard to understand it. If the mitigation of consequences is missing, a decision under analysis might be incorrectly rejected due to high risk.
- C5: **No preparation.** Preparation considers gathering data and trying to present the basis for the correct assessment of a decision. Lack of preparation results mainly in an inability to analyze the current situation correctly. Without data support, any decision taken can be unreliable, increasing the probability of unexpected negative consequences. Having incorrect data might also lead to incorrect debt evaluation. One example would be trying to mitigate consequences with a low impact on the project due to misinformation - the problematic consequences would not be mitigated as a result.

Detailed information on these characteristics of recklessness are presented in Table 4. Based on them the following definition of recklessness is proposed.

Definition 2. *Recklessness is a characteristic representing an incautious approach towards decision-making, increasing the risk of encountering unexpected, negative consequences of a decision made in the context of EA debt.*

Note: There are certain mistakes increasing recklessness:

- *Not considering the concerns represented by both the enterprise and project*
- *Lack of information for involved stakeholders*
- *Not considering the consequences and their mitigation strategies*

Such a formulation relates the two definitions in a natural way to each other. The proposed definition of recklessness is also applicable in the context of EA debt as it considers the to-be aspects of the enterprise.

5 Evaluating Prudence of EA Debt

Having proposed new definitions of prudence and recklessness in the context of EA debt management based on the performed SLR, a systematic approach to

Table 4: Characteristics describing recklessness along with the corresponding list of citations and their short descriptions

Characteristics	References
stakeholders not informed	- without plans to be managed and repaid - no attempt to learn TD and eliminate it [38] - no care for consequences including risks [51] - unawareness of debt trade-offs [36] - disregarding the data, model does not match context [42]
consequences not considered	- without plans to be managed and repaid - no attempt to learn TD and eliminate it [38] - no care for consequences including risks [51] - unawareness of debt trade-offs [36] - disregarding the data, model does not match context [42] - introducing problems, with a negative impact, consequences of recklessness [41]
lack of risk awareness	- crucial to analyze [lack of] awareness (reckless or prudent) and intention [43] - lack of awareness (reckless or prudent) 2 [31] - no care for consequences including risks [51] - unawareness of debt trade-offs [36] high risk accepted - failing to recognize danger [30] - acceptance of unacceptably high risk, tolerance [34]
lack of strategies	- without plans to be managed and repaid - no attempt to learn TD and eliminate it [38] - decision made without strategy/plan [7] - introducing problems, with a negative impact, consequences of recklessness [41]
no preparation	- no care for consequences including risks [51] - disregarding the data, model does not match context [42] - decision made without strategy/plan [7]

apply these concepts is needed. To this end, a process suitable for this purpose is presented, followed by a small example of how this process can be applied.

5.1 Prudence Evaluation Process

Based on the definitions obtained from the SLR and their analysis, a process for evaluating the prudence (and thereby also indirectly recklessness) of EA debt was developed, which allows collaboration among stakeholders. The **prudence evaluation process** consists of five sub-processes that are interconnected as shown in Figure 2. These sub-processes and all their activities (A1-A11) are described in detail below.

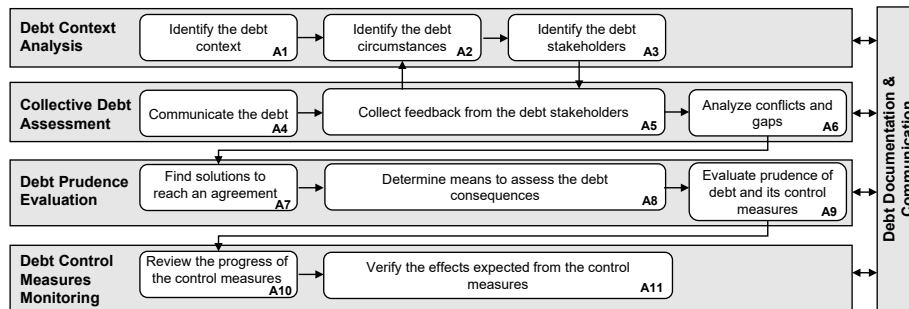


Fig. 2: Structure of the prudence evaluation process (based on [40])

Debt Context Analysis To evaluate the prudence and recklessness of debt, it is essential to understand the underlying premises, as suggested in [3], [6], and [15]. Therefore, the debt context analysis sub-process aims to identify the various contexts, circumstances, and stakeholders that need to be considered when analyzing the EA debt. Firstly, the debt context is identified (A1), which can be some organizational layers or entities. This is done by discussing with the relevant domain experts and analyzing available documentation (e.g., EA models). Secondly, the debt circumstances are identified (A2), which are the organizational factors that support or oppose the need for the EA debt under analysis (e.g., organization rules, constraints, or requirements that turn the EA debt into an advantage or disadvantage). Lastly, the debt stakeholders are identified (A3), who are the people whose understanding and cooperation are necessary for managing the EA debt (e.g., the person in charge of the related processes or applications). All these activities help to put the EA debt into a broader perspective and allow for a more reasonable evaluation.

Collective Debt Assessment After identifying the debt stakeholders, it must be ensured that they are informed about all possible consequences of taking on the debt, as suggested in [9], [10], [37], [38], [44], [49], and [51]. Therefore, the collective debt assessment sub-process focuses on preparing and conducting a collaborative debt assessment among all debt stakeholders. Firstly, the debt is communicated to its stakeholders (A4) using the debt representations that suit their specific viewpoints [27]. Secondly, feedback from the debt stakeholders is collected (A5) to obtain a comprehensive view of the debt's consequences (e.g., financial, functional, strategic consequences) from all relevant perspectives [12]. Here, approaches to eliciting structured feedback (e.g., questionnaires and checklists) can be used to establish clear and structured communication with the stakeholders. Additionally, the feedback received may suggest new debt contexts and circumstances that require further examination by other stakeholders. Thirdly, conflicts (i.e., any disagreement) and gaps (i.e., any knowledge discrepancy) among the stakeholders are analyzed (A6) based on their feedback. These issues are brought into discussions to improve shared understanding about the debt's consequences.

Debt Prudence Evaluation According to [6], [37], [38], and [44], it is crucial for all relevant stakeholders to consent to the debt and its control measures. To achieve this consensus, the debt prudence evaluation sub-process focuses on determining the prudence of the debt being analyzed and the feasibility of its control measures. This sub-process begins with finding solutions to reach an agreement (A7) among the conflicting interests, needs, or attitudes of the stakeholders as identified during the previous activity. A moderator knowledgeable about the organization's methods, projects, and stakeholders can be helpful in managing such conflicts. After the stakeholders reach a consensus, the criteria to evaluate the prudence and recklessness of the debt are determined (A8) by looking into the organization's goals, principles, and general recommendations

(e.g., a debt is prudent when its payoff is greater than the costs of paying it off [16]). Additionally, suitable metrics to measure these criteria are determined by looking into the various performance indicators used in the organization (e.g., EA key performance indicators [28]). Finally, the criteria and metrics selected are applied to the evaluation of the debt and its control measures (A9). Here, the evaluation criteria and metrics can also be given different weights and thresholds to reflect the organization's priorities and tolerance. Based on this evaluation, stakeholders can classify the debt as prudent or reckless.

Debt Control Measures Monitoring To ensure that the debt and its circumstances are controlled as planned, this sub-process focuses on continuously tracking the progress and results of planned debt control measures. It involves reviewing the implementation and progress of the control measures (A10) (e.g., checking on current status, success factors, and inhibitors) and verifying the expected implementation results (A11) (e.g., confirming the quality or monetary benefits). Here, the use of collaboration and dependency analysis tools can help to, e.g., manage change progress, dependencies, and issues during the implementation.

Debt Documentation and Communication This sub-process aims to ensure that all information involved throughout the prudence evaluation process is well-documented, up-to-date, and meaningfully communicated among stakeholders. Here, structured documentation and communication approaches (e.g., forms, reports, and catalogs) can be used to achieve consistency and clarity, thereby reducing dependency on "tribal memory" which often occurs in the reality of enterprise-level management [6] [24].

5.2 Applying the Prudence Evaluation Process - An Example

Next, a simple problem scenario involving a company dealing with EA debt issues is presented and an example is provided to show how the prudence evaluation process can be applied in this situation.

Problem Scenario A company was internally using and further developing a complex application landscape that has many dependencies. As the application landscape was difficult and expensive to maintain, the company decided to reduce the existing architectural debt through architecture refactoring and enforcement of new architectural guidelines. The new guidelines included avoiding further direct dependencies between modernized or newly developed applications and non-refactored applications, called legacy applications. Obviously, due to time and budget constraints, the company was only able to incrementally refactor the landscape leading to a mixture of modernized and legacy applications.

Figure 3 shows an excerpt of the landscape. While application A is already modernized B and C are still legacy applications. Application A is decoupled

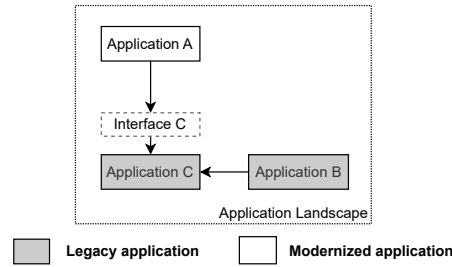


Fig. 3: Excerpt of an application landscape

from the legacy application A by means of an interface, application B depends directly on application C.

Besides the modernization of legacy applications, new applications need to be developed and integrated into the landscape as well. In the presented scenario the internal client requires a new application D. As it should offer a market-critical functionality, it has to be available very quickly. To speed up the development of D, it was proposed that some parts of the legacy application B could be reused (after some code modifications) by the new application D. To meet this requirement a stakeholder suggested temporarily deviating from the guidelines and incurring EA debt by directly reusing some parts of the legacy application B for the new application D.

Going forward, there are three options to integrate the new application D into the landscape (visualized in Figure 4):

- Option 1: Developing application D with a direct dependency on the legacy application B.
- Option 2: Wrapping application B by a newly developed interface that provides the functions of B needed by the new application D.
- Option 3: Modernizing application B first in order that B can be reused by the new application D.

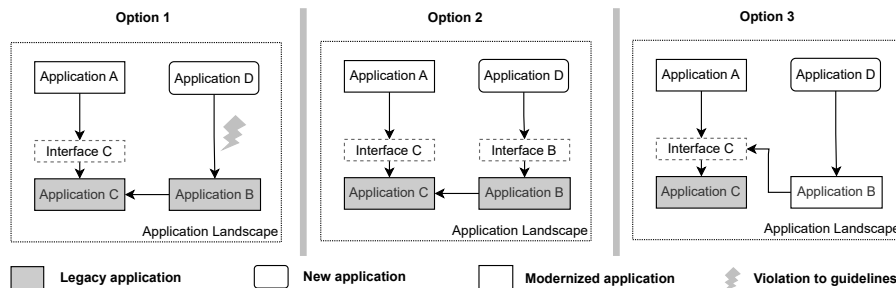


Fig. 4: Options to integrate the new application D

Exemplary Application of the Prudence Evaluation Process Starting with the **debt context analysis**, the enterprise architects formulate the direct reuse of the legacy application B in the new development application D as a debt within the context of landscape modernization. Minimizing this debt is crucial as the budget for legacy applications has been reduced and only a few people can maintain them. Moreover, taking on this debt would be a hard violation of the architectural guidelines. After analyzing the scope of this issue, the enterprise architects considered the modernization team leader, the engineering teams of both modernized and legacy applications, and the product owner of the new application D as the debt stakeholders.

As per **collective debt assessment**, the debt stakeholders were invited to discuss and assess the available options to integrate the new application D (see Figure 4). The product owner emphasized the need for very quick delivery, while the modernization team leader mentioned the tight constraint on budget in the next few years. Considering these concerns, the enterprise architects conclude that modernizing application B (option 3) within the given time frame is not feasible, thereby leaving two options: Implementing the new application D directly reusing the legacy application B (option 1) or implementing it with access to application B via an interface, which still needs to be developed (option 2).

The engineering team for the legacy applications argued that option 1 would be quicker despite violating new architecture guidelines. On the contrary, the team responsible for the modernized and new applications advocates option 2 to maintain architectural integrity, despite the need to develop a new interface for application B that is undocumented and difficult to understand. The legal representative is concerned about the time needed to deliver application D and notes that there is a contractual penalty for not meeting the deadline. In the end, the enterprise architects identified a conflict of cost and time saving versus architectural integrity and an opinion gap between the two teams of software engineers, leading to further discussions.

Table 5: Costs and benefits analysis of the two options [40]

	Option 1	Option 2
Benefits	<ul style="list-style-type: none"> – speeds up the development – delivery deadline can be met 	<ul style="list-style-type: none"> – conforms to guidelines – new application is decoupled
Cost	<ul style="list-style-type: none"> – violates guidelines – higher costs over time – needs additional modernization work 	<ul style="list-style-type: none"> – higher cost now – might not met delivery deadline – technology stacks are less familiar

After analyzing the conflict, the enterprise architects performed the **debt prudence evaluation** to evaluate the two options on cost and benefit (see Table 5). Option 1 requires less time and less initial investment but it violates architecture guidelines and introduces additional debt, which may cost additional work in the future. Option 2 follows architecture guidelines and promises fewer problems in the future, but it requires significantly higher initial investment and

is less reliable because the software engineers of the modern system are less familiar with legacy application B.

The enterprise architects suggest option 1 but propose collaboration between the two engineering teams to mitigate the incurred debt and modernize the affected application of the landscape in the future. All findings throughout the prudence evaluation process are documented and presented to the board for final evaluation and decision.

The enterprise architects performed an audit and observed that the team for the modernized and new applications is more knowledgeable about the legacy system, thanks to the collaboration. All recommendations are followed, and the documentation is up-to-date. This activity is part of the **debt control measures monitoring**, and the process is documented for future reference and communicated to all stakeholders as part of **debt documentation and communication** activities.

6 Interviews with EA Debt Experts

In order to check the appropriateness of the proposed definitions and the prudence evaluation process, we chose expert interviews to collect information and feedback from those subjects involved in EA debt research and management. In the following, the feedback from in-depth expert interviews is presented.

6.1 The Expert Interviews

Selection of Experts As the field of EA debt is relatively new, there are not many experts in the field. Kindly three experts, all working in the field of EA debt management, participated in our interviews. All participants took part in the interview voluntarily and gave their consent to the recording of the interview.

Structure and Conduction Each interview was conducted separately face-to-face (by Zoom) and consisted of three parts: (1) the participants' background, (2) feedback on the definitions, and (3) feedback on the prudence evaluation process. Prior to these interviews, the participants were given a brief introduction of the research topic, the goals of the interview, and the interview agenda.

6.2 Part 1: Participants' Background

During the first section of the interview, the aim was to gain an understanding of the participants' backgrounds through three different aspects. Firstly, the work performed by each participant was discussed. All three have extensive experience in EA research, with two working as associate and full professors respectively. The third participant has a background in industry as a lead information architect for a large-scale enterprise.

The second aspect focused on the participants' comprehension of EA. They agreed that EA involves a holistic approach to aligning IT and business needs

within an organization. Additionally, they believed that it is necessary to use EA models, structure, and visualization to gain a comprehensive overview of the organization.

The third aspect centered on the participants' consideration and understanding of prudence and recklessness. One participant associated debt with the delta between the holistic perception and the reality of the situation. In this understanding, prudence means attempting to decrease the delta, while recklessness entails allowing the delta to persist or increase. Another participant emphasized consciousness, with prudence being defined as making an informed decision, and recklessness as not being aware or not caring about doing wrong. The third participant did not take a definitive stance on the two concepts. They argued that prudence requires common understanding, which necessitates definitions, examples, and best practices.

6.3 Part 2: Feedback on the Proposed Definitions

During this part, the focus was on the evaluation of the proposed definitions. In order to obtain valuable feedback, the two definitions were first presented by going iteratively over them. Two types of questions were asked, namely those specific to certain parts of the definitions, and the general ones. Questions about the characteristics affecting the definition were included, asking for example whether reaching an agreement of all stakeholders contributes to a decision being prudent.

Most of the feedback was positive and discussed an intuitive understanding of the definition, which is extremely important if the definition is to be used in practice. Corrective feedback pertained to some difficulties in using some parts of the definition in practice. One aspect discussed was that cautious implies ignoring the facts, whereas recklessness might mean accepting too many of them. However, it might be prudent to take on a debt consciously, like in the case of start-ups taking the debt to leverage their capabilities. Secondly, one cannot avoid risks that have not been identified. The risks need to be known so that one can try to mitigate them. Thirdly, it is almost impossible to get an agreement from all people. The more people are involved in the decision-making, the harder it is to reach a consensus. However, every stakeholder does not need to agree to the measures, but they should understand them and the reasoning behind them. Finally, it is not worth considering all consequences, as some might require high cost, and have high impact, but extremely low probability of success. Possibly such cases are not worth considering, which should be taken into account in the definition itself.

6.4 Part 3: Feedback on the Proposed Process

During this part, the focus was on determining if the proposed prudence evaluation process was applicable. This part was structured as follows:

1. First, we explained the process to the participant.

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2. Then, we focused on the usability of the prudence evaluation in decision-making, the person responsible for executing the prudence evaluation process, and the collaboration within the process.
3. Next, activity-related questions, grouped by the defined sub-processes were asked as presented in table 6.¹
4. Finally, questions about the potential difficulties of applying the process in real-world contexts were asked.

All of the participants' feedback, opinions, and suggestions regarding the accuracy and validity of the proposed design and definitions Were carefully noted down and documented.

Table 6: Activity-related process questions [40]

Debt Context Analysis
- Which data/documents can be used to determine the context of a debt?
- How can the stakeholders relevant to making a decision be identified?
Collective Debt Assessment
- Can comprehensive concerns be determined from the gathering of the stakeholders?
- How can it be verified if all relevant concerns were identified?
- How to manage potential disagreements?
Debt Prudence Evaluation
- Can comprehensive consequences be determined from the gathered concerns?
- Given the consequences and based on the provided definition, can the prudence of the debt be determined?
Debt Documentation and Communication
- Who can document the activities performed?
- How can the activities carried out be documented?

7 Results from Expert Interviews

In this section, we describe the refinements and improvements to the proposed definitions and to the prudence evaluation process.

7.1 Refined Definitions

Based on the various obtained relevant feedback, the definitions of prudence and recklessness have been refined in the relevant places to make them as applicable as possible. Those changes (marked with **bold**) should resolve the issues identified by the expert interviews.

¹ As *Debt Control Measures Monitoring* is a standard sub-process, the questions about it were omitted.

Definition 1. *Prudence is a characteristic representing a **risk-aware** approach towards decision making, allowing to **reduce** unexpected, negative consequences of a decision made in the context of EA debt.*

Note: There are certain efforts to be done to exercise prudence:

- Consider the concerns represented by both the enterprise and project
- Seek the common **understanding** of involved stakeholders
- Consider **relevant** consequences and their mitigation strategies

Definition 2. *Recklessness is a characteristic representing a **risk-unaware or having too high of a risk threshold** approach towards decision making, **not reducing** the risk of encountering unexpected, negative consequences of a decision made in the context of EA debt.*

Note: There are certain mistakes increasing recklessness:

- Not considering the concerns represented by both the enterprise and project
- Lack of **understanding from** involved stakeholders
- Not considering **relevant** consequences and their mitigation strategies

7.2 Findings on the Process' Applicability

Although all experts considered the proposed prudence evaluation process useful and applicable, the interviews yielded valuable detailed feedback which we carefully analyzed. As a result of this analysis, we have created the following thematic descriptions of important aspects.

On facilitating common understanding: Although understanding the concepts of prudence and recklessness is necessary to make reasonable EA debt decisions, a collaborative process for evaluating them is needed to allow for a shared understanding among stakeholders. The evaluation result shows that the proposed prudence evaluation process can help to facilitate collaboration and integration among stakeholders by prescribing ways to achieve joint agreement and considering a decision from various contexts.

On identifying relevant stakeholders: The identification of relevant stakeholders requires the analysis of various documentation, e.g., project documents and EA models. However, up-to-date and complete documentation rarely exists in the reality of software development. Therefore, methods and tools are needed to maintain and analyze such documents. To develop such methods and tools, it is crucial to understand the company, the relations among its stakeholders, and the sources of its information.

On performing a screening test: Gathering feedback from all relevant stakeholders and identifying disagreements in it can be challenging. To support this process, a screening test that shows possible outcomes can be developed. Such a test can help stakeholders to identify disagreements during the evaluation process, prioritize them, and solve them using conflict management methods.

On assessing the accuracy of evaluation: Determining whether an EA debt is prudent or reckless requires the accurate identification of relevant concerns and possible consequences. This accuracy depends on the evaluation method

used and the reliability of the data. Analyzing, e.g., the correlations between concerns and consequences can increase the reliability of the process.

On performing the re-evaluation: New or changed information may require a re-evaluation of the results. Such re-evaluation should involve as few stakeholders as possible to avoid disturbing the company's usual workflow.

On keeping central documentation: It is essential to document all information gathered during the process execution using the right approach. A dedicated tool is necessary to establish central data storage, allowing easy access and analysis by stakeholders.

On applying the process in practice: The evaluation showed the proposed prudence evaluation process to be lightweight and practical. However, the governance and standardization methods that are suggested in it still require further investigation to describe their practical details.

8 Study Contributions and Validity

Following, we summarize the contributions of our research and discuss possible threats to the validity of our study results.

8.1 Contributions

This study has two main contributions. Firstly, it provides valuable insights for the research community, and secondly, it has practical implications for EA practitioners.

For researchers, this study sheds light on the concepts of prudence and recklessness in the context of EA debts. The review of existing literature revealed a lack of research on these concepts, highlighting the need for further investigation into the decision-making process. Additionally, the proposed prudence evaluation process approach aims to increase awareness of EA debts and help to understand the reasoning, benefits, and risks behind specific EA debt decisions.

For EA practitioners, this study offers several benefits. Firstly, it provides a classification of EA debts into prudent and reckless categories based on various criteria, as discussed in section 2. This classification can help practitioners make informed decisions and better manage EA debts, leading to improved communication among stakeholders. Secondly, it supports a comprehensive understanding of the consequences of EA debts, facilitating prioritization in decision-making. Finally, the proposed process activities provide initial guidelines that can be adapted to meet the specific needs of an enterprise, enabling tailored prioritization of debt based on the enterprise's goals and stakeholder concerns.

8.2 Threats to Validity

In order to ensure the validity of this study, the guidelines established by [48] were followed to identify and analyze potential threats. Internal validity refers to the trustworthiness of the relationship between the study and its results. To

maintain objectivity, all content was consulted with an expert at each stage of the study and the results were further discussed with additional experts during the evaluation. This process ensures that the results are reliable and unbiased. Also, only scientific works that were objectively peer-reviewed before publication were considered in this work.

External validity refers to the consistency of the presented results when applied in different contexts. A detailed explanation of the procedure underlying the literature review and analysis was provided to enable the replication of the results. The process is specific to the context of EA, but it can easily be adapted to other contexts. For example, the measures in the debt prudence evaluation sub-process can be selected and adjusted for specific projects. The feedback from both EA researchers and practitioners was gathered and applied to strengthen the external validity of the findings.

9 Conclusions and Future Work

In TD and FD literature, the concepts of prudence and recklessness are used to distinguish good decisions from bad ones. However, there is no defined process for evaluating these concepts in the context of EA debt. This paper proposes a process for assessing the prudence and recklessness of EA decisions, which is developed based on the insights gathered from related literature. The process prescribes a collaborative way to examine the consequences and root causes of the EA debt being analyzed, allowing the stakeholders to select appropriate decision strategies and to make timely and effective decisions.

Furthermore, through this study, we identified the need for further research in this area, especially for identifying decision-making contexts and gathering stakeholders' perspectives on these contexts. Future research should focus on developing methods and tools to collect and organize relevant information and bridge communication among stakeholders. Additionally, research should investigate the relationship between information pieces and debt-related performance indicators and develop practical ways to conclude the prudence or recklessness of an EA debt.

Another potential future research direction is to evaluate the proposed process, especially in an environment that involves complex projects and EA landscapes. Such empirical research can provide further validation and identify development potentials to make the process more practical for real-world applications.

Finally, further research in this context can develop approaches to storing and managing the information gathered throughout the process execution. Such an approach should classify information based on various parameters and register relations between various information pieces, thereby making it easier to find relevant information for decision-making.

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