Managing technical debt in software architecture

Li, Zengyang

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Appendix A  Appendix to Chapter 2

A.1. Selected studies

Appendix A


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Appendix A


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Appendix A

Appendix to Chapter 2


## Appendix A

### A.2. Distribution of selected studies over publication sources

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<td>2.40</td>
<td></td>
<td></td>
<td>3.40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean score</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.40</td>
<td>1.00</td>
<td>0.77</td>
<td>0.79</td>
<td>0.21</td>
<td>3.17</td>
</tr>
</tbody>
</table>

The study quality assessment questions are as follows:

Q1: How much evidence supports the claims related to TD in the study?
Q2: Is there a clear statement of the aims of the research?
Q3: Is there a clear statement of the definition of TD?
Q4: Is there a clear statement of which types of TD the paper focuses on?
Q5: Are the limitations of the study discussed explicitly?
Appendix B  Appendix to Chapter 6

B.1. ATD concerns

We came up with the concerns on ATD according to two sources: (1) concerns adapted or derived from the concerns on TD in general (TD concerns) collected during our mapping study on TD, i.e., the work reported in Chapter 2; (2) concerns derived from the five main ATD management (ATDM) activities in the ATDM process proposed in Chapter 4 (ATDM activities). From the first source (mapping study), we extracted TD concerns from the primary studies through: (1) the problems addressed by the primary studies; and (2) the problems expected to be solved in future work of the primary studies. We subsequently derived ATD concerns from the identified TD concerns, based on the following criteria: (1) if a TD concern is directly related to the architecture (i.e., not the system details), then the concern is considered as an ATD concern; OR (2) if a TD concern is not about architecture but makes sense to ATD stakeholders, then this concern is regarded as an ATD concern.

Table B.1. ATD Concerns and their sources

<table>
<thead>
<tr>
<th>Description of source</th>
<th>Derived concerns</th>
<th>Concern source</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can I efficiently measure how much debt I already have? (Eisenberg, 2012)</td>
<td>C2</td>
<td>TD concern</td>
</tr>
<tr>
<td>How large is my technical debt? (Nugroho, Visser, and Kuipers, 2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much interest am I paying on the debt? (Nugroho, Visser, and Kuipers, 2011)</td>
<td>C5</td>
<td>TD concern</td>
</tr>
<tr>
<td>What is the consequence of holding onto a debt for future maintenance? (Nugroho, Visser, and Kuipers, 2011)</td>
<td>C19, C20</td>
<td>TD concern</td>
</tr>
<tr>
<td>Is the debt growing, and how fast? (Nugroho, Visser, and Kuipers, 2011)</td>
<td>C16, C17</td>
<td>TD concern</td>
</tr>
<tr>
<td>Technical debt can be considered as a particular type of risk in software maintenance and the problem of managing technical debt boils down to managing risk and making informed decisions on what tasks can be delayed and when they need to be paid back. (Guo and Seaman, 2011)</td>
<td>C6, C15</td>
<td>TD concern</td>
</tr>
<tr>
<td>The analysis and measurement of TD-Principal can guide critical management decisions about how to allocate resources for reducing business risk and IT cost. (Curtis, Sappidi, and Szynkarski, 2012b)</td>
<td>C4, C6</td>
<td>TD concern</td>
</tr>
<tr>
<td>A technical debt “SWAT” team, led by one of the company’s most senior architects, tasked with learning how to reduce the technical debt and then rolling that knowledge out to the rest of the development staff, should be established. (Gat and Heintz, 2011)</td>
<td>C13</td>
<td>TD concern</td>
</tr>
<tr>
<td>Which delayed (maintenance) tasks [a type of TD] need to be accomplished, and when. (Seaman and Guo, 2011)</td>
<td>C6, C15</td>
<td>TD concern</td>
</tr>
<tr>
<td>The proposed approach to technical debt management centers around a “technical debt list.” The list contains technical debt “items,” each of which represents a task that was left undone, but</td>
<td>C1</td>
<td>TD concern</td>
</tr>
</tbody>
</table>
that runs a risk of causing future problems if not completed. (Seaman and Guo, 2011)

| Overall, it is important for a project team to understand (1) where TD exists in a system so that it can be tagged for eventual removal, (2) the cost of removing TD (i.e., Principal) and (3) the consequences of not removing TD (i.e., Interest). (Faleesi et al., 2013) | C4, C5, C10 | TD concern |
| The person who takes on technical debt is not necessarily the one who has to pay it off. (Allman, 2012) | C8 |
| Is technical debt increasing or decreasing for a system or for a component? (Seaman and Guo, 2011) | C18 | TD concern |
| How much debt is “too much” (i.e. high interest) versus manageable (i.e., low interest)? (Eisenberg, 2012) | C21 | TD concern |
| Developers tend to vote for investments into internal quality but managers often tend to question these investments’ values and, therefore, tend to decline to approve them. (Bohnet and Döllner, 2011) | C7 | TD concern |
| Our questions focus on how technical debt is propagated along those dependencies and how technical debt accumulates at various points in the chain. (McGregor, Monteith, and Jie, 2012) | C20 | TD concern |
| It enables taking into account not only the sunk cost of development but also the cost yet to be paid to reduce the amount of technical debt. (Cat, 2012) | C4 | TD concern |
| Practices related to identification provide the developer ways to identify Technical Debt in the code whereas classification helps to categorize them in order to understand the reason. (Krishna and Basu, 2012) | C11 | TD concern |
| After acquiring the source implementation components for technical debt, the DebtFlag mechanism completes the projection by propagating technical debt through dependencies while following a possible rule set. (Holvitie and Leppänen, 2013) | C10, C20 | TD concern |
| ATD identification detects ATD items during or after the architecting process. An ATD item is incurred by an architecture decision; thus, one can investigate an architecture decision and its rationale to identify an ATD item by considering whether the maintainability or evolvability of the software architecture is compromised. (See Section 3.4.1) | C1, C7, C11, C12 | ATDM activity |
| ATD measurement analyzes the cost and benefit associated with an ATD item and estimates them, including the prediction of change scenarios influencing this ATD item for interest measurement. (See Section 3.4.1) | C2, C3, C4, C5 | ATDM activity |
| ATD prioritization sorts all the identified ATD items in a software system using a number of criteria. The aim of this activity is to identify which ATD items should be resolved first and which can be resolved later depending on the system’s business goals and preferences. (See Section 3.4.1) | C6 | ATDM activity |
| ATD monitoring watches the changes of the costs and benefits of unresolved ATD items over time. (See Section 3.4.1) | C9, C14, C16, C17, C18, C19, C21 | ATDM activity |
| ATD repayment concerns making new or changing existing architecture decisions in order to eliminate or mitigate the negative influences of an ATD item. (See Section 3.4.1) | C13, C15 | ATDM activity |
From the second source (ATDM activities presented in Section 3.4.1), we derived ATD concerns based on the concrete tasks performed in each ATDM activity and the intents of the tasks. For instance, in the ATDM activity ATD measurement, the involved tasks are to estimate the benefit, interest, and cost of each ATD item, thus, we got the ATD concerns on the quantities of these properties of ATD items. As a result, we derived the ATD concerns C2, C3, C4, and C5. All the resulting ATD concerns and their detailed sources are shown in Table B.1.

B.2. Viewpoint definitions and correspondence rules

In this section, we first propose a shared metamodel of the six ATD viewpoints, then give each ATD viewpoint a detailed definition that can act as guidelines to generate ATD views governed by the ATD viewpoint, and finally define the correspondence rules for the ATD viewpoints.

B.2.1 Metamodel of ATD viewpoints

To facilitate the generation of ATD views that are governed by the proposed ATD viewpoints, we constructed a common metamodel that integrates all the elements of the ATD viewpoints. The metamodel also serves to maintain traceability and consistency between different ATD views. Figure B.1 shows the metamodel of the
ATD viewpoints. The elements in the dark part of Figure B.1 are concepts adopted from ISO/IEC/IEEE 42010 (ISO/IEC/IEEE, 2011). An **architecture decision** can incur **ATD item(s)**, which is adopted from Table 3.1 and shown in detail in Table 6.4. An **ATD item** relates to one or more **components**, which are influenced by one or more architecture decisions. One or more architecture decisions can be made to repay ATD item(s). An **ATD item** has a specific **status**. An **ATD item** has some **cost** to the future maintenance and evolution of a software system, which is the reason why the ATD item should be managed. The cost of an ATD item has a **principal** and **interest**. The interest of an ATD item is comprised of one or more **scenario interests**, each corresponding to a **change scenario** impacted by the ATD item. A change scenario has an associated **probability**, indicating the possibility that the change scenario will happen. An **ATD item** has some **benefit(s)** which is the reason why the ATD item is incurred. An **ATD item** has a **compromised quality attribute**, i.e., one of the six QAs mentioned in Table 6.4. An ATD item can raise new **system concern(s)** when the ATD item has significant impact on the system under consideration. For instance, if the ATD item is possible to negatively influence over certain functionality of the system, a new system concern is raised to eliminate or mitigate the negative influence. An **ATD rationale**, which considers the **benefit** and **cost** of the corresponding ATD item, tells why the ATD item is incurred. A **stakeholder** performs an **action** on an **ATD item**, for which the **status** of the ATD item is changed. An ATD item corresponds to an **intentionality**, indicating that it was incurred intentionally or unintentionally. An ATD item may be changed in an **iteration** that has one **iteration endpoint**.

**B.2.2 ATD Decision viewpoint**

The ATD Decision viewpoint shows the relationships between ATD items and architecture decisions of a software system. A view conforming to the ATD Decision viewpoint shows all ATD items, which were incurred from the beginning of the ATDM process till the current iteration in a software system, and their relationships with related architecture decisions.

**B.2.2.1 Model kind**

The metamodel of the ATD Decision viewpoint is shown in Figure B.2. This metamodel documents the model kind, which describes the conceptual elements for architectural models that conform to the ATD Decision viewpoint. The notation of UML class diagrams is used to describe this metamodel.

![Figure B.2. Metamodel of ATD Decision viewpoint](image-url)
The constraints listed below apply to the elements within this model kind:
- Every ATD item has a unique ID and name.
- Every architecture decision has a unique ID and name.
- An ATD item is incurred by one architecture decision.
- An ATD item is repaid by one or more architecture decisions.
- An architecture decision can incur or repay zero or more ATD items.

B.2.3 ATD-related Component viewpoint

The ATD-related Component viewpoint shows the components that are related to ATD items. The number of the related components to a specific ATD item may vary in different versions over time, but, in a view conforming to the ATD-related Component viewpoint, it only shows the ATD items and their related components in the latest versions.

B.2.3.1 Model kind

The metamodel of the ATD-related Component viewpoint is shown in Figure B.3. This metamodel documents the model kind, which describes the conceptual elements for architectural models that conform to the ATD-related Component viewpoint. The notation of UML class diagrams is used to describe this metamodel.

The constraints listed below apply to the elements within this model kind:
- Every ATD item has a unique ID and name.
- Every component has a unique ID and name.
- An ATD item relates to one or more components.
- A component is related to zero or more ATD items.

![Metamodel of ATD-related Component viewpoint](image-url)

Figure B.3. Metamodel of ATD-related Component viewpoint

B.2.4 ATD Distribution viewpoint

The ATD Distribution viewpoint shows the costs and benefits of all ATD items in two neighboring iterations.
Appendix B

B.2.4.1 Model kind

The metamodel of the ATD Distribution viewpoint is shown in Figure B.4. This metamodel documents the model kind, which presents the conceptual elements for architectural models that conform to the ATD Distribution viewpoint. The notation of UML class diagrams is used to describe this metamodel. An iteration endpoint has a date and a type that can be chosen from the following:

- **Milestone**: “A version of the architecture that has reached a stable state (or an intermediate stable state) (van Heesch, Avgeriou, and Hilliard, 2012a).”
- **Release**: “A version of the architecture that is delivered to a customer or made available to the public for use (van Heesch, Avgeriou, and Hilliard, 2012a).”

The constraints listed below apply to the elements within this model kind:

- Every ATD item has a unique ID and name.
- Every iteration has exactly one endpoint with a unique name.
- An ATD item has one or more benefits. A benefit can be technical benefit (e.g., quality attribute benefit) or non-technical benefit (e.g., business benefit). Only the measurable benefit is shown in the ATD Distribution viewpoint.
- An ATD item has one cost. The cost is the sum of principal and interest of the ATD item.
- An ATD item (its benefit and cost) can change in one or more iterations.
- In each iteration, zero or more ATD items (their costs and benefits) change.

![Figure B.4. Metamodel of ATD Distribution viewpoint](image)

B.2.5 ATD Stakeholder Involvement viewpoint

The ATD Stakeholder Involvement viewpoint shows the responsibilities of relevant stakeholders in the ATDM process. A view conforming to the ATD Stakeholder Involvement viewpoint presents the activities performed by the involved stakeholders on ATD items in the current iteration and their statuses.

B.2.5.1 Model kind

The metamodel of the ATD Stakeholder Involvement viewpoint is shown in Figure B.5. This metamodel documents the model kind, which describes the conceptual elements for architectural models that conform to the ATD Stakeholder...
Involvement viewpoint. The notation of UML class diagrams is used to describe this metamodel.

A Stakeholder conducts an Action on an ATD item in a specific development iteration, the Status of this ATD item changes accordingly. A stakeholder can be any of the defined stakeholders in Section 6.3.1. We defined the following types of actions in the ATDM process according to the main ATDM activities that are defined in Section 3.4.1:

- Identify: stakeholders find out the location of the ATD item.
- Measure: stakeholders estimate the benefit and cost of the ATD item.
- Re-measure: stakeholders estimate the benefit and cost of an ATD item that was measured in previous iterations.
- Prioritize: stakeholders assign a priority to be resolved to the ATD item based on available information related to this ATD item, such as interest.
- Repay: stakeholders resolve the ATD item by making new or modifying existing architecture decisions.

Accordingly, the status of an ATD item can be Identified, Measured, Re-measured, Prioritized, and Resolved.

![Figure B.5. Metamodel of ATD Stakeholder Involvement viewpoint](image)

The constraints listed below apply to the elements within this model kind:

- Every ATD item has a unique ID and name.
- Every iteration has an iteration endpoint with a unique name.
- All ATD items that changed in one iteration are shown.
- Every stakeholder shown performed at least one action.
- Every stakeholder has a unique name and at least one role.
- Every action points to an ATD item or an iteration endpoint. If the target is an iteration endpoint, the corresponding action is performed for all ATD items changed in that iteration.

**B.2.6 ATD Chronological viewpoint**

The ATD Chronological viewpoint shows how the ATD items in a software system evolved over time and how they were managed in the ATDM process.
B.2.6.1 Model kind

The metamodel of the ATD Chronological viewpoint is shown in Figure B.6. This metamodel documents the model kind, which describes the conceptual elements for architectural models that conform to the ATD Chronological viewpoint. Again, the notation of UML class diagrams is used to describe this metamodel.

Figure B.6. Metamodel of ATD Chronological viewpoint

The constraints listed below apply to the elements within this mode kind:
- Every ATD item has a unique ID and name.
- Every ATD item has exactly one status at a time.
- Every iteration has exactly one endpoint with a unique name.
- Every ATD item shown is changed in one or more iterations.
- Only an ATD item with the status ‘measured’ shows its benefit and cost.
- Only an ATD item with the status ‘re-measured’ shows its benefit delta and cost delta compared with the previously measured benefit and cost, respectively.

B.2.7 ATD Detail viewpoint

The ATD Detail viewpoint provides a comprehensive textual description of each ATD item documented in a software project. A view conforming to the ATD Detail viewpoint is comprised of multiple models, each used to describe a single ATD item.

B.2.7.1 Model kind

The metamodel for the ATD Detail viewpoint is identical to the common metamodel for all the ATD viewpoint as shown in Figure B.1.
B.2.8 Correspondences between viewpoints

We have proposed six ATD viewpoints to document ATD. We use multiple views governed by these ATD viewpoints to document the ATD of a software system. Each ATD view is comprised of one or more models. Because the same subject is represented in multiple models, there is a risk of inconsistency between different models. Therefore, there is a need to establish rules to express and maintain the consistency of cross-model relationships between ATD description elements. Cross-model relations can be expressed by correspondences, which are introduced in ISO/IEC/IEEE 42010 (ISO/IEC/IEEE, 2011) to express relations between architecture description elements. This international standard further introduces correspondence rules to govern correspondences.

We define a set of correspondence rules in the following to keep the consistency between ATD views:

- An ATD Decision model must contain all ATD items that have ever appeared in the ATD Detail views.
- An ATD-related Component model must exist for every iteration shown in the ATD Chronological model. Every ATD-related Component model contain the ATD items which latest versions are in the status of ‘identified’, ‘measured’, ‘re-measured’, and ‘prioritized’.
- An ATD Distribution model must exist for every iteration shown in the ATD Chronological model. Every ATD Distribution model must contain the existing ATD items that are not in the status of ‘resolved’ in the earlier iteration, and the newly identified ATD items in the later iteration.
- An ATD Stakeholder Involvement model must exist for every iteration shown in the ATD Chronological model. Every stakeholder involvement model must contain the involved stakeholders and their actions in the versions of ATD items belonging to the respective iteration.
- An ATD Chronological model must contains all ATD items that have ever appeared in the ATD Detail views.
- The status of an ATD item in the ATD Detail model must correspond to the status of the latest occurrence of the ATD item in the ATD Chronological model.
- The history of an ATD item represented in the ATD Detail model must contain all actions that are performed by the related stakeholders on that ATD item shown in all ATD Stakeholder Involvement models.
Appendix C  Appendix to Chapter 7

C.1 Selected Studies


Appendix C


Appendix C

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[S41] G. Vazquez, J. Andres Diaz Pace, M. Campo, Reusing design experiences to materialize software architectures into object-oriented designs, Information Sciences, 0 (2010).


Appendix to Chapter 7


Bibliography


