A Model to Assess the Use of Reference Architecture in Responding to Disruptive Innovation: A Higher Education Case

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Abstract

This master thesis looks at the use of reference architecture in supporting the challenges of potential disruptive innovations. It looks at higher education in the Netherlands, with the Higher Education Reference Architecture (HORA) as a reference architecture. It studies the function of reference architecture and the dynamics of disruptive innovation in higher education, and how the use of HORA in this context can be improved. The focus of this research is on reference architecture used for business design of redesign. Reference architecture is defined as an architecture which is intended by its producer to be used in supporting the construction of another architecture. For the assessment of HORA, an Assessment Model has been developed. This Assessment Model is based on the premise that a reference architecture supports the challenges in two processes: (1) an architect making an architecture description based on a reference architecture, and (2) a stakeholder using this architecture description to address their concerns. The Assessment Model was used in expert meetings with enterprise and domain architects working in higher education and representatives from HORA. The use of the Assessment Model proved successful in gathering information and provided new insights for the participants of the expert meetings. Reflecting on the use of reference architecture in this context, this thesis comes to the conclusion that a new way of looking at reference architecture is needed: a bimodal reference architecture. This bimodal reference architecture contains both stable elements describing the real world, as well as elements about upcoming innovations.

Keywords: reference architecture, disruptive innovation, higher education, assessment model, bimodal reference architecture

Preface

Context

The journey for this thesis started with a preliminary idea to look at the current reference architecture used in the Dutch higher education (HORA) and to investigate how this reference architecture could be improved for dealing with the ongoing flexibilisation of education. The moment could not have been better: With the introduction of a new national database for higher education, work on a new national standard for exchanging information, and experiments with learning outcomes and microcredentials, there is a bounty of matters where a reference architecture in this field could be of help. At the same time, SURF, the owner of HORA, was working on a new assignment to form a team of enterprise architects, which, among other things, could work on a major revision of HORA. The insights gained from my thesis could be of direct use for that update process.

During the process of working on my thesis, the scope shifted to the use of HORA in managing disruptive innovation. As this research will show, flexibilisation will still be a big part of it. But it will also make the resulting Assessment Model applicable on a wider range of potential disruptive innovations that higher education is facing. There is an apparent contradiction between a reference architecture (being static and a result of a joint effort to model a common ground) and disruptive innovation, where there is still no clear and shared vision what those innovations mean for higher education institutions. The Assessment Model presented in this research appears to be a useful tool for investigating that contradiction.

This master thesis is written as the final assignment for the Executive Master in Enterprise IT Architecture at the Antwerp Management School. The format of this thesis (including citations, headers, tables, and figures) is, with a few exceptions, in accordance with APA 7 guidelines (American Psychological Association, 2020). This thesis is written in British English, but citations and names of models or frameworks are spelled according to the original source.

Acknowledgements

I would like to thank my promotor Roland Ettema for guiding me during the process of writing this thesis. He inspired me to look more closely into the relationship between the reference architecture HORA and disruptive innovation. I also would like to thank Hans Mulder for helping me in preparing for the expert meetings and for his review on my Assessment Model. Furthermore, I would like to thank Tim von der Fuhr, Ide Hingstman, and Jan Schoonderbeek for collaborating with me on the case study on disruptive innovation at AUAS, which has been used as additional input for this research.

A few fellow students invested their time in reviewing earlier versions of my thesis, providing me with valuable feedback. So, thanks to Jan Schoonderbeek, Shakha Mirza, and Henk-Jan Hopman. I especially enjoyed the multiple discussions with Jan about the ontology for modelling and model quality. Of course, during class, lunch, and the drinks in Barbossa I have discussed the subject of my thesis with many other fellow students. I really enjoyed the great atmosphere we had during the master. Thanks to all of you for being there during the journey. You were great companions!

And yes, this is also the place to give credits to my wife Monica. Not only was she patient when I had to spend yet another weeknight or Sunday behind my laptop, she was also there when I got stuck and needed a sounding board. Her astute feedback helped me to get the story to a higher level.

Also, I am grateful for my employer the Amsterdam University of Applied Sciences for making this possible. Special thanks for my manager, Ivo van der Werk, for letting me spend the time and energy on this endeavour.

Finally, I would like to thank my fellow architects from UvA-AUAS and the SURF Architectenberaad for participating in the expert meetings, helping me obtaining valuable insights for my thesis. Special thanks for the HORA representatives, Tom van Veen, Frank Grave, and Diede Wooldrik, for the time we spend together investigating on how to use the Assessment Model to improve HORA. I look forward on working on that project together.

Declaration of Authorship

I, Richard Valkering, declare that this thesis titled “A Model to Assess the Use of Reference Architecture in Responding to Disruptive Innovation: A Higher Education Case” and the work presented in it are my own. I confirm that:

- This work was done wholly while in candidature for a master’s degree at the Antwerp Management School.
- No part of this thesis has previously been submitted for a degree or any other qualification at the Antwerp Management School or any other institution.
- Where I have consulted the published work of others, this is always clearly attributed in accordance with APA 7 guidelines (American Psychological Association, 2020).
- Where I have quoted from the work of others, the source is always given in accordance with APA 7 guidelines. Except for such quotations, this thesis is entirely my own work. No text in this thesis has been written by artificial intelligence.
- I have acknowledged all main sources of help.

Content

Introduction

Disruptive Innovation in Higher Education

Higher education institutions face the challenge of how to incorporate new technologies in their organisation and their IT landscape. From the emergence of massive open online courses (MOOCs), to the swift transaction to temporary online education due to the coronavirus pandemic, and till the recent rise of artificial intelligence (AI), institutions are looking for ways to respond to those technologies (SURF, 2023; Tierney and Langford, 2016). Individuals as well as organisations can adapt to new technologies to do things better or to do new things. This is called *innovation*. This can be *sustaining innovation*, where established organisations make their existing products better without disrupting the market. It can get them a bigger market share or more profit, but sustaining innovation will not lead to a big market shift. But when an innovation does lead to significant changes in the market, and when the incumbent organisations are forced to react to it on a strategic level, this is seen as *disruptive innovation*. While innovation is mostly seen as something positive, disruption often has a negative connotation. When things change and the market reacts to an innovation, some organisations will not react in time to adapt. Companies who were once market leaders might find themselves being much smaller after a disruptive innovation, or even cease to exist at all (Christensen, 1997; see also Kilkki et al, 2018).

Higher education in the Netherlands has its own specific dynamics and challenges related to disruptive innovation, which might reduce the potential disruptive effects: Newcomers must adhere to many regulations, which give a high barrier to enter the market. On the other hand, compared to elementary education, there is more room for market forces because of the age of the participants. When starting in higher education, potential students have more options to move to another city (or even another county) and to combine study with work. Higher education institutions also provide vocational programmes, where the regulations are less and there are more market parties.

Whether or not a new technology turns out to be a disruptive or a sustaining innovation can only be judged ex post. This research looks at the concerns stakeholders might have regarding a *potential* disruptive innovation. This stakeholder needs advice on how to act on that in a design or a decision process. Innovations might lead to changes in the way institutions organise their education or lead to changes in the IT landscape. The stakeholder wants those changes and its effect to be addressed in that advice.

The use of enterprise architecture is seen as one of the means for that. It can give guidelines and a coherent design of the information chains and the IT landscape to incorporate new developments. Even in times where disruptive innovation leads to rapid changes, enterprise architecture is being adopted for the orchestration of business and IT assets and resources (Van de Wetering et al., 2021). In that way, implementing architecture can help to guide the changes needed to answer the challenges of higher education institutions.

Using Reference Architecture for Facing the Challenges in Higher Education

To save on resources and time for the implementation of architecture, it can be efficient to use available reference architectures (Timm et al., 2017). In a reference

architecture, existing knowledge is already incorporated in ready-made models or guidelines. It saves resources and time to make use of those reference architectures, on the premise that it indeed contains what the organisation needs and can easily be adapted to fit the specific organisation. In this way, the effort to make local models should be lower. This will lead to a higher return on the modelling effort, as long as there is no trade-off in the value of the models (Proper & Guizzardi, 2022). So, if reference architectures are available within the higher education sector, it is worthwhile to investigate this fit.

For the Dutch higher education, there is a specific reference architecture: the Higher Education Reference Architecture (in Dutch: Hoger Onderwijs Referentie Architectuur [HORA]; SURF, n.d.-b). Next to that, there is a reference architecture for education in general: the Reference Education Sector Architecture (in Dutch: Referentie Onderwijs Sector Architectuur [ROSA]) which contains the Core Model Education Information (in Dutch: Kernmodel Onderwijs Informatie [KOI]; Edustandaard, n.d.). All these architectures are seen as daughters of the Dutch Government Reference Architecture (in Dutch: Nederlandse Overheid Referentie Architectuur [NORA]; NORA Beheer, n.d.). For this research, the focus is specifically on HORA, since this reference architecture is tailor-made for the higher education sector.

Problem Statement and Research Questions

Higher education institutions struggle with the challenges brought upon by innovation. The changes that might be needed to address those challenges will have an effect on the organisation of education and on the IT landscape. The organisation of education involves a complex system of processes, applications, and information streams where architecture can help in its orchestration (Lankhorst, 2005). When applying architecture, an organisation can invest in making its own architecture from scratch or use reference architectures to support making this architecture (Timm et al., 2017). Can the reference architecture HORA that is available for the higher education sector be of help, especially for concerns about potential disruptive innovation? And how can HORA be further optimised to do so?

To investigate this, an assessment framework is needed. There are multiple frameworks available on quality of architecture, reference architecture, conceptual models, and reference models. But as it will show in this research, they all have a specific perspective that is not completing fitting to address the problem statement. Combining different aspects from different frameworks might lead to a more comprehensive assessment of how HORA can be used and potentially improved in addressing concerns related to disruptive innovation.

The research question that addresses the problem statement is:

1. How can HORA support the challenges of disruptive innovation in higher education in the Netherlands?

The four research subquestions helping to answer the first research question are:

1.1 What is the effect of disruptive innovation on the Dutch higher education?

1.2 What is the intended use of HORA?

1.3 How useful is HORA to address the challenges of disruptive innovation?

1.4 How can HORA be enhanced to make it more effective in addressing the challenges of disruptive innovation?

And to be able to answer the first research question, an assessment framework is needed:

2. What framework can be constructed to obtain a comprehensive assessment that will be able to answer the first research question?

Research Design and Approach

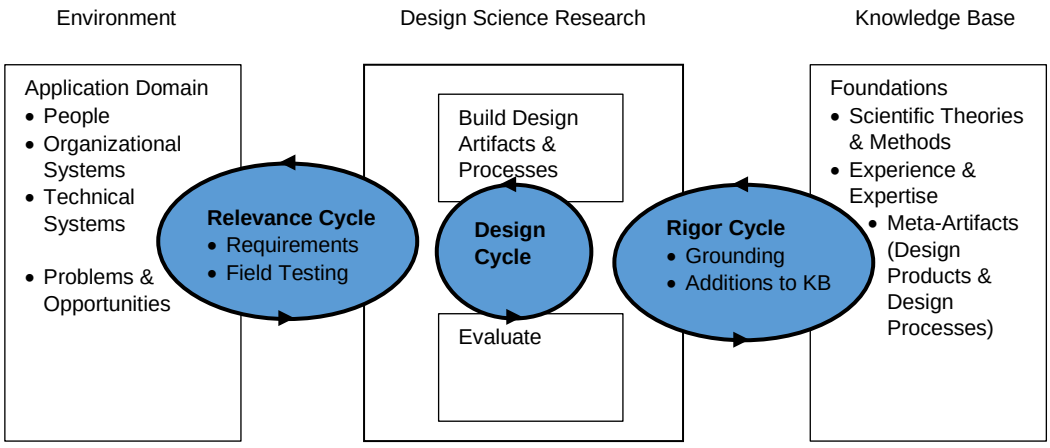
To see if HORA can indeed be of use for addressing the challenges, this research will first look at the dynamics of disruptive innovation in higher education. Second, it looks at the intended use of HORA. Then, this use will be matched with the actual use in the higher education institutions for concerns related to disruptive innovation and the perceived benefits by the organisation. To assess the use, an Assessment Model is proposed.

This research will be based on an exploratory approach since the combination of reference architecture, disruptive innovation, and the related quality attributes is novel in the context of higher education. Different theories and concepts will be combined. During the research a combination of research methods will be used. The first research question will be investigated using qualitative methods, in line with the exploratory nature of the research. There will also be quantitative data involved, regarding scoring on statements in expert meetings. That data is collected to assess the opinion of the participants during the expert meetings and does not have the intention to reflect the opinion of a broader population. See more about the data collecting in section “Survey Methods” (page 12). The second research question is investigated by design science. A new artifact (the Assessment Model, see Figure 16 on page 46) will be created to help answering the first research question.

For the design science process, the design science research framework presented by Hevner (2007) is used, see Figure 1. The three different research cycles (the relevance cycle, the design cycle, and the rigor cycle) ensure that the artifact constructed is useful for the application domain but is also grounded in academic knowledge. This method seems especially useful because both the theories on reference architecture and disruptive innovation are not yet sufficiently applied to the domain of higher education. The three different expert meetings are part of the relevance cycle. The thesis can be seen a iteration on itself, since to Assessment Model and the methods to apply it can still be improved in further iterations. Suggestions for further improvement will be provide in subsection “Further Research” (see page 79).

Figure 1

Design Science Research Cycles



Note. Source: Hevner (2007, p. 2).

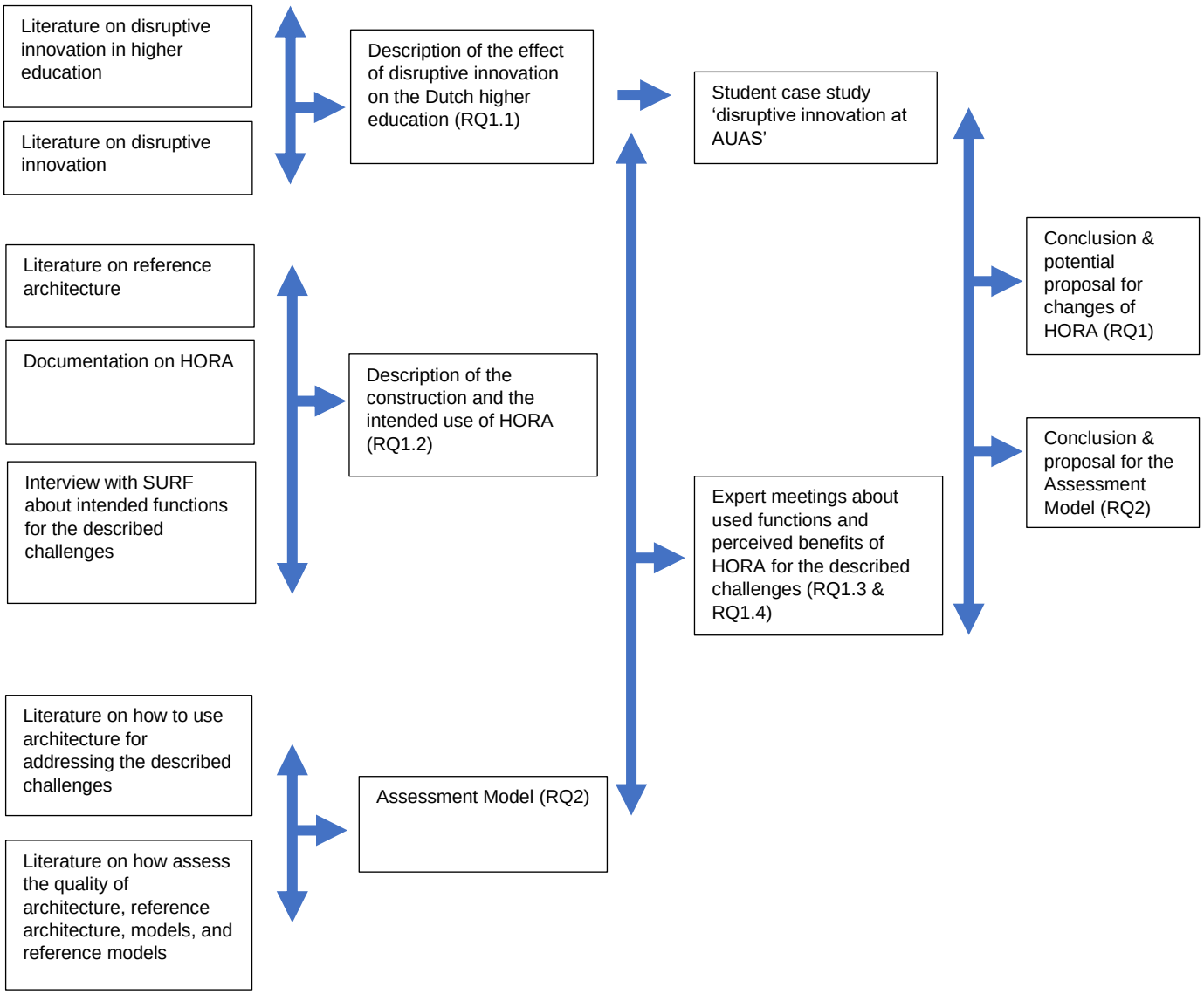
For the research design (see Figure 2 below), this means that two aspects of the environment will be researched. First, the Dutch higher education and the problems and opportunities that come with disruptive innovation. Second, the use of a reference architecture, HORA, to address the related concerns. For both subjects of research, the knowledge base is used to describe the concepts, so that it can be related to the Assessment Model, which is grounded in the same knowledge base. Based on that literature, a preliminary version of the Assessment Model is presented.

The next step is to use the Assessment Model in expert meetings as field testing. First, a trail expert meeting will be held. After this trail expert meeting, the model can be adapted if needed before the main expert meeting. More details on the set-up of the expert meetings can be found in the subsection “Survey Methods” (page 12). Finally, the results of the expert meeting will be used to propose potential improvements on both HORA and the Assessment Model. Those results will be shared with HORA representatives in a evaluation expert meeting. With the results from those expert meetings, the research questions will be answered.

Next to the expert meetings, I go back to an earlier assignment that has been done during this thesis’s master programme. In that assignment, a case study on disruptive innovation and flexible education has been done at the Amsterdam University of Applied Sciences. See chapter “Case Study: Disruptive Innovation at the Amsterdam University of Applied Sciences (AUAS)” (page 17). The insights from that case study will be triangulated with the results of the expert meetings in the reflection on disruptive innovation in higher education.

Figure 2

Research Design



Note. The RQ-codes refer to the research questions on page 8.

The answers to subquestion 1.1 are presented in chapter "The Effect of Disruptive Innovation on Higher Education in the Netherlands" (page 14). The answers to subquestion 1.2 are presented in chapter "The Intended Use of the Higher Education Reference Architecture (HORA)" (page 17). The Assessment Model, the preliminary answer to research question 2, can be found in chapter "Designing the Assessment Model" (page 28; the model itself can be found in Figure 16 on page 46). The results of the expert meetings, answering subquestions 1.3 and 1.4, can be found in chapter "Expert Meetings: The Effectiveness of HORA in Addressing Disruptive Innovation" (page 47). Finally, the conclusions for HORA

and the Assessment Model, answering the research questions 1 and 2, are presented in chapter “Wrap-up: HORA Addressing Disruptive Innovation” (page 69).

Survey Methods

To help answering the first research question “How can HORA support the challenges of disruptive innovation in higher education in the Netherlands,” three types of surveys will be held:

An interview will be held with a representative of the organisation that publishes HORA. This is in the form of an open, exploratory interview (Recker, 2012, p. 90). With this interview, more insight will be gained in the purpose and the intended use of HORA. This interview is meant to get deeper insight on the information that is already available on the website of SURF. Given the open, exploratory form of the interview, analysis of the resulting text will be in the form of memoing (Recker, 2012, p. 92). The results of that interview can be found in subsection “Interview With HORA Representative” (page 25).

Second, literary research will be done on the use of reference architecture in general, disruptive innovation in general, and disruptive innovation in higher education. To find relevant literature, a technique of snowballing is used to get an overview of relevant frameworks and model (Wohlin, 2014). See more on that in section “Frameworks to Assess the Usability of Reference Architectures in Responding to Disruptive Innovation” (page 31).

Second, expert meetings will be held to assess the usability of HORA in addressing disruptive innovation. There will be three expert meetings: a trail expert meeting, a main expert meeting and an evaluation expert meeting. An expert meeting is an open setting where the knowledge, opinions, and insights from experts in the field can be gathered. This is chosen because with an expert meeting the information can be gathered both about the experts’ previous experience with the use of HORA in the context of disruptive innovation, as well as assessing their ideas about potential improvements of HORA and the Assessment Model. Being able to have discussions during the meetings provides an explorative setting, which is fitting for the relevance cycle.

A Group Support System (GSS) application will be used to structure the meeting and collect the results. The GSS application Meetingwizard has been selected for this purpose. The choice for this application is based on a practical reason: The involved AMS professors had experience with this application and could support setting up the meeting. There are other applications available, but many share the same key features (L. F. Lewis, 2010, p. 257). The use of a GSS application has a view benefits. Based on the variables named by L. F. Lewis (2010, pp. 255–256), it will first of all provide equality of participation. During the brainstorm, the voting, and commenting on the voting all participant have the same time to give the input, without some participants dominating the discussion (although during the discussions about the results, this group dynamic might still occur). The other benefit is parallel production, increasing the amount of output given by the participants. Although anonymity can be used as an option in a GSS application, this was not deemed necessary for this meeting. The experts were peers who are used to operate in an open network that is used for knowledge sharing. Because the results are not anonymous, during the discussion the specific participants can be asked to elaborate on their input. In the analysis of the results, knowing who gave the input can provide extra context. The application gives the opportunity

to gather information via a brainstorm session, where participants can enter text. That information can be used in a later stage to vote on information gathered in that brainstorm. Also, during voting on statements participants can leave comments to elaborate on their score. During the meeting, the results can be shown to the participants, to reflect on those result together. Finally, the fact that a GSS application gives structure for the meeting makes the expert meeting more controlled and repeatable.

The experts who are asked to participate in the expert meetings are architects from higher education institutions who have worked with HORA before. Representatives from HORA will also be asked to participate: They can provide insight on the content and intended use of HORA and they can help in evaluating the results from applying the Assessment Model. The different steps of the Assessment Model will be applied during the expert meetings. Some questions will be in the form of a brainstorm session, in other steps participants will be asked to vote on statements. As described above, this will be done via the GSS application Meetingwizard. The trail expert meeting and the main expert meeting will start with an introduction video on the case, after which every separate step will be introduced and guided with additional instructions. After those four steps, the participants are asked to reflect on the Assessment Model itself. The script of the video and the instructions per step can be found in Appendix A (trail expert meeting) and Appendix B (main expert meeting). A final expert meeting will be held with HORA representatives, to reflect on the outcomes of the main expert meeting and the use of the Assessment Model. This will be guided by statements in the application Meetingwizard (see Table 18 on page 64).

The Effect of Disruptive Innovation on Higher Education in the Netherlands

In the introduction the effect of disruptive innovation is presented as a potential result of the introduction of new technologies. If an innovation is not disruptive, it is seen as a sustaining innovation. Whether an innovation will be disruptive or sustaining, is something that can only be assessed ex post. Some argue that damping effects like government regulation decreases the chance of disruptive innovation in higher education. This chapter will explore the dynamics of disruptive innovation in the higher education sector in the Netherlands.

Forecasting Disruptive Innovation in Higher Education

The dynamics of disruptive innovation can affect public or semi-public organisations, but the level of disruption might be smaller then in the public sector: Because of protective factors like regulations the changes will be lower that a higher education institution will be forced out of the market if it does not react in time to an innovation. Some argue, like Tierney and Langford (2016), that innovation in higher education will not be disruptive, but that it is still useful to study the dynamics:

> While many predict that disruptive innovations, such as online education, are destined to dramatically change the landscape of higher education, we caution that universities are different from businesses in that they rely upon the accrued prestige, often established over decades, of their faculty and their departments for legitimacy. Hence, the rhetoric surrounding disruption should be judged in a critical manner, even while the theory of disruptive innovation may prove useful for understanding the emergence of new educational paradigms. (p. 3)

So, even if current regulations shield some of the effects of disruptive innovation, it is useful for higher education institutions to investigate the dynamics of it.

A disruption is usually the result of a newcomer entering a market, providing new products based on an innovation (Kilkki et al., 2018). How big a threat a disruptive innovation is in a market, will for a part depend on how easy it is for newcomers to enter a market. Regulations might hold back newcomers in the public sector, so the disruptive effect may be smaller or even absent. Higher education in the Netherlands now still has a solid base in the Law on higher education and scientific research (in Dutch: Wet op het hoger onderwijs en wetenschappelijk onderzoek [WHW]), seemingly protecting them from disruption. But within the higher education institutions there are worries that government rules might change, to open the market for new (international) competitors. This has happened before: In the late nineties of the last century the WHW has been changed to open the higher education sector for private institutions. In that period, this only mostly led to new competitors on vocational programmes, because the quality assessment for the academic programmes were not feasible for most private institutions (Huisman & Theisens, 2001).

Research on disruptive innovation has mostly been done ex post. Therefore, according to Danneels (2004) and Govindarajan and Kopalle (2006), it is not valid to use this hindsight to make ex-ante predictions about new technologies. For example, the discussion on the level of potential disruption can be seen in the discourse on the introduction of MOOCs. Where some, like Dennis (2012), saw it as a disruptive innovation, others argued that it does not fit

the definition of being disruptive and that it is more comparable to sustaining innovation (Al-Imarah & Shields, 2019).

Developments in Higher Education in the Netherlands Leading to Innovation

This section will highlight developments that are related to innovation in the higher education sector. This will include developments that are technological but includes also innovation in the organisation of higher education on a national level. This list is not meant to be comprehensive but is meant to give examples and to give a general idea at with the effects of the developments might be.

- Digitalisation of education has for some years been seen as a threat for classic institutions. Since MOOCs became available, those courses have been seen at the time as a development that would cause disruption, for example Dennis (2012) stating "MOOCs have the potential to become a global higher education game changer" (p. 25). The pace in which that happens might have been slower than anticipated by some, but still institutions are looking for answers on how to deal with a potential disruption by MOOCs in the near future. One example of that is that teachers are being stimulated to work on their own open study material (Versnellingsplan Onderwijsinnovatie met ICT, 2021).
- In the Netherlands, the Central Register of Higher Education Programmes (in Dutch: Centraal Register Opleidingen Hoger Onderwijs [CROHO]) is being replaced by its successor Registration Institutions and Programmes (in Dutch: Registratie Instellingen en Opleidingen [RIO]; RIO, n.d.). The biggest change is that in the new register not only programmes can be administrated, but also courses. Those courses then are available as open data, which in turn could be used for business platforms comparable to booking.com, where prospect students can look for educational options nationwide (SURF, 2021b). This can be disruptive, if this will lead to a strong shift in the market and some higher education institution will lose a significant amount of market share.
- In March 2022, a new subsidy had been made available for Dutch residents called Incentive for Improvement of Labour Market Position (in Dutch: STimulering Arbeidsmarkt Positie [STAP]), in which everyone above 18 could apply for a budget of 1,000 euro for labour market related training (UWV, n.d.). One of the conditions was that the course or programme someone wanted to follow must be available in the central register of STAP. This forced institutions who wanted to cater to people with a STAP grant, to make their course information available in that central register. This may have an extra effect on the above-mentioned possible effect of disruption, because this stimulated the use of a central, nationwide platform for educational information. For the moment however, the future of that platform is unclear, since the STAP budget will not continue in 2024 as part of cutbacks (Ministerie van Sociale Zaken en Werkgelegenheid, 2023).
- Within SURF (the IT organisation of educational and research institutions in the Netherlands), there are projects on microcredentials, paving the way of crediting smaller parts of a programme (Versnellingsplan Onderwijsinnovatie met ICT, n.d.). This might make it easier for newcomers on the market to gain a significant market share, which in turn may decrease the market share of the incumbent higher education institutions.

Challenges of Innovation in Higher Education

New technologies and other developments that may lead to innovation, provide challenges for higher education institutions. The impact and the opportunities need to be assessed and choices will have to be made on how to react. First, there are challenges to adjust to the changing world and changing demand of students and society. Students have to be prepared to meet the demands of this changing world. Tierney and Langford (2016) give two challenges in this context: the emergence of the knowledge-intensive economy and the need to train a creative and innovative workforce. Tierney and Langford see a combination of further massification of higher education, while at the same time funding and resourcing are decreasing. Second, there are the forementioned challenges to respond to innovation in the organisation of education itself. How fast does a higher education institution need to react to innovations? How is this possible with an IT landscape where there are many legacy applications? And even if the IT landscape can be changed quickly: Can the staff follow? This might require a change in culture, and staff working on IT and the organisation of education must have the time to make the adjustments needed. The overarching challenge for the higher education institutions will be how to manage those changes.

More flexibility in education is seen as a necessity to answer the challenges of innovation in higher education. This gives more freedom for students to combine courses to get the education they want and gives more opportunity to change the curricula to changing market demands. Bakker (2021) cites that if the higher education in the Netherlands wants to be flexible in 2030, major system changes and a fundamental change in funding is needed. Next to that, institutions need to have more internal standardisation. If students are to pick courses from different faculties to add to their curriculum, from a user perspective it is undesirable that there are differences between faculties regarding educational structures (like timetabling or the process of course enrolment) and the applications in use (like the digital learning environment), because this will lead to extra complexity. As mentioned before, the organisation of education is a complex system of processes, applications, and information streams. So, to make the higher education more flexible, changes are needed in this complex system. Stakeholders who have a responsibility for those organisational elements can be supported by architects in analysing the cohesion and assessing the effects of the stakeholders' designs or decisions (Lankhorst, 2005).

Conclusion on Disruptive Innovation in Higher Education

The key findings in this stage of the research are:

- The potential effects of disruptive innovation in higher education are not clear. Most research on disruptive innovation has been done in commercial sectors, which differ from the higher education sector. Next to that, research has been done ex post, so should not be used to make ex-ante predictions.
- Nevertheless, since there are stakeholders who have concerns about disruptive innovation, architects can help in addressing those concerns.
- In the remainder of the research, HORA will be judged on how it might support challenges regarding potential disruptive innovation.

Case Study: Disruptive Innovation at the Amsterdam University of Applied Sciences (AUAS)

In this chapter, a case study is presented from an earlier course of this thesis's master programme. The case study looked at disruptive innovation at my employer, the Amsterdam University of Applied Sciences (AUAS, in Dutch: Hogeschool van Amsterdam). The proposition for the case was that disruption in higher education is driven by the need from the students for flexibility. We focussed on one of the main challenges: the relationship between programmes and courses. This relates to the process of the enrolment of students in courses, the consuming of the course, examination for that course, and completing courses and programmes.

Including the case study in this thesis's research provides additional insights on the challenges of disruptive innovation in higher education. In the assignment we had to apply Design & Engineering Methodology for Organizations (DEMO) on the case study. This allowed us to look at a higher abstraction level, rising above the implementation and its issues. This can separate the implementation challenges—which can be complex enough by themselves—from the challenges where the institutions might have to change the essence of the organisation.

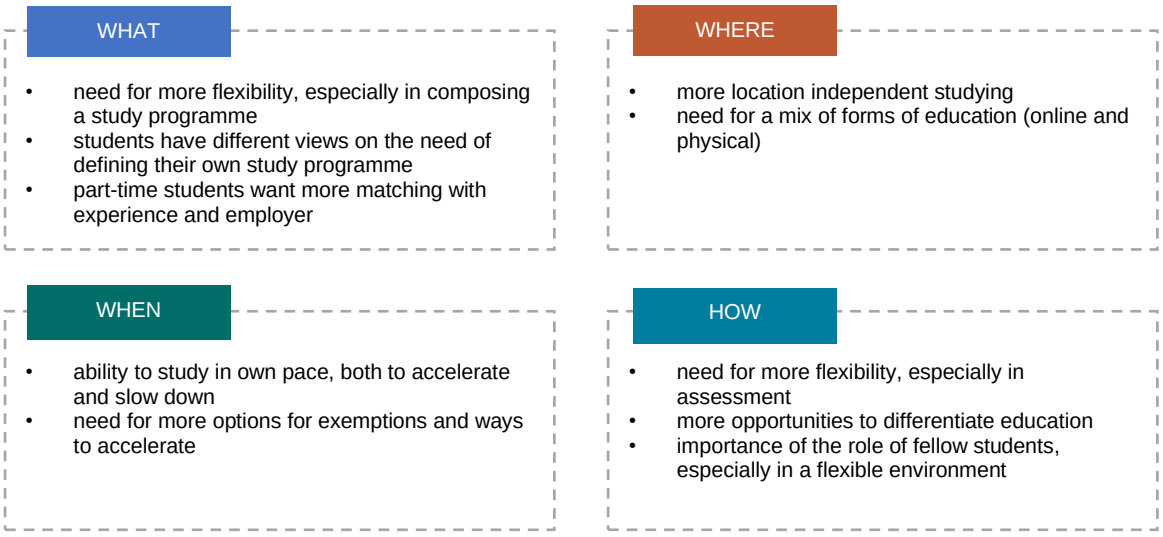
The case study was part of the course "Agile Enterprise Architecture & Engineering Module 3," in the first semester of the college year 2022–2023. I worked on this case study with my fellow students Tim von der Fuhr, Ide Hingstman, and Jan Schoonderbeek.

Disruptive Innovation and Flexible Learning Pathways

Based on Huizinga et al. (2022), in the case study we presented four categories of needs of students for more flexible education, see Figure 3 below.

Figure 3

Categories of Needs for Flexibility in Higher Education



Note. Source: Huizinga et al. (2022, p. 6).

Next to those categories of flexibility, we presented the concepts to facilitate more flexible education, based on Brinkman et al. (2022): learning outcomes, learning path-independent assessments, and learning activities. Finally, we presented the impact of flexibilisation on educational logistics, based on Scheers and Pinchetti (2020), see Table 1 below.

Table 1

Four Key Challenge Areas on Educational Logistics in Flexibilisation of Education

Challenge area	Description	Typical challenges
Study at own pace	Eliminate practical obstacles for students to study at their own pace	• uncouple the sequence of courses in a curriculum • regularly updating the Education and Exam Regulations • the validity and intermediate changes of grade registration • policy on support and coaching with students on different paces • course offering (incl. lectures, exams, etc.) available for upcoming rolling year • examination planning: combining different courses in one room
Out of the box	Implement country-wide facilities for cross-entity and cross-education information sharing	• standardising curricula across educational entities • automated chargeback models between entities • enable external courses in scheduling • exchange course information and progress among entities
My degree	Educational agreement for customized programmes	• transparent fee per course of customised programme • avoid teacher-oriented scheduling • inform prospect students on course level (not programme level) • personal educational agreement between student and entity
Modular studying	Think in micro-units of education	• putting learning outcomes central • pre-definition of exams (prior to course provision) • validity of exams in context of programme • validation of obtained competences • graduation-as-a-service (private graduation party)

Note. Based on: Scheers and Pinchetti (2020). Summary, presentation, and translation to English from: Student report "Flexible Student Learning Pathways Amsterdam University of Applied Sciences (AUAS)," 12 December 2022, made by Tim von der Fuhr, Ide Hingstman, Jan Schoonderbeek, and Richard Valkering.

Precondition of the flexibility is that the student is in control of the choices that can be made. The student must be able to obtain the information to make a choice: What are the options to compose a course programme, what are the options in time and place, and so forth. Next, a student must be able to register the choices that are made, so the operation of the educational logistics can use it in follow-up processes and reports. Also, the choices should be made available for the student in the AUAS student portal. Therefore, the choice was made to focus the case study on course enrolment.

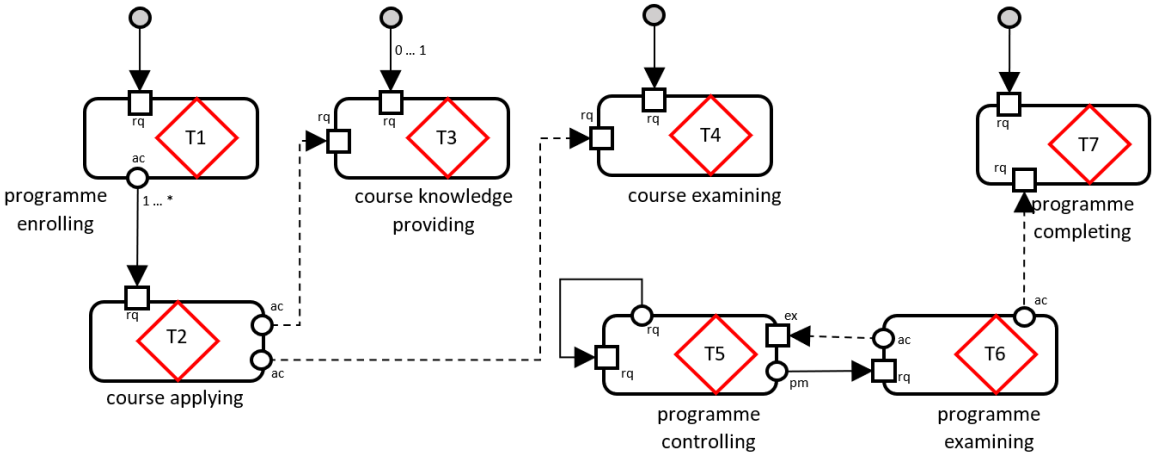
Analysis of the Current and Future Enrolment Process

Using DEMO (Dietz & Mulder, 2020) an analysis has been made during the case study on the current process and on a process that might be the way enrolment could work in the future. For the current process, we looked at the process currently implemented at AUAS. For the future process, we interviewed a representative of the Open University (OU), Roland Ettema. The OU is different from the other higher education institutions, because it focusses on part-time education for adults and online education. Students are flexible in the pace of education. Although it has a different business model, it can be studied to see how flexibility might take shape. At the OU, a process model has been developed where there is a disconnect between enrolment on programme level and the course level.

Both descriptions of the enrolment processes where subjected to a PIF analysis (as part of DEMO). PIF stands for Performa-Informa-Forma and is meant to abstract the essence of the organisation. Then, the different models were made that are part of the essential model (consisting of the Cooperation Model, the Action Model, the Process Model, and the Fact Model). To illustrate the results, see the Process Models in Figure 4 and Figure 5 below.

Figure 4

Process Model Current Education Organisation at AUAS

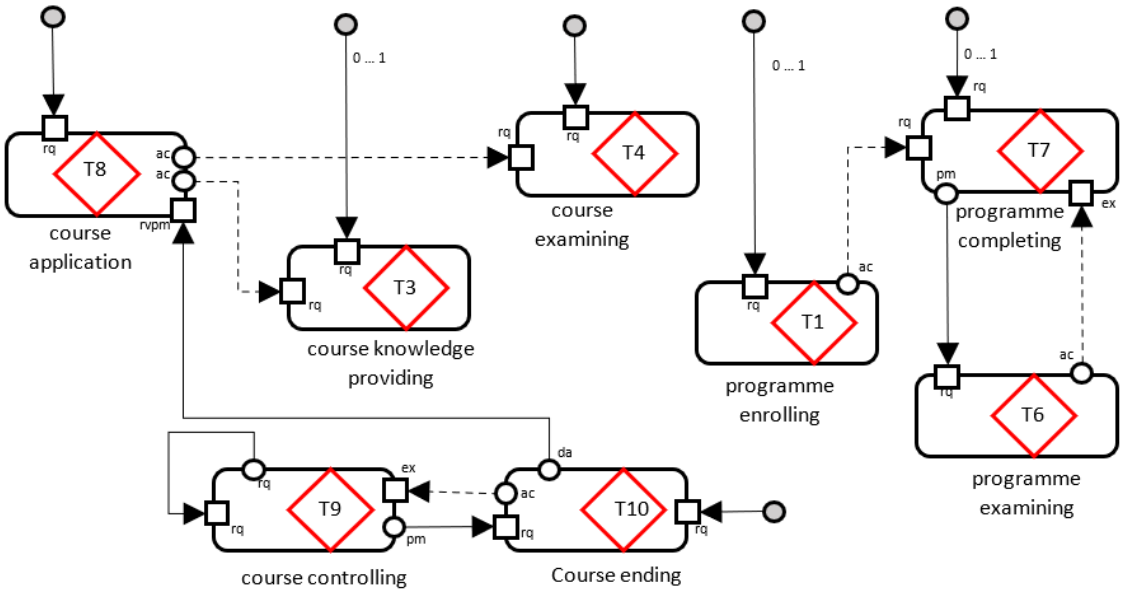


Note. Source: Student report "Flexible Student Learning Pathways Amsterdam University of Applied Sciences (AUAS)," 12 December 2022, made by Tim von der Fuhr, Ide Hingstman, Jan Schoonderbeek, and Richard Valkering.

The to-be essential model is different from the as-is essential model on a couple of aspects. First of all, the student is more in control. In the future scenario, the students have to actively enrol for the courses they decide that will part of the study programme. It will also be the student who decides that it is time for the programme completing. The second major change is the disconnection of enrolling on courses and programmes. In the future scenario, a student can enrol for separate courses, without being enrolled in a programme. Those courses can be used by the student for a future programme completing, at a time this will suit the student. Of course, there will be a process of checking whether certain courses are eligible for specific programme requirements. This will lead to some changes in the essential model,

Figure 5

Process Model Potential Future Education Organisation at AUAS



Note. Source: Student report "Flexible Student Learning Pathways Amsterdam University of Applied Sciences (AUAS)," 12 December 2022, made by Tim von der Fuhr, Ide Hingstman, Jan Schoonderbeek, and Richard Valkering.

as can be seen in the Process Model (Figure 4 and Figure 5 above). At minimum, there will be different actors and triggers at certain transactions, and in the Process Model there is a disconnect between course enrolment and programme enrolment in the future scenario.

But despite those changes, the conclusion of the case study was that the essential model for enrolment is relatively stable. In the future scenario, the end goal is still a completed programme. To reach that goal, a student has to follow courses. Lecturers are still designing the courses and teaching the students. Courses are to be matched with the requirements of the programme and the end result has to be checked by a programme examinator. So, this means that for a large part, in this case the enterprise ontology stays mostly the same.

Conclusion of the Case Study

The key findings in this stage of the research are:

- With DEMO we were able to study the effects of potential disruptive innovation separated from the implementation. This gave the insight that—in the scenario of the case study—the changes on the essence of the organisation were relatively limited.
- This extra dimension in looking at disruption and how to handle it, gives an extra perspective to sharpen the results of the expert meetings. This will be reflected upon at the end of this research, in chapter "Reflection" (page 76).

The Intended Use of the Higher Education Reference Architecture (HORA)

To look at the intended use of HORA, this chapter will first look at the concept of architecture and reference architecture. After that, HORA itself will be described. The chapter will end by summarizing the intended use of HORA, using the theory provided, and present the insight that will be used for the remainder of the research.

The Concept of Architecture

Architecture is used to manage change in the information landscape. It describes different aspects of the information landscape (like processes, application landscapes, and IT infrastructure) and gives principles and guidelines for designing it. The formal ISO/IEC/IEEE definition of architecture is: “Fundamental concepts or properties of an entity in its environment and governing principles for the realization and evolution of this entity and its related life cycle processes” (ISO/IEC/IEEE, 2022, sec. 3.2). This is an adaptation of the earlier definition that is more widely used but is from a discontinued version of the standard: “The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution” (IEEE, 2000). Following the latest ISO/IEC/IEEE definition, the architecture description expresses the concepts or properties of an entity, which can be a system or an element like a process or data. These descriptions are often made in visual representations of those entities, called “architecture views.” Those architecture views are models: They are used to obtain information about the reality (or a possible future reality) without looking at the entity itself (Dietz & Mulder, 2020, p. 73). The principles guiding the design and evolution of the architecture help the organisation in the development of the desired future reality. Those principles are normally in the form of text. When using architecture as a means to manage the information landscape, one needs architecture in a usable instance. So, while according to the IEEE definition, architecture (next to the guiding principles) is seen as the concepts or properties of an entity itself (current or future state), when using architecture to manage change, this is done by means of the representations in models.

Making the architecture models and the architecture principles is most of the time a laborious task. The architects need to study the existing architecture (the real world) and make a representation of that in models. They need to formulate the principles guiding the design and evolution, then design the future state of the architecture and design the roadmap to come to that desired future state. This work can have a long runtime, longer than is desirable when there are challenges in the organisation where actors are waiting for architecture advice (Timm et al., 2017). It would save time when part of the work can be done by ready-made architecture descriptions, or building blocks of architecture descriptions that can be used in making the architecture models. Those ready-made building blocks are part of what is called a reference architecture description, which can include reference models.

The Concept of Reference Architecture

For the definition of what is a reference architecture, both the definitions of reference architecture and reference models can be of use since a model is part of an architecture description. In both cases the distinctiveness is about *referring*. The definition of the

adjective reference is: “used or usable for reference, especially: constituting a standard for measuring or constructing” (Merriam-Webster, n.d.). A reference architecture can be defined as an architecture which can be used in supporting the construction of another architecture. This definition is an adaption from the definition of Thomas (2006, p. 491): “A Reference model – specifically: reference information model – is an information model used for supporting the construction of other models”. In those definitions, there is a clear perspective on use, or in other words, a teleological perspective. According to those definitions, the usability of an architecture to support the construction of other architectures (including the elements within them), is what makes an architecture a reference architecture.

The definitions mentioned above are not distinctive: Any architecture can be used to support the construction of other architectures. “Support” and “use” are broad concepts, which does not specify how the reference architect might be used. Any architecture can be used as an example, as an inspiration or can be copied or adapted, and in that way support the construction of another architecture. It can be an architecture made by another company for a comparable kind of entity or it can be an architecture for a completely different entity. This is defined as an affordance: “an action possibility which is latent in the natural environment” (Dietz & Mulder, 2020, p. 96). Since this research looks specifically at architectures that are supposed to be used as a reference architecture, the definition will include a functional perspective: for this research the *intended* use of the architecture will define it to be a reference architecture. The ISO/IEC/IEEE 42010:2022 standard looks at it in a comparable way. It also speaks of an intended use: “For an AD [architecture description] intended to serve as a reference for another AD, the entity of interest is abstract, or a generalisation of entities of interest, and the purpose of the AD is to express a reference architecture which could provide a basis for further ADs” (ISO/IEC/IEEE, 2022, sec. 6.1).

Another view on the definition could be what a reference architecture is made of. In the ISO/IEC 23093-1:2022 standard about the architecture of the internet of things (IoT), reference architecture is defined as a “description of common features, common vocabulary, guidelines, interrelations and interactions among the entities, and a template for an IoT architecture” (ISO/IEC, 2022, sec. 3.2.15). Also, since a reference architecture description can be seen as a specific kind of architecture description, based on ISO/IEC/IEEE 42010:2022 a reference architecture description can consist of architecture rationales, correspondences, correspondence methods, architecture views, and architecture viewpoint (see Figure 8 on page 31). Both are white-box or construction perspective on reference architecture (Dietz & Mulder, 2020, p. 164), although the last part of the ISO/IEC definition talks about a “template,” a term also associated with the function of being used to create something else. Since reference architecture is by its nature defined by the way it is used, for this research the black-box or functional perspective will be used to formulate the definition of it.

So, the definition of reference architecture in this research is: *A reference architecture is an architecture which is intended by its producer to be used in supporting the construction of another architecture*. This definition is transferable to the reference architecture description that express the reference architecture: A reference architecture description is an architecture description which is intended by its producer to be used in supporting the construction of another architecture description. Since models are part of an architecture description, the definition of reference model in this research is: A reference model is a

model which is intended by its producer to be used in supporting the construction of another model.

Note that the definitions do not mention how the use of the reference architecture is enforced. It could be a voluntary best practice, or it could be a constraining guideline that should be followed because of sector-wide agreements or even by law.

HORA: A Reference Architecture for Higher Education in the Netherlands

SURF is a cooperative association of Dutch educational and research institutions. They offer among other things shared services, the promotion of knowledge exchange, and architecture and standards (SURF, 2022). One of their products is a reference architecture for higher education: the Higher Education Reference Architecture. The reason that SURF is investing in a reference architecture is that it is assumed to be beneficial for the higher education sector. First of all, the idea is that because a reference architecture is available for higher education institutions, those institution will have to invest less resourcing in making their own architectures. This makes the work on architecture more efficient. Second, by having a reference architecture available, all higher education institutions start with the same template. All the local adaptions will be based on the same terminology or ways of describing things. This will make the cooperation between higher education institutions easier: There is less error in communication when the same terminology is used. This is an incentive to see it as an obligation to use the reference architecture with as minimum adaptions as possible, but there is no governance mechanism enforcing that.

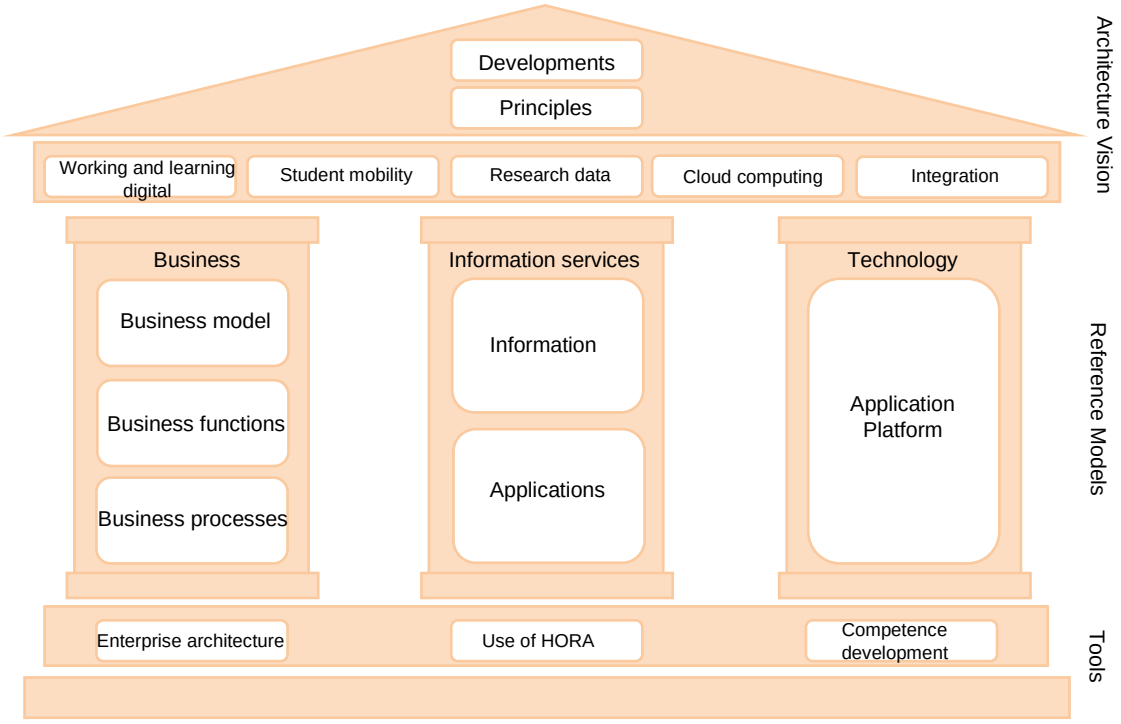
Contents of HORA

HORA is made available via the public website https://hora.surf.nl/ (SURF, n.d.-b). The current version is 2.1. The content of the website is divided in four sections: General, Architecture Vision, Reference Models, and Implementation. Those last three section are seen as the content of HORA itself. In “General,” information can be found about HORA and how it is maintained by SURF and the Architects Council HE[1] (in Dutch: Architectenberaad HO [ABHO]), a council founded by SURF. It also provides a self test on architecture maturity, downloadable files, and a reference list. The main page of “General” provides a model with the elements of HORA (see Figure 6).

[1] HE = higher education, in Dutch HO = hoger onderwijs.

Figure 6

The Components of HORA



Note. Adaptation from SURF (n.d.-b, sec. General). Original is in Dutch.

In "Architecture Vision," a couple of themes are presented, for example, "Working and learning digital" and "Cloud computing." Those architecture visions are provided to help institutions to make architectures for those themes, by providing an ontology, criteria, and models. A set of architecture principles is also provided in this section.

The core of HORA are the reference models. In the model of HORA, they are presented by the tree pillars: Business, Information services, and Technology. It contains eight types of models and a metamodel, see Table 2 below. Next to these main models, every element in the models has their own lemma, containing a definition, other metadata, and relations to other elements. Those relations are given in text and are presented in a context diagram.

Table 2

Reference Models Available in HORA

Model type	Pillar in HORA model
Business model	Business
Business function model	Business
Information model	Information services
Business process model	Business
Application function model	Information services
Application component model	Information services
Application platform	Technology
Metamodel	-

Note. Source: (SURF, n.d.-b, sec. Reference Models). Sorted according to the presentation by SURF on their website.

The last section of HORA provides tools for implementation. A standard format for a project start architecture can be found here, as well as a standard way of implementing enterprise architecture. Two models are provided on how enterprise architecture fits in the enterprise governance and in project management processes. Finally, it gives more information how to use HORA in the organisation and the competences that are needed.

History and Future of HORA

HORA started as part of a project called "Control in the cloud" (in Dutch: Regie in de cloud) in 2012 and was published as version 1.0 in October 2013. In the years after, small adaptions were done without publishing an updated version formally. Five years later, HORA 2.0 was published in October 2018, which was a major update. This version contained more details and included new architecture concepts (such as the application function). In September 2019, the research domain was further expanded, leading to version 2.1. This is the current version of HORA (SURF, n.d.-b).

At this moment, SURF is working on version 3.0. The assignment for that is an internal document, provided for this research on 28 March 2023 by a representative from the Architects Council HE[2]. It states that HORA 2.1 is in need of a major update. Elements that are missing are related to flexibilisation of education and exchanging information between institutions. Other themes are security and public values. Next to that, it is needed to update HORA to align it with the HOSA target architectures (see subsection "Interview With HORA Representative" below).

Interview With HORA Representative

On 26 January 2023, an interview was held with enterprise architect Tom van Veen, a representative from HORA. The representative worked on HORA the last six years and was involved in producing the first version. He is also working on the Higher Education Sector

[2] The assignment, finalised on 22 March 2023, is called Start Assignment Enterprise Architects AB HE (in Dutch: Startopdracht Enterprise Architecten ABHO). The document was provided by René Schenk, representative of the Architects Council HE.

Architecture (in Dutch: Hoger Onderwijs Sector Architectuur [HOSA]). The insights gained from the interview regarding to the use of HORA are presented below.

HORA is defined by SURF as a reference architecture because higher education institutions can draw inspiration from this to develop their own architecture. According to the representative, “There are institutions that have already based their architecture for a very large part on HORA (some not yet at all).” He sees this as an attention point for the upcoming update: It can be a lot of work to update the local architectures when HORA is changed too much.

The current version of HORA (2.1) needs an update. The representative mentioned that during his work on the HOSA architecture on flexibilisation of education, he wanted to match that with HORA. But he concluded, “I looked in HORA and my conclusion was: I can't do much with this, because I think that what is written here is no longer the truth. And that is the problem behind HORA, that it has not kept up with the developments.”

HORA is made with the intention of being used as a reference architecture. But according to the representative it is used in another way as well: “[…] the character has changed. The more heavily you lean on it, the more often parties look at HORA […] then the character changes, then it is no longer a reference to something that can exist, but it is the representation of reality.” Because HORA needs an update, this can lead to the wrong conclusions: “This is still very grafted from ‘an institution is like this and has never changed’, And that is not right. So that update is badly needed, also to provide a good framework for suppliers or sector partners, etc.”

But even when HORA will be up to date again, the representative saw a changing perspective that HORA not only should describe the current situation, but also look into the future: “And then the question comes into play: Is HORA still a reference architecture or is it just the description of the IST situation? And then I say: ‘IST plus a little’. So, there must be some developments that also look a little more to the future.”

Does HORA indeed reflect the reality of the institutions, or at least did it reflect the reality in a earlier moment in time when HORA was more up to date? According to the representative, this has never been assessed formally. It is an assumption that this is the case, based on the fact that HORA is made together with representatives from the higher education institutions.

Next to HORA, SURF is also responsible for what they define as a sector architecture, named HOSA (SURF, n.d.-c). In the interview, the difference between HORA and HOSA was explained by the representative. The entity of interest is different from HORA. Where HORA has the institution itself as the entity of interest (or more specific, a generalisation of multiple institutions), HOSA is about the collaboration between institutions in the sector. Work on HOSA started in 2020, so it is a more recent product then HORA. There are at this moment three products in HOSA: about Research Data Management, about the flexibilisation of education, and about Identity & Access. As the representative stated, “We want to construct this landscape as we described it in HOSA, so it is no longer really a reference. Then it is more: This something we are going to do. The target. That is why we call it very explicitly a target architecture.” This means that according to the definition of this research, HOSA is not a reference architecture. But is does have a connection to HORA: The new

concepts described in HOSA are about new developments on concepts where HORA has to be updated to keep them aligned.

Conclusion on the Intended Use of HORA

The key findings in this stage of the research are:

- Although there are many definitions on reference architecture, a clear definition could be formulated in the context of this research.
- HORA seems to have a strong foundation as a reference architecture in higher education. It contains multiple reference models and appears to be valued by the sector as a trustworthy source.

Those insights will be used in the proceeding of this research. As input for the Assessment Model, a reference architecture is defined as an architecture which is intended by its producer to be used in supporting the construction of another architecture. For the higher education sector in the Netherlands, the Higher Education Reference Architecture (HORA) is available (SURF, n.d.-b). This reference architecture contains eight types of reference models (see Table 2 above), a metamodel, and for each element metadata and a context diagram with the relations between elements. Next to that, HORA provides architecture visions on specific themes and gives support with implementation tools.

The findings also indicate an urgency, as the current version HORA 2.1—published in September 2019—is seen as out-of-date. There are missing elements on flexibilisation of education and it is in need of extra additions on themes like security and public values. Work has started in 2023 on an updated version, HORA 3.0. This urgency will help in organising the input from the experts, since they will most likely benefit from the results of this research in the anticipated update of HORA.

In the next part of the research, it can be assessed how well HORA is supporting the architects in addresses the stakeholders' concern regarding disruptive innovation. This will be done by designing the Assessment Model and then using this model in the expert meetings.

Designing the Assessment Model

In this chapter a framework will be designed to assess the use of reference architectures in dealing with disruptive innovation in higher education, trying to answer the research question “What framework can be constructed to obtain a comprehensive assessment that will be able to answer the first research question?”

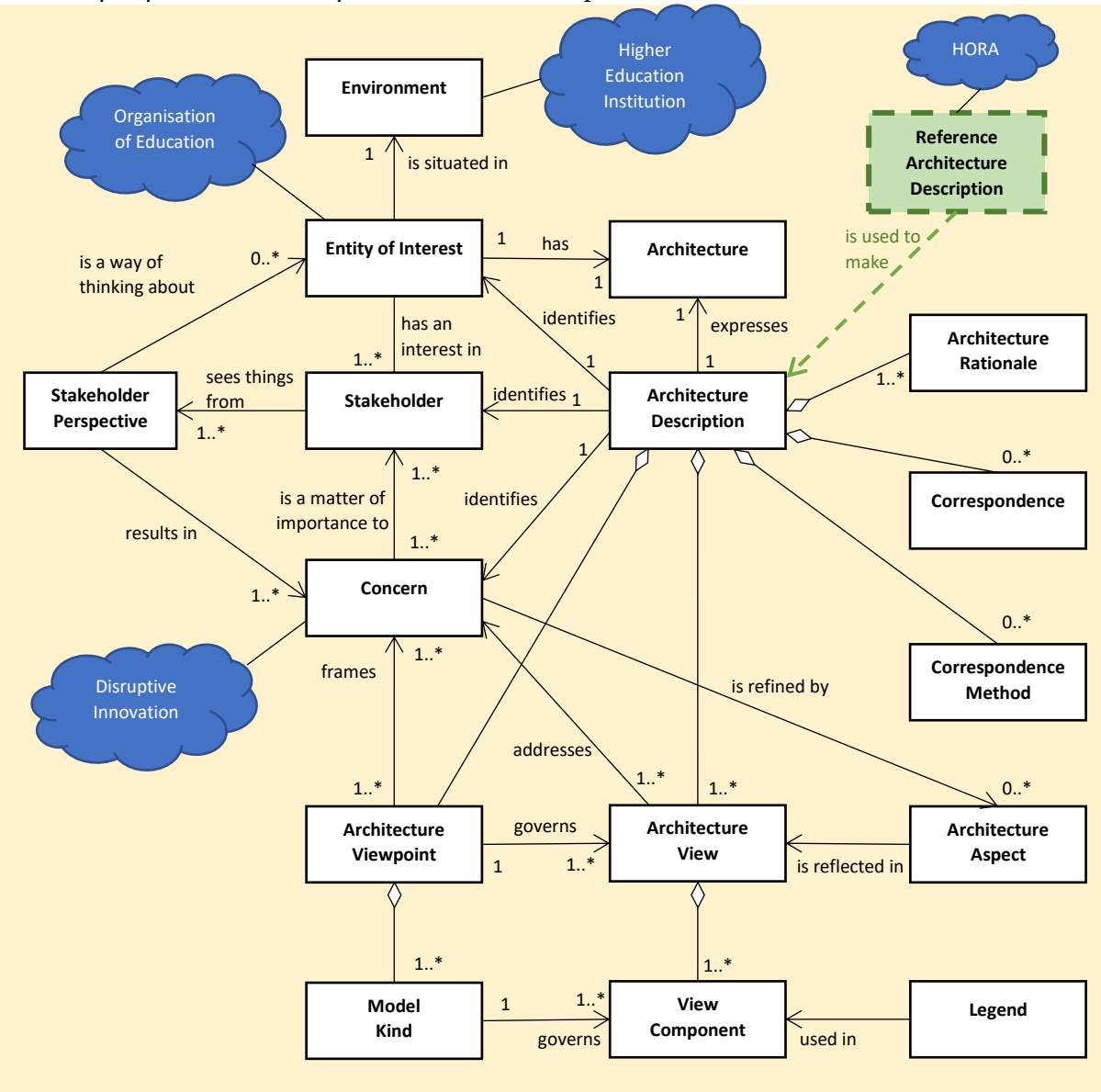
Frame of Reference for the Assessment Model

To start with the Assessment Model for the judgement of the usability of HORA, a frame of reference model based upon the ISO/IEC/IEEE 42010:2022 standard is introduced in Figure 7 below (Hilliard, n.d.; ISO/IEC/IEEE, 2022). The ISO/IEC/IEEE 42010:2022 standard is used because it gives a comprehensive structured overview of architecture, its components, and where it is used. It is a widely known standard by a renowned institution, and the definition of architecture that is in it has been revered to regularly in literature (e.g., Lankhorst, 2005).

De model in Figure 7 has been adapted and supplemented for this research. The added cloud elements are representations of the concepts that are subject of the application domain of this research. The green elements are additions to the model, to include the concept of reference architecture. This frame of reference model shows the construction of the reference architecture and the context in which it is used.

Figure 7

Frame of Reference Model of Architecture Description



Note. This conceptual model is an adaptation from the one presented by Hilliard (n.d.). Permission has been given to use and adapt the model. From the original model, the colours that indicated the changes made by Hilliard earlier were removed. Added elements are the concepts that are subject of this research (the cloud elements) and the addition of reference architecture in the model (the green element with dotted lines). The element "Reference Architecture Description" is seen as a specialisation of an architecture description, so it has a comparable conceptual model (see Figure 8, on page 31).

For the first research question "How can HORA support the challenges of disruptive innovation in higher education in the Netherlands?" the following premises are used:

- The concern at stake consists of the potential disruptive innovations. It is a matter of importance to stakeholders in higher education institutions. Those stakeholders have to decide how to act upon this concern.
- It is also possible that an architect identifies a concern for the stakeholder.

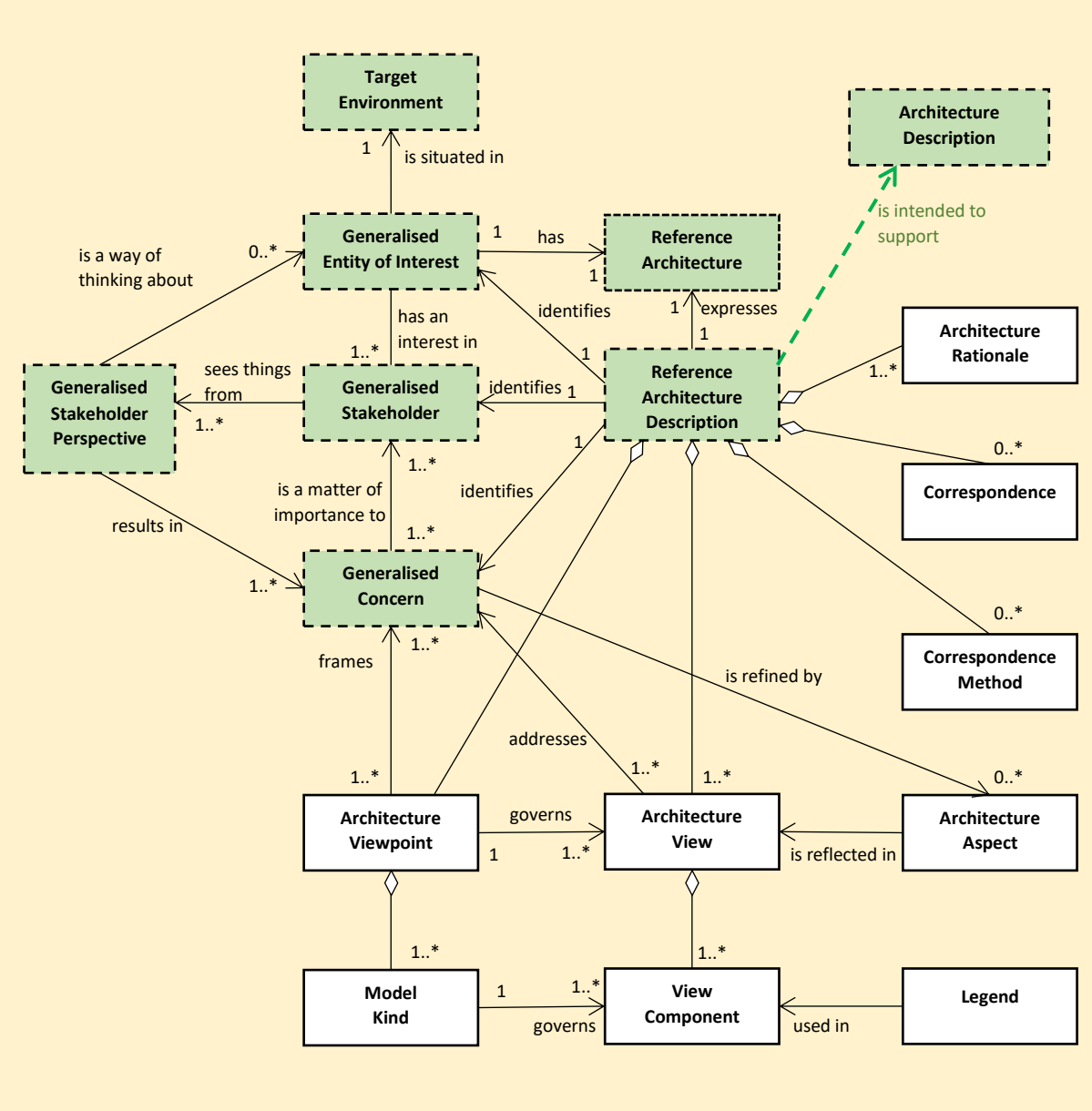
- The entity of interest in this research consists of the higher education institutions but excludes the education itself. The scope consists of stakeholders who have an interest in the organisation of education and the IT landscape supporting that. It can be a product team working on a solution, or a member of the board who is responsible for the organisation of education.
- An architecture description will express the architecture of that same entity of interest. This architecture description and the architecture views which are part of that description, should help the stakeholders in addressing the concern by acting upon the entity of interest.
- A reference architecture description, an added element in the model, is meant to help produce this architecture description more efficiently (in less time and/or with less effort). In the model, a relationship is shown between "reference architecture description" and "architecture description." Because most of the elements on the lower part are seen as part of the architecture description (via the composite relation), the relationship with the reference architecture description is by proxy with those elements as well. In other words, a reference architecture description could be used to produce any of those elements.

The second conceptual model is of the reference architecture itself. In the ISO/IEC/IEEE 41020:2022 standard, a reference architecture is a specialisation of an architecture (ISO/IEC/IEEE, 2022, sec. 6.1). Therefore, it can be described by using the conceptual model of an architecture description, as has been presented in Figure 7 (page 29).

Since the reference architecture expresses a *generalised* entity of interest, the reference architecture description will therefore identify a generalised concern, a generalised stakeholder, and a generalised stakeholder perspective. Since the producers of the reference architecture description have a generalised entity of interest in mind, the different entities of interest on which this generalisation is based are part of the target environment. Furthermore, added in the model is the target architecture description: the architecture description which the reference architecture description is intended to be used for. This element will also connect the conceptual model in Figure 8 with the conceptual model in Figure 7.

Figure 8

Frame of Reference Model of Reference Architecture



Note. This conceptual model is an adaptation from the one presented by Hilliard (n.d.). From that original model, the colours that indicated the changes made by Hilliard earlier were removed. The light green boxes with dotted lines are adaptions or additions.

The entity of interest would be a generalisation of entities of interest, in the case of HORA a generalisation of the entities of interest pertaining to the different institutions of higher education. The same generalisation applies to stakeholders and concerns.

Frameworks to Assess the Usability of Reference Architectures in Responding to Disruptive Innovation

The discussion about the quality and usability of enterprise architecture and conceptual models spans many decades. Frameworks for assessing model quality have been around since the eighties of the last century. It is not the aim to get a comprehensive overview

of all the different frameworks and the surrounding discussions. Instead, an attempt has been made to get an overview with the most relevant frameworks that can be of help in answering the first research question.

The methodologies have been found by searching for relevant literature via Google Scholar. The literature that seemed relevant has then been subjected to forward and backward snowballing (Wohlin, 2014). Literature that could not be obtained via downloading or via the Antwerp Library is not taken into account. Also excluded is literature in a language other than English, Dutch, German, French, or Spanish. To search for applicable frameworks (including models, methods, and classifications) a start set was made with the terms "*quality enterprise architecture*," "*quality aspects enterprise architecture*," "*quality aspects reference architecture*," "*quality aspects models*," and "*usability of enterprise architecture*." The top 20 results were assessed by title and abstract. This led to 28 relevant articles which were then used for forward and backward snowballing, based on title alone. An extra 82 articles were found this way, making a total of 110 (see Appendix C).

The same has been done for articles about disruptive innovation. A start set was made with "*architecture patterns for disruptive innovation*," "*architecture support in disruptive innovation*," "*enterprise architecture and disruptive innovation*," "*reference architecture and disruptive innovation*," and "*conceptual models for disruptive innovation*". This search provided 5 relevant articles, one of them related to MOOCs and higher education. The same procedure as above was followed, which led to 14 articles in total (see Appendix D).

Each list includes books, journals articles, conference proceedings, PhD theses, and master theses. Those articles were then scanned for applicable frameworks, models, methods, and classifications that can be used for answering the research question.

The usability of reference architecture is seen from both the perspective of conceptual models as well as enterprise architecture. On the one hand, the reference architecture HORA contains many artifacts that are used (and are intended to be used) as models, the so-called reference models. There is much literature on the use of reference models, but many of them is about reference models used for software architecture, for example, the RAModel (Nakagawa et al., 2012). In Frank (2006) a classification on reference models has been given, classifying them by use for (1) developing software, (2) documentation of existing software, and (3) business design of redesign. This literature concerning the first and second use are left out of scope, since it is not the goal of HORA to use it in software engineering. Next to the models, HORA also gives principles and implementation guidelines. This is in line with Figure 8, where a reference architecture is presented in a context of how the architecture description (including principles) is being used by stakeholders. When looking at the quality aspects of enterprise architecture, this thesis looks at the enterprise architecture products and services and how they meet the stakeholders needs. It does not look at the quality of the architecture of the system that is being designed or investigated. Therefore, Analytic Hierarchy Process, which gives a Multi-Criteria Decision Making method for choosing between scenarios (Razavi et al., 2011), and PERDAF, which is aimed at System Quality Analysis (Närman et al., 2007), are not included. So, when looking at possible frameworks to assess the usability of HORA, the perspective of conceptual models and enterprise architecture are considered, both in the context of enterprise architecture products and services to be used by stakeholders.

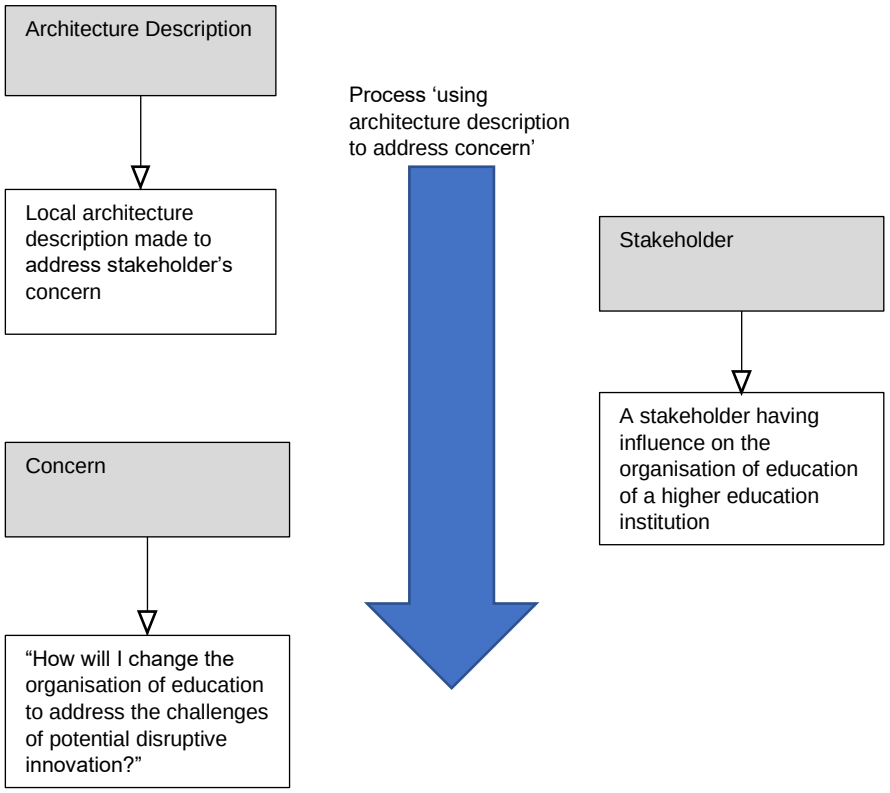
The Concept Usability of Reference Architectures in Responding to Disruptive Innovation

When assessing the usability of a reference architecture, there are multiple aspects to assess. First of all, the end goal is that a stakeholder can use an architecture description to satisfy their need. The stakeholder can have a direct or indirect interest in an entity and can have control or influence over this entity. The types of influence can be operational, financial, or political, or can pertain to designing systems. This research is about the concern "disruptive innovation," and the entity of interest is "the organisation of education in higher education institution, including the IT landscape." The premise of this research is that the stakeholder involved should benefit from architecture descriptions when addressing that concern in relation to that entity of interest.

So, as shown in Figure 9, proposition 1 is that with the help of an appropriate architecture description, a stakeholder having influence on the organisation of education of a higher education institution can address their concern related to potential disruptive innovation with better results. There is some kind of process, for example, decision making or designing, for addressing the concern. This is based on the ISO/IEC/IEEE 42010:2022 standard, indication that a concern (in this case, a potential disruptive innovation) is a matter of importance to a stakeholder, who has an interest in a entity of interest, which might be affected by that potential disruptive innovation (ISO/IEC/IEEE, 2022). The stakeholder can use a architecture description for addressing the concern related to the potential disruptive innovation (Niemi & Pekkola, 2013; Van de Wetering et al., 2021).

Figure 9

Proposition 1: A Stakeholder Uses an Architecture Description to Address Disruptive Innovation



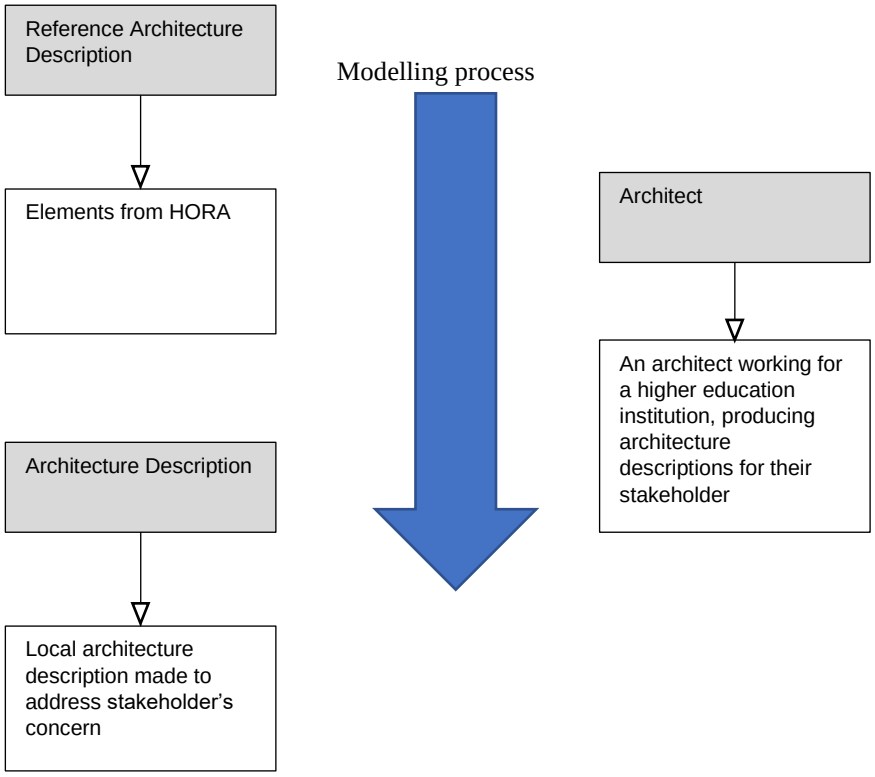
Note. Proposition 1: With the help of an appropriate architecture description, a stakeholder addresses their concern related to potential disruptive innovation.

Since the architecture description can exist of many elements, each element can have its own impact on the result. It might be for example that a specific viewpoint or set of viewpoints normally is of major help for the stakeholder, but the architecture view that addresses this specific concern is not useful enough.

The next aspect to consider is how well the architect working for the specific higher education institution can use the reference architecture description while producing the local architecture description. As show in Figure 10, proposition 2 is that with the help of HORA as a reference architecture description, an architect can produce a more effective architecture description to address the stakeholder's concern mentioned in proposition 1. The architecture description can also be a selection of unchanged elements from HORA, in which case the modelling process entails only selection of those elements and (if needed) changes in the presentation of those elements. This is based on the adaption of the ISO/IEC/IEEE 42010:2022 standard, as presented in Figure 8 (page 31).

Figure 10

Proposition 2: The Architect Uses HORA to Make an Architecture for the Stakeholder



Note. Proposition 2: With the help of HORA an architect produces an architecture description to address the stakeholder's concern mentioned in proposition 1.

Since both the reference architecture description and the architecture description consist of multiple elements, those elements can have their individual effect on the above-mentioned relationships.

To investigate these two propositions, an operationalisation is needed. In literature, there are multiple models and frameworks to assess the use and the quality of concepts like enterprise architecture, reference architecture, models, and reference models. This will be assessed in the next section. The investigation is aimed at three distinct aspects: enterprise architecture, conceptual models, and the modelling process. First, enterprise architecture is seen as an approach for managing change in the organisation's structure and IT landscape, with the use of architecture descriptions (Niemi & Pekkola, 2013, p. 3878). And like mentioned earlier, a reference architecture description is seen as a specialisation of an architecture description. So, when looking at quality and usability attributes of reference architecture, the context of enterprise architecture and its attributes is relevant as well. Second, reference architecture descriptions and the local architecture descriptions contain conceptual models in the form of viewpoints. So, quality and usability attributes of conceptual models will be relevant as well since they can be used to describe those elements of the architecture. Some quality and usability attributes can be specifically related to reference models, while others may only be relevant for the local models that were made

based on the reference model. Third, the modelling process is taken in account as well. Since the research focuses on HORA as a readily available reference model as input for proposition two, only the modelling process of the local model based on the reference model is taken into account, not the modelling process of making HORA.

Quality of Modelling Frameworks

Conceptual Modeling Quality Framework (CMQF)

In the last decades, multiple frameworks have been proposed to assess the quality and use of enterprise architecture, conceptual models and reference models. A part of them are lists of quality attributes, were there is no relation between the attributes or there might even be contradiction in them. Also, definitions are sometimes not precise enough (Nelson et al., 2012). In 1994, an influential article proposed a framework that included a distinction between goals and means and was linked to linguistic concepts (Lindland et al., 1994)[3]. This semiotic view on the quality of conceptual models had been used in many proposals for other frameworks, like SEQUAL ("SEmiotic QUALity" framework; Krogstie, 2015), QoMo ("Quality of Modelling" framework; Van Bommel et al., 2007), and CMQF (Conceptual Modeling Quality Framework; Nelson et al.,2012).

The framework proposed by Lindland et al. (1994) stands out, because of the semiotic view on the quality and the distinction between goals and means. The years afterwards the framework was enhanced by Krogstie et al. (1995) to the SEQUAL framework, as summarized in Krogstie (2015). It gives a list of quality attributes that take in account many aspects like semiotics, stakeholder knowledge, and social interpretation. Because of this comprehensive view, the SEQUAL framework is considered to be useful for assessment of the use of HORA. It will look at many aspects, providing the assessment with many viewpoints.

The SEQUAL framework looks mainly at the conceptual model and its context, not at the process of how the model is made. But in the production of a model there are aspects that effect the quality of models as well. In the process of modelling, stakeholders share knowledge and come to mutual understanding, even before the modelling process is over. Different authors have seen this lack of a process perspective as an omission and proposed an extension. Van Bommel et al. (2007) presented a preliminary modelling process oriented "Quality of Modelling" framework (QoMo), based on the SEQUAL framework. This preliminary framework was based on knowledge state transitions and a goal structure for activities-for-modelling. Five years later, a separate framework was put forward by Nelson et al. (2012): the Conceptual Modeling Quality Framework (CMQF). This framework is not only based on the SEQUAL framework, but also incorporates the Bunge–Wand–Weber (BWW) model, based on the ontological theory of Bunge. Both SEQUAL and the BBW-model are seen as having a solid theoretical foundation but look at conceptual modelling quality from two different perspectives. Nelson et al. combines both frameworks, addresses

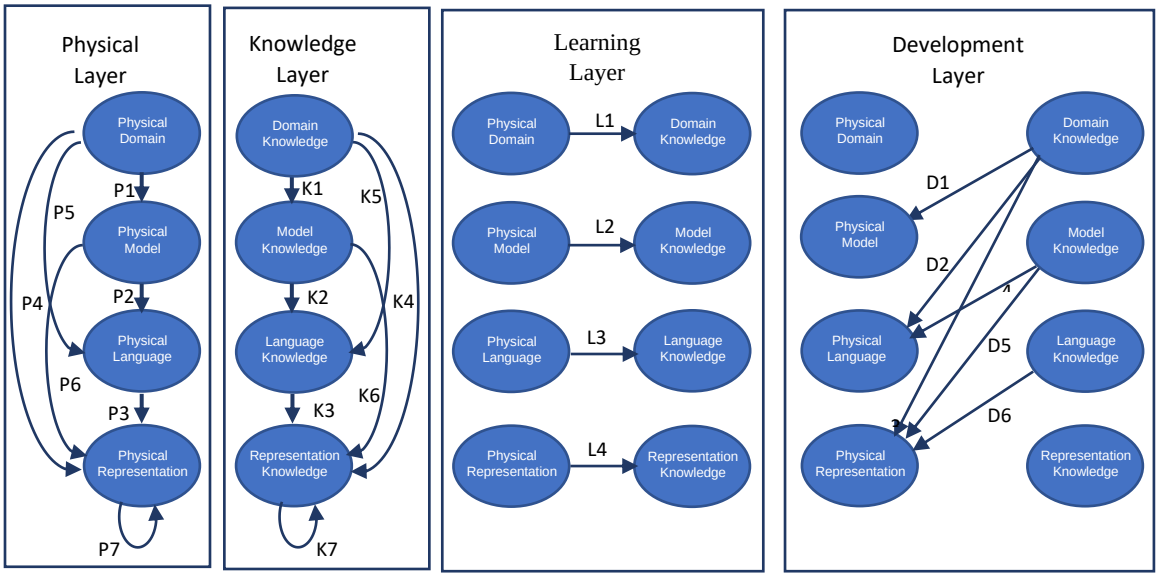
[3] This proposed framework had not been given a name. Nelson et al. (2012) refer to it as the "LSS framework," named after the authors Lindland, Sindre, and Sølvberg. Nelson et al. sees the later iterations by Krogstie et al. (1995) as part of the LSS framework. Those later iteration have been dubbed the SEQUAL framework at one point. In this thesis the 1994 version will be referred to as "the framework by Lindland et al.," the later iterations by Krogstie et al. will be referred to as the SEQUAL framework.

the overlap, and adds extra elements where both frameworks appear te have an omission. The result is shown in Figure 11 below.

Since this thesis looks at the usability of the reference architecture HORA, the modelling process is part of the items to be researched. After all, HORA is used in the modelling process making internal models for internal stakeholders. A method that combines a perspective on the semiotic quality and on the modelling process will give a comprehensive view on the usability of HORA. The Conceptual Modeling Quality Framework from Nelson et al. (2012) seems to provide a solid and comprehensive framework to do so.

Figure 11

The Conceptual Modeling Quality Framework



Note. Adapted from: Nelson et al. (2012, p. 211). See Nelson et al. (pp. 210–215) for a detailed description of the model and its elements. De quality types represented by the arrows can be found below in Table 3.

The arrows in the model represent quality types, based on the cornerstones (the ellipses in the model) they are connecting. See below in Table 3. These quality types should give a comprehensive assessment of the quality of both the models in the reference architecture, as the local models made with the help of them. For this research, expert meetings will be held to investigate the opinions and experiences of the stakeholders of the models. The models themselves will not be investigated for now. That means that the quality types P1 to P7 will not be used in the Assessment Model. Quality types K1 to K7 will function as a surrogate for them, since they are about the quality perceived by the architects (Nelson et al., 2012, p. 214).

Table 3

Quality Types and Their Associated Quality Cornerstones

Label	Quality type	Quality reference	Object of interest
P1	Model–domain appropriateness	Physical domain	Physical model
P2	Ontological quality	Physical model	Physical language

Label	Quality type	Quality reference	Object of interest
P3	Syntactic quality	Physical Language	Physical Representation
P4	Semantic quality	Physical Domain	Physical Representation
P5	Language–domain appropriateness	Physical Domain	Physical Language
P6	Intentional quality	Physical Model	Physical Representation
P7	Empirical quality	Physical Representation	Physical Representation
K1	Perceived model–domain appropriateness	Domain Knowledge	Model Knowledge
K2	Perceived ontological quality	Model Knowledge	Language Knowledge
K3	Perceived syntactic quality	Language Knowledge	Representation Knowledge
K4	Perceived semantic quality	Domain Knowledge	Representation Knowledge
K5	Perceived language–domain appropriateness	Domain Knowledge	Language Knowledge
K6	Perceived intentional quality	Model Knowledge	Representation Knowledge
K7	Perceived empirical quality	Representation Knowledge	Representation Knowledge
L1	View quality	Physical Domain	Domain Knowledge
L2	Pedagogical quality	Physical Model	Model Knowledge
L3	Linguistic quality	Physical Language	Language Knowledge
L4	Pragmatic quality	Physical Representation	Representation Knowledge
D1	Applied domain–model appropriateness	Domain Knowledge	Physical Model
D2	Applied domain–language appropriateness	Domain Knowledge	Physical Language
D3	Applied domain knowledge quality	Domain Knowledge	Physical Representation
D4	Applied model–language appropriateness	Model Knowledge	Physical Language
D5	Applied model knowledge quality	Model Knowledge	Physical Representation
D6	Applied language knowledge quality	Language Knowledge	Physical Representation

Note. Source: Nelson et al. (2012, p. 212). See Nelson et al. (pp. 210–215) for a detailed description of the elements. De graphical representation of the elements can be found above in Figure 11.

In the beginning of the chapter, a frame of reference was presented in Figure 7 and Figure 8. To see how the CMQF model ties into that, the cornerstones are mapped to the elements in that frame of reference. The following elements appear to be related:

- The “Physical Domain” is the same as the “Entity of Interest” and the “Generalised Entity of Interest.”
- “Domain Knowledge” does not have a similar element in the frame of reference models, but “Stakeholders Perspective” and “Generalised Stakeholder Perspective” are part of the domain knowledge.
- The “Physical Model” is not the end result of the modelling process but defines the rules for the model on an ontological. In the frame of reference model, this is part of the “Model Kind.”
- “Model Knowledge” does not have a similar element in the frame of reference model.
- The “Physical Language” is part of the “Model Kind”.

- "Language Knowledge" does not have a similar element in the frame of reference model.
- "Physical Representation" is the end result of the modelling process. It is the "Architecture View" in the frame of reference model.
- "Representation Knowledge" does not have a similar element in the frame of reference model.

Return on Modeling Effort, Value in Action and Retention of Modeling Effort

As stated earlier, the starting point of making a reference model is the premise that using a reference model will save time. So, the resources invested in HORA should be lower than the combined savings on resources used to make local models and/or lead to a higher quality of the local models, both leading to a higher return on modelling effort. To take this into account, three concepts from Proper and Guizzardi (2022) are investigated: Return on Modeling Effort (RoME), Value in Action (ViA), and Retention of Modeling Effort (RiME). Those concepts describe how the value of modelling relates to the investment and how this value might be retained.

The RoME-ViA-RiME framework is in the beginning of its development phase, but some insight can be drawn from it at this moment. To assess the return on modelling effort, one can ask questions regarding the *purpose & requirement*, the *context & challenge*, the *activities & effort*, the *resulting model*, and the *return on modelling effort*. When looking at the value, three perspectives are given: *value in creation*, *value in use*, and *value in transaction*. The last value relates directly to reference architecture and is split in direct value for the actor using the reference architecture, and the value for the owner of the reference architecture. When looking at retaining value, there are ways to retain a higher value in the lifetime of the model. This is for example about storing the model in such a way that it cannot be edited by third parties. Next to that, the shelf life of the model can be short if the entity that has been modelled changes quickly (Proper & Guizzardi, 2022).

For a complete assessment of the use of HORA, return on modelling effort should be taken in account. There should be a positive Return on Investment (ROI) for SURF—or more precisely the whole of the higher education sector that funds SURF—on developing and maintaining HORA. Research on how this ROI can be made higher will benefit the sector as well. Next to that, architects use HORA to make local models should have a higher ROI on that modelling process then without using HORA. Also in this case, research on how to make that ROI even higher benefits the higher education sector.

The concepts RoME, ViA and RiME will be added to the Assessment Model. This will result in questions related to those concepts, to get a idea of how HORA can be improved to have a higher return on modelling effort.

Evaluation of Reference Models

Reference models are seen as a specific type of conceptual models, which are—according to their developers—supposed to be used to make other models. When applying the above-mentioned frameworks, the focus on the quality attributes and the value will be different from models that are not reference models. There is much research on reference models, but many have software engineering as a focus. Since HORA is meant for business engineering, not software engineering, that research is not applicable to this case. The

evaluation method proposed by Frank (2006) also has software engineering as perspective but does provide a multi-perspective framework in which business design or redesign is taken into account. This work refers among other things to the SEQUAL Framework and the BWW framework as a starting point. It leads to a set of aspects based on four perspectives: the *economic perspective*, the *deployment perspective*, the *engineering perspective* and the *epistemological perspective*. Those perspectives are divided in focus points, which themselves are divided in categories. Not all aspects are applicable in the context of business engineering. In Table 4, only the ones that are applicable in that context—as marked in Frank (2006) —are listed. See Frank (pp. 124–136) for more details on the aspects.

Table 4

Aspects for Evaluating Reference Architecture

Perspective	**Focus**	**Category**	**Aspect**	**Specific to reference model?**
Economic	Costs	Introduction	Acquisition	Yes
			Training	Yes
			Adaptation	Yes
			Strategic redesign	Yes
			Organisational redesign	Yes
			Integration	No
		Maintenance	Conceptual support	Yes
			Tools	No
			Skills	Yes
	Benefits	Efficiency/ effectiveness	Business/ management	No
		Flexibility/ integration	Expressive Power	No
	Coordination/ knowledge management	Coordination/ knowledge management	Coordination	No
			Knowledge management	Yes
		Protection of investments	Spreading/ commitment	Yes
Deployment	Deployment	Deployment	Understandability	No
			Attitude	Yes
Engineering	Engineering	Engineering	Definition	No
			Explanation	No
			Language features	No
			Technical model features	No
Epistemological	Epistemological	Epistemological	Evaluation of theories	Yes
			Generic principles	Yes
			Critical distance	Yes
			Scientific progress	Yes

Note. Adaption from: Frank (2006). See Frank (pp. 124–136) for more details on the aspects.

The framework from Frank (2006) has aspects than can be related to quality attributes in CMQF model, for example the criteria in "Technical Model Features" that relate to "Empirical Quality." This is not surprising, since both frameworks took inspiration from the SEQUAL framework and the BWW framework. But where the CMQF model tries to tie the

quality attribute at the relations between a logical set of cornerstones, the framework from Frank is a list of various aspects and their criteria. The same problem with other lists of quality attributes arises here: there seems to be no sharp logic behind the different criteria. So, for the Assessment Model the basis will still be the cornerstones and their relations from the CMQF model, based in its comprehensiveness. With the economic perspective in the framework from Frank, it also looks at return on modelling effort. This perspective can be used in a next iteration of the Assessment Model when the Return on Modeling Effort theory does not prove to give sufficient insight.

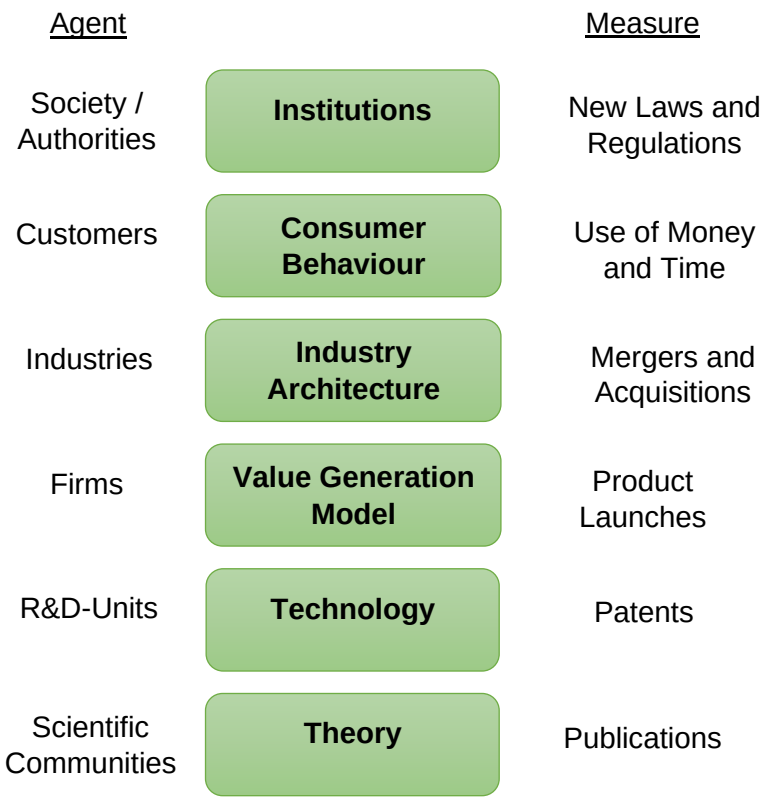
Disruptive Innovation

This research does not look at the use and quality of HORA as such, but at its use to address a specific concern of stakeholders: “How will I change organisation of education to address the challenges of potential disruptive innovation?” The architecture description made by the architect using elements from HORA should help the stakeholder in answering that question. To address the question when innovation is disruptive, the following statement in Kilkki et al. (2018) is given: “An agent is disrupted when the agent must redesign its strategy to survive a change in the environment.”

The term disruptive innovation has been used in literature for many decades now. Google Scholar gives 491 articles on this term. Those are not only articles on IT innovation, but other sectors as well. For instance, B. Lewis (1985) uses the term in the context of railways, where the ruling elite in China were worried that the introduction of trains in the nineteenth century might be a disruptive innovation impacting their position. The term disruptive technology gives a number of around 64,000 articles. According to Kilkki et al. (2018) the number of articles on disruptive innovation and disruptive technology really took off after the article The Innovator's Dilemma in 1997, by Clayton Christensen. For the potential use in the Assessment Model, two models from Kilkki et al. are taken in account, see Figure 12 and Figure 13. Those two models give a good view on how disruptive innovation works.

Figure 12

Layers of Disruptive Innovation

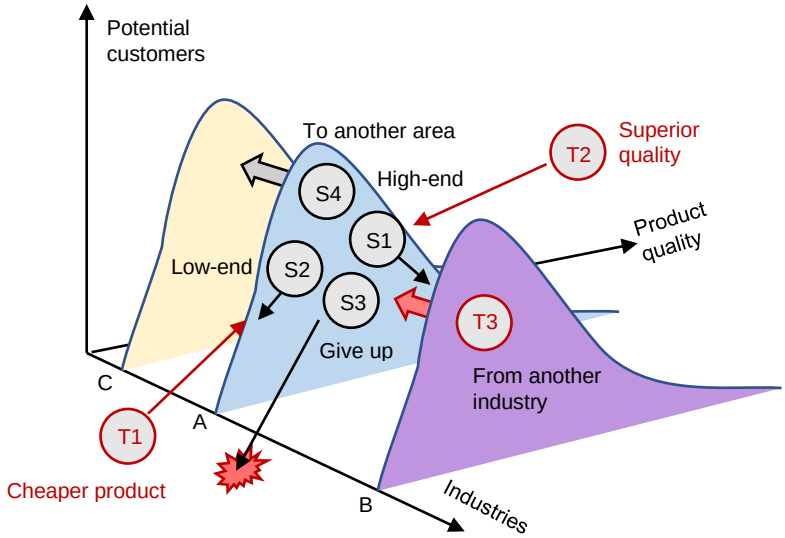


Note. This model is an adaption of the model by Kilkki et al. (2018, p. 277). The terminology is unchanged, but the relationships between de elements is left out, and two centre columns are merged to one column (the green elements in the centre).

In Kilkki et al. (2018) six layers are described on which a disruptive entity can emerge. See Figure 12. Note that the higher education institutions are at the firm layer in this model. When we talk about higher education institutions the word institution is defined as "an established organization or corporation (such as a bank or university) especially of a public character." The word institution in Figure 12 refers to the definition of "a significant practice, relationship, or organization in a society or culture" (Merriam-Webster, n.d.). On the left, the agents are shown, who can either be disrupters, disruptees, or neutral agents if the disruptive innovations do not affect them. In the middle, the green boxes are the potential disruptive entities. On the right, per layer is indicated how the effect of a disruption can be measured. Disruptive innovation (and also sustaining innovation) can happen at any layer. It might have an effect on other layers, for example when an innovation on the Technology layer causes disruption on the Firm layer. This layered model can help to classify the type of disruption the stakeholder is worried about and will be of influence on the advice that has to be given.

Figure 13

A Model of the Effects of Disruptive Innovation



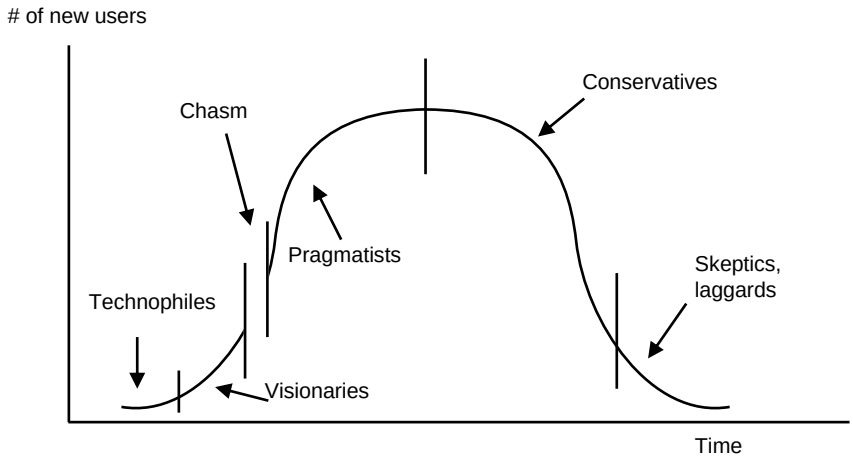
Note. Adapted from: Kilkki et al. (2018, p. 278).

Depending on the impact of the disruptive innovation, there are different strategies to follow. Kilkki et al. (2018) state that companies need to act when innovation leads to newcomers in the market. See Figure 13. A company can try to make its product more exclusive (S1), make it cheaper (S2), or look for new markets themselves (S4). Doing nothing is an option (S3), but according to Kilkki et al. this will likely lead to the end of the company. These scenarios will make it clearer when a development is expected to be a disruptive innovation, but also will give scenarios for the advice for the stakeholders.

The question is how quickly a firm, in this case a higher education institution, should react to a disruptive innovation. This will be related to how fast the market is changing: There must be enough time to change the strategy before it is too late and the predicted result of strategy S3 will unfold. But in the early phase of the disruptive innovation, it is not yet clear how the market will be affected. It can be pragmatic to be a fast follower and adapt to the new technology at a later moment when it is clearer what the impact and possibilities are. In Geoffrey Moore's technology adoption life cycle, there are five adopter categories: technophiles, visionaries, pragmatists, conservatives, and sceptics. See Figure 14 below. Visionaries are the ones that see the vision of gaining a competitive advantage through adoption. The chasm in the figure is about the decrease in sales, where according to Moore there is still no adaption by the pragmatists, but there are also no new visionaries. This model can be used to classify the phase in which the higher education institution is in relation to the development of the disruptive innovation in the market.

Figure 14

Moore's Technology Adoption Life Cycle

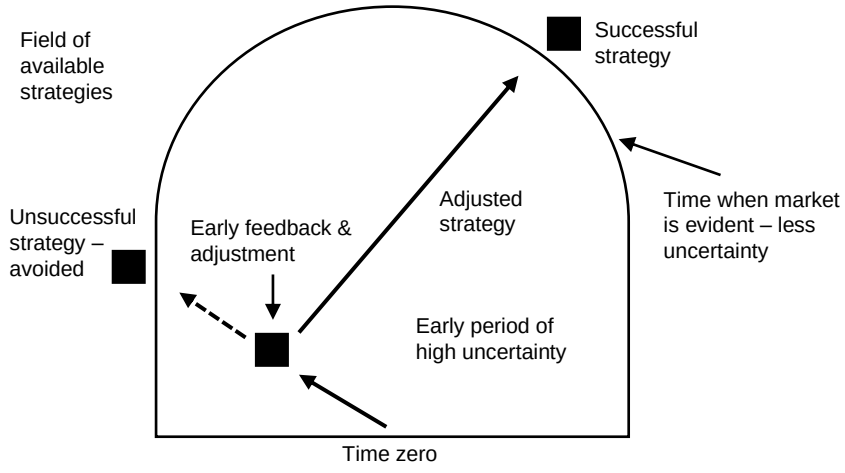


Note. Adapted from: (Giglierano et al., 2017, p. 32, adapted from Moore, 1991).

The timing perspective can also be addressed as a period of time, starting at the emergence of a potential disruptive innovation, where an organisation has time to investigate the possible strategies, field test them, and adjust them to reach a successful strategy. See Figure 15 below. This model is about the process of getting to a successful strategy. It can be a way to deal with the uncertainties an architect will face in formulation the advice for a stakeholder.

Figure 15

Adjustment of Early Strategy in Christensen's Model of Disruptive Innovation



Note. Adapted from: (Giglierano et al., 2017, p. 34, adapted from Anthony et al., 2008).

The Assessment Model

In the previous section the models and frameworks were selected that seems useful to assess the use of HORA in addressing the concern of the stakeholders regarding disruptive innovation. Below, the Assessment Model is presented in Figure 16 (see next page).

The earlier mentioned propositions 1 and 2 (Figure 9 on page 34 and Figure 10 on page 35) are combined to one process flow with two process steps. There is a concern, caused by a potential disruptive innovation in higher education, which has to be addressed by a stakeholder. In that process, the stakeholder is aided by a suitable architecture description. An architect has made this description via a modelling process using elements from HORA. To see if HORA can be beneficial in those two processes, the assessment starts at the end goal of the two processes. So, step 1 in the assessment is to validate if one of the stakeholders indeed has this concern. In this step, the definitions and models by Kilkki et al. (2018) are used. In step 2, the modelling process is validated: Does the architect produce (or intends to produce) an architecture description suited to help the stakeholder addressing the concern?

In step 3, the assessment of the use of HORA takes place, using the CMQF framework. Both the architecture description as the reference architecture description are assessed. From the modelling processes, only the modelling process of the architecture description is assessed. For this moment, HORA is seen as an end product, where the local architect or stakeholder did not directly benefit from the modelling process producing HORA. Of course, it can be argued that the higher education sector, including the architects and stakeholders, have benefited from the earlier modelling process, but for this framework this will be out of scope.

In the last step 4, the effect of HORA on the return on modelling will be assessed, using Proper and Guizzardi (2022). The architects making the description are asked whether they think by using HORA the modelling process was more efficient, and whether they think the quality was higher.

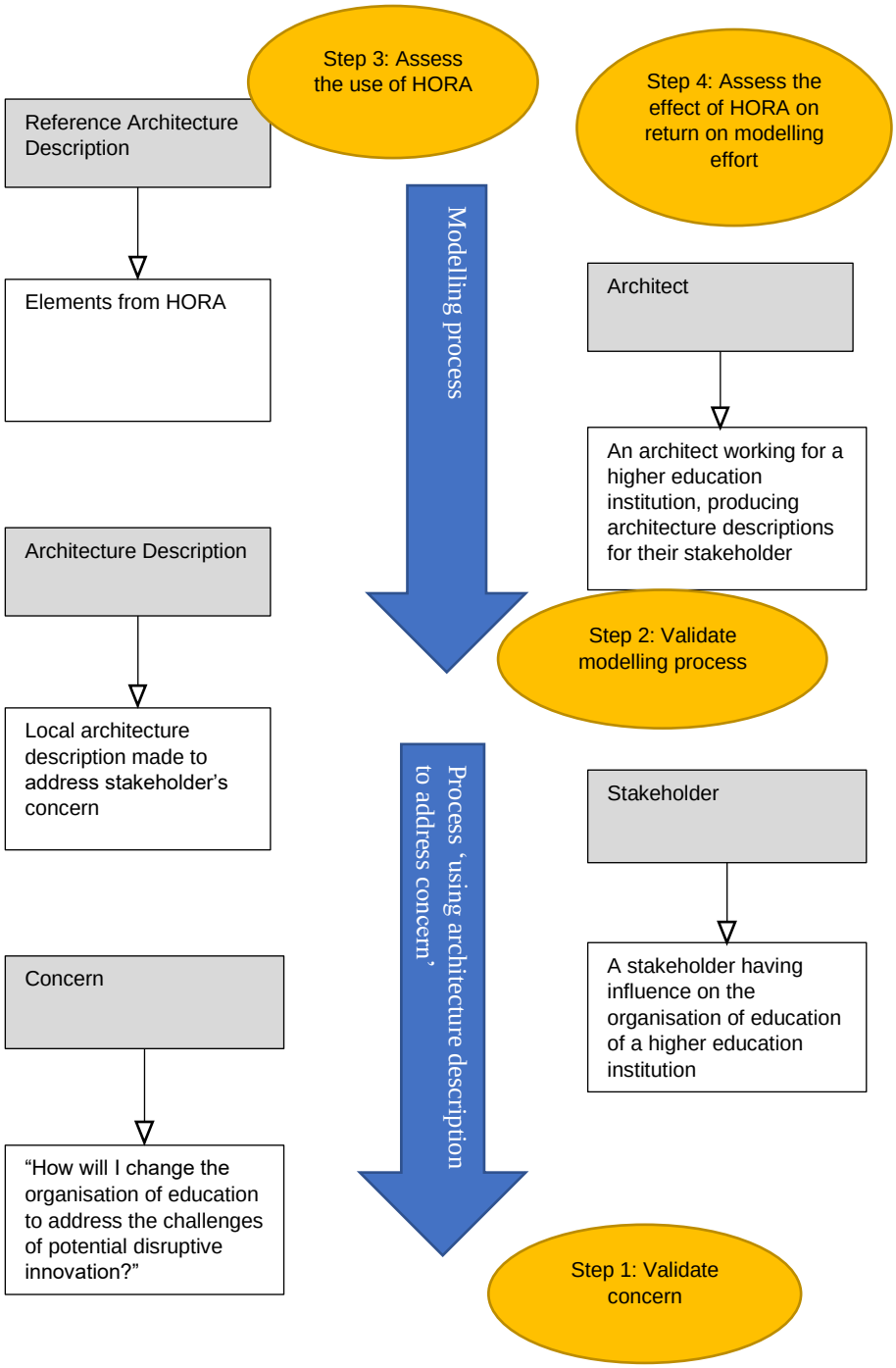
Conclusion on the Assessment Model

The key findings in this stage of the research are:

- When a reference architecture supports the challenges of disruptive innovation, it does this in two steps:
    - Directly by supporting the architect in making the architecture description.
    - Indirectly via the architecture description by supporting the stakeholder in addressing the concern.
- Since it is the architect who is using the reference architecture directly, the next step in this research will look at how those architects evaluate the use of HORA in supporting their work. In doing so, the stakeholders' needs will be seen through the eye of the architects.

Figure 16

The Assessment Model



Note. The Assessment Model shows the two processes (blue arrows) in which HORA can be of use in dealing with the challenges of disruptive innovation. To assess the value of HORA, an assessment process in four steps—going in the other direction—is plotted on the process flow.

Expert Meetings: The Effectiveness of HORA in Addressing Disruptive Innovation

In this chapter the results are presented of the expert meetings. A first trail expert meeting was held on 5 July 2023 where the Assessment Model and the use of Meetingwizard was tested with two participants. On 6 July 2023, an interview was held with an enterprise architect who worked on new models about applied research in higher education, leading to a list of missing elements in HORA. The work on that research model and the effect on HORA can be used as a comparison (page 49). On 12 July 2023, the main expert meeting was held, with eight participants sharing insights based on their working experience as an IT architect in higher education (page 52). On 2 August 2023, an evaluation expert meeting was held with the representatives of SURF working on an update of HORA (page 64). The results of the meetings are summarized at the end of this chapter (page 66).

Results of the Trail Expert Meeting

On 5 July 2023, a trail expert meeting was held to test the set-up of the expert meeting and to get a first response on the Assessment Model. The meeting was done online and was supported by the application Meetingwizard. The set-up of this first meeting can be found in Appendix A. Participating experts were an enterprise architect from Wageningen University & Research (WUR) and a representative from HORA. Promotor Roland Ettema participated as an observer. The meeting was planned for 90 minutes.

Up until step 2, the meeting did not encounter any problems. The introduction of the case was understood by the participants, and the questions in step 1 and 2 could be followed by the participants without extra help or explanation. In step 3, there were more questions from the participants. Multiple statements needed extra clarification: Either the statements could have been formulated better or needed more introduction. But the main problem was that the statements were too generic about quality of the models and the modelling process, instead of being focused on the connection with disruptive innovation. The same problem arose with step 4, where the statements were also too generic.

In the last part of the expert meeting, the participants scored differently on the usability of the Assessment Model (see Table 5). The representative of HORA reacted, “The model provides an insight into how HORA is valued and used, [but] it says nothing about the content of HORA. At its core, which is what it should be about and that is precisely the bottleneck. The content of HORA is not in order.” He scored the usability a 2 on the scale of 10. The enterprise architect of WUR was more positive on the model as a whole, with an average of 6.7, but in the following discussion also indicated that he agreed with the HORA representative that the statements were too generic and did not provide enough input on HORA and disruptive innovation.

Table 5

Evaluation on the Use of the Assessment Model in the Trail Expert Meeting

Statement	Participant WUR	Participant SURF
Thanks to this model I can better assess HORA.	7	2
This model allows me to assess HORA from more perspectives.	6	2

Statement	Participant WUR	Participant SURF
Thanks to this model I can assess HORA more efficiently.	7	2

Note. On a scale 1 to 10, participants were asked whether they agreed with the statements.

An important result of the trail meeting was that step 3 was changed completely. Instead of a list of quality attributes, the list of innovations will be used in step 3. Participants will be asked to score whether HORA can help them make models about those innovations and the scenarios for their institutions. The second amendment is that in step 4, about return on modelling effort, the statements will be specially formulated about models for disruptive innovation. The amendments for the set-up of the meeting can be found in Appendix B.

Additional feedback obtained from this meeting:

- The Assessment Model is introduced around the stakeholder having a concern, and the architect responding to that concern by making an architecture description. But one of the participants pointed out that it is also the job of an architect to be aware of possible concerns that the stakeholder is not yet aware of: "[…] my first reaction is, I don't know if stakeholders in our environment are that sensitive. Is this not a role that has more and more often ended up on the architect's own plate? That he does the environmental scan of what is coming?" Still, the architect does work for a stakeholder that has to take action in response to a concern. So, the model still stands, but it might have a different starting point. The architect could already be making the architecture description before the stakeholder is aware of the concern.
- HORA is a reference architecture for higher education. One of the participants pointed out, "[…] we should not work towards a uniform conceptual model or something like that, but I notice that if you look beyond the sector, and those issues are of course increasingly approaching us, we cannot just look at HORA." So, the challenge is here to make a useful reference architecture for higher education, without losing sight on the sectors higher education is working with. How can one make sure the reference architecture matches with reference architectures from related sectors?
- One participant pointed out that HORA is a good repository, but it lacks more useful views: "[…] when you browse through it, you see just like in a repository […] all kinds of connections between objects. But to say that I have a clear overview, for example, that is difficult. […] I can't get that out of HORA. And certainly, also landscape models or layout models and model a change with them or identify deltas, I cannot do that with HORA." So even if the elements and relations are available in HORA and of high quality (quality attribute K4 "Perceived semantic quality"), the users of HORA might expect more types of models that are appropriate for the concerns they are modelling about (quality attribute K1 "Perceived model–domain appropriateness").
- The current version of HORA focusses on models for processes, business functions, applications, and information. There are no infrastructure models. One of participants said, "Our field is shifting a bit further away from, say, the application-like layers. Much more to business, strategy. And you actually see that HORA, especially in the field of strategy, does not actually add much. And I think it is becoming increasingly important for us, that relationship to the strategy, the influences that come from the outside in order to be able to show them what that ultimately means in your application landscape or in

your process landscape." So, adding more elements on the business and strategy level might make HORA more useful.

- During stap 4 "Assess the effect of HORA on return on modelling effort," the scores were on average 5.9 on a scale of 10. As mentioned above, this is more about HORA in general, due to statements not being specific on disruptive innovation. Participants were asked to provide an explanation when the score was lower that 8. Reasons named for lower scores were:
    - "The fact that HORA is outdated has a negative influence on its effectiveness."
    - "[…] focus is much on the application level and not enough on the strategy or motivation layer."
    - "HORA does not mean much to business stakeholders. For business analysts and architects purely a reference that saves work." And "HORA and ArchiMate do not mean much to business stakeholders. More internal use."

A Case Practice From HORA and Research

On 6 July 2023, an interview was held with enterprise architect René Schenk, who works for the Avans University of Applied Sciences. René Schenk participated in a working group that used HORA to make new models about research at the Dutch universities of applied sciences. In the process, they gathered the things they were missing in HORA to make the new model (like elements, relations between elements, and model types). The information in this section is based on this interview and additional material send by email on 7 July 2023.

Background

The universities of applied sciences work together to facilitate the maintenance of research data produced by applied research conducted by those institutions. This is organised in a Digital Competence Centre (DCC) Applied Research, which is facilitated by SURF (SURF, n.d.-a). Within this DCC is a working group IT. In the first half of 2023, this working group was asked to make an overview of value streams in applied research and to relate that to elements in HORA.

The Process

On 13 June 2023, the working group IT organised a workshop to finalise the architecture product. Three reference architecture descriptions were input for the modelling process:

- HORA, version 2.1
- HOSA Domain Architecture "Research Data Management" (SURF, 2021a)
- National integrated research support model for universities of applied sciences (in Dutch: Landelijk Integraal Onderzoekondersteuningsmodel [LIOM]; SURF, 2020)

Next to those three reference models, examples were collected from universities of applied sciences. According to the participant of the interview, "Well, there we had I think six or seven different value streams send to us and we eventually found the best practices from that."

There was a different number of steps in the value chains from LIOM and HOSA, so one part of the process was to consolidate this. With the use of the three reference architecture descriptions, a specific model could be made to address the questions of the stakeholders. During the meeting, missing elements from HORA were noted, in order to provide them to the people of SURF working on the current revision of HORA. This could be either missing elements that should be part of the repository of already existing types, like the information object "permit," or types of elements that are not yet part of the repository, like "value stream." In some cases, relations between elements were missing. Two representatives of HORA were present in the workshop as well. So, the missing elements could be discussed directly with the people working on the current update of HORA. In what way the elements will be used in HORA will be decided later. One thing that has to be checked is whether the missing elements based on applied research are the same for academic research, since HORA is used by both types of universities that are part of the Dutch higher education system.

A separate product was a meta model. This meta model was based on the HORA meta model, with some elements left out, and the missing elements value chain and value stream added.

The view of the model constructed by the working group was not available in HORA. HORA is more of a repository with models regarding types of elements (for example a process model) and does not provide overview models where different layers of architecture are combined.

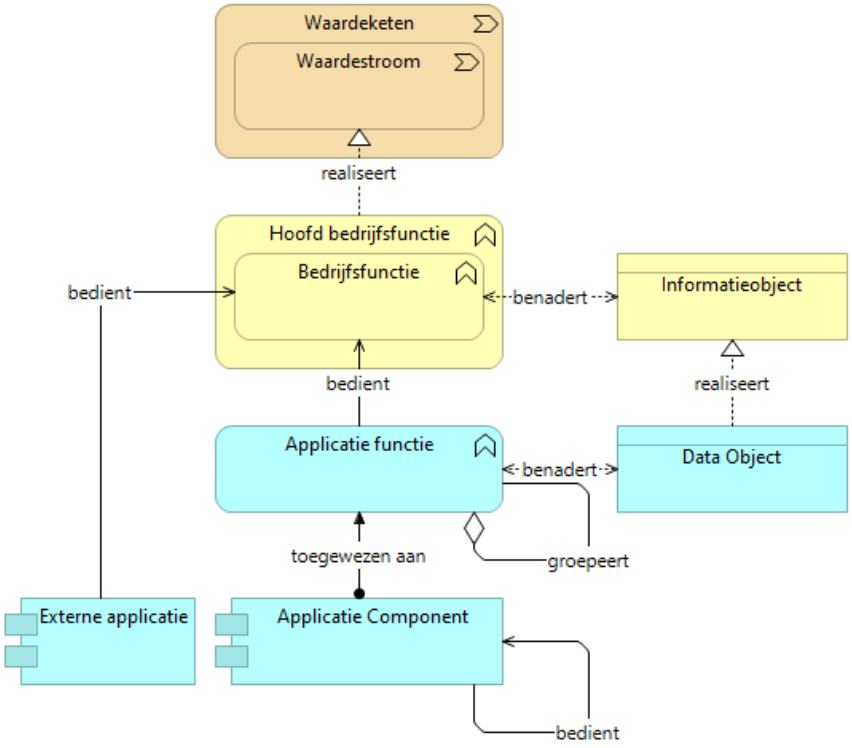
In this model, disruptive innovation was not a direct concern of the stakeholder. According to the participant of the interview, "[…] research is of course quite stable in terms of structure, in terms of doing. Certainly, in comparison with education. [...] Undoubtedly there are innovations and there are also changes, but doing research in phases, I think, is reasonably stable, for now and in the coming years."

Results

There were multiple outcomes from the modelling process. First of all, the main product: a model, containing value chains and value streams, connected to business functions, information objects, and applications. The model is based on a meta model, which is also a product from the working group (see Figure 17).

Figure 17

The Meta Model Provided by the Working Group IT From the DCC Applied Research



Note. This meta model is the results of a workshop on 13 June 2023 organised by the working group IT from the Digital Competence Centre Applied Research. It was provided by one the organisers, enterprise architect René Schenk, by email on 7 July 2023.

Next to the architecture model itself, a list with missing elements in HORA was provided by the working group IT from the Digital Competence Centre Applied Research (see Table 6).

Table 6

Missing Elements Research Domain in HORA, Provided by the Working Group IT

Missing elements
1. Value streams, HORA and HOSA not well aligned:
a. HOSA ‘exploiting knowledge’ realizes 2 value streams
b. HORA main business functions ‘Research Development’ and ‘Research Dissemination’ do not fit well with HOSA and value streams
c. include ‘Strategy and Control’ as a value stream
2. HORA: Business functions without or incomplete application layer:
a. peer review
b. dissemination creation
c. knowledge protection
d. research data management
e. research partnering
f. research protocol review
g. research review

Missing elements
3. HORA: Missing Elements:
a. missing information objects
i. permit
b. application functions without assigning reference components
i. research data collection function
ii. research object acquisition function
c. object approach differences between business and serving application functions
i. PhD student supervision versus PhD monitoring function
ii. data processing and analysis versus VRE functions

Note. These are the results of a workshop on 13 June 2023 organised by the working group IT from the Digital Competence Centre Applied Research. It was provided by one the organisers, enterprise architect René Schenk, by email on 7 July 2023.

Conclusion

The modelling process used by the working group provided an overview of missing elements in HORA. The analyse of whether HORA was adequate enough for addressing the concern of the stakeholder was done during the production of the model. This provided a clear list of missing elements, so the meeting was effective in that way. The focus was not on disruptive innovation, so the missing element are not related to that topic. So, the above-described process is about validating the use of HORA in general. In that way, it does give insight on how that process worked, with can be compared with the process steps of the Assessment Model.

Results of the Main Expert Meeting

The main expert meeting to test the Assessment Model took place on 12 July 2023. The statements in Meetingwizard were changed following the insights from the trail meeting on 5 July 2023. The amendments can be found in Appendix B. Step 3 was completely changed, and step 4 was made more specifically about disruptive innovation. The meeting was planned for 90 minutes, comparable to the trail meeting. The time each step took is measured, to give an indication on the timeframe that would be needed for the different steps of the Assessment Model. That information can be used in the next iteration of the design of the set-up of the expert meeting.

In total eight experts participated, see Table 7. Promotor Roland Ettema and thesis process coordinator Hans Mulder participated as an observer. Two participants currently work for SURF on an assignment to update HORA and were invited from that perspective. But since both worked for a higher education institution as an architect in the recent past, they participated in Meetingwizard from the perspective of that former role and context. Three participants work or have worked for a university of applied sciences, two participants work or have worked for an academic university. Three participants work for a shared service centre that caters both types of universities.

Table 7

Participants of the Expert Meeting

Label	Function	Institution
P1	Information architect	University of Amsterdam & Amsterdam University of Applied Sciences
P2	Producer HORA (also information architect on the domain of education at Tilburg University unit April 2023)	SURF
P3	Producer HORA (also enterprise architect at Windesheim University of Applied Sciences until September 2021)	SURF
P4	Information manager, starting as enterprise architect next September	HAS Green Academy
P5	Enterprise architect	Inholland University of Applied Sciences
P6	Domain architect research	University of Amsterdam & Amsterdam University of Applied Sciences
P7	Enterprise architect	Saxion University of Applied Sciences
P8	Information architect	University of Amsterdam & Amsterdam University of Applied Sciences

Results Step 1: Validating the Concern

After the introduction, the experts were asked to answer the question: "Which stakeholders ask you for advice?" In a brainstorm session, participants could type in as many stakeholders as they wanted. This part took 3 minutes. All 8 participants filled in one or more items, where some participants filled in more stakeholders per entry, while others filled in one stakeholder per entry.

The data was cleaned as followed:

- Entries with more than one stakeholder were copied and changed to one stakeholder per entry.
- Different ways of spelling were corrected to one version (e.g., "project leader" changed to "project leaders").
- "Domain architects," "information architects," and "architect colleagues" are seen as one role "fellow architects."
- "Project manager" and "project leader" are seen as one role "project leader."

As shown in Table 8, the 26 types of stakeholders range from top level (Executive Board) to the level of departments and product teams. Architects and project leaders are named most frequently, followed by information mangers. On the fourth, fifth, and sixth place there are the higher management functions Executive Board, CIO[4], and directors of operations.

[4] In the Dutch higher education system, the CIO is not part of the board.

Table 8

Stakeholders

Stakeholder	Mentioned by # of participants
Fellow architects	5
Project leaders	5
Information managers	4
Executive Board	3
CIO	2
Directors of operations	2
Product owners	2
Academic affairs	1
Business analysts	1
Central IT department	1
Degree programme managers	1
Department managers	1
Directors of the service departments	1
Open Science Directors	1
Domain leads	1
Functional application managers	1
Higher management	1
IT manager	1
Programme managers	1
Research directors	1
Researchers	1
Service managers	1
Support staff	1
Education team leaders	1
Functional application management team leaders	1
University Library	1

The next question was: “Which disruptive innovations are we talking about?” This is also done in a brainstorm, where participants could type in as many concerns as they wanted in Meetingwizard. This time, the participants were asked specifically to enter one innovation per entry, since they will be used at step 3. Also, participants were asked not to type in an innovation if they saw someone else already filled that in. This brainstorm session took 4 minutes.

The result were 30 entries, which then were discussed with the participants. In the discussion, some results were removed because they were about solutions to the innovations, not the innovations themselves. In total, 23 entries remained. This part of the session took 19 minutes because of the amount of discussion per item.

The concerns are listed in Table 9. Note that these are *perceived* stakeholder concerns, since the stakeholders themselves were not in the session. The concerns have been translated to English, the original text can be found in Appendix E. At a later moment after the meeting, during the processing of the data, a column has been added with "Theme." 10 concerns were related to flexible education and the possible logistical challenges that they may bring, like microcredentials or following education at other universities. 5 concerns were related to specific technological innovation, where the impact on the business is not yet clear. 4 concerns were related to research and 2 concerns were related to data. Finally, 1 concern was related to learning, and 1 concern related to how society is changing.

Table 9

Perceived Stakeholder Concerns About Potential Disruptive Innovation, Provided by the Architects

#	Concerns	Theme
1	Flexibility of education	Flexible education
2	Wide use of ChatGPT for educational purposes	Technology
3	Collaboration with researchers outside own institution (Identity & Access Management)	Research
4	Modularization of educational offerings	Flexible education
5	The impact of open science	Research
6	The impact of AI in general	Technology
7	Data Driven	Data
8	Combining regular and commercial students in class groups	Flexible education
9	Multiple starting times for educational modules	Flexible education
10	Registration and review of research plans with recommendations for follow-up	Research
11	Integral "customer view"	Flexible education
12	Just-in-time learning from lifelong learning	Flexible education
13	Further developments in blended learning	Learning
14	Exchange of achieved results (micro-credentials)	Flexible education
15	Research data management: capture and manage data or metadata for archiving, publication, reuse	Research
16	Assessing qualification without following education	Flexible education
17	More cooperation between institutions, and between institutions and sector partners, such as Studielink and DUO	Flexible education
18	Follow education at another educational institution	Flexible education
19	What will quantum computing bring?	Technology
20	Cloud native high-performance computing	Technology
21	Low coding	Technology
22	Data engineering: pipelines for data processing and analysis	Data
23	Faster changing content of the working field	Society

Note. These are the results of the main expert meeting on 12 July 2023. The meeting and the original entries were in Dutch, translation has been done after the meeting. The original input can be found in Appendix E. The column "Theme" is added on a later moment and was not part of the expert meeting.

Results Step 2: Validating the Modelling Process

Step 2 is about the modelling process. Four statements were presented, where via voting the experts could indicate on a scale from 1 till 10 how much they agree. If wanted, participants can add comments at each statement. This took 4 minutes. See Table 10 for the results of the scoring.

About the statement "I write advice for stakeholders regarding potential disruptive innovations," five participants agreed, giving numbers in the range from 7 till 10. Participant P3 gave a 10 and the comment "I think this is an important task of an architect to do this both solicited and unsolicited." Three participants did not agree that much, giving numbers in the ranges from 3 till 5. In total this led to an average of 6.8 with a spread[5] of 46%.

The statement "I make models to support that advice" led to an average of 7.8 with a spread of 36%. Participant P2, who gave a score of 3 on the first statement, agreed strongly he makes models, with a score of 10. Participant P3 gave score of 7 with the comment "I do not think every advice needs a model. But models can often facilitate communication."

The statement "I use HORA as input for these models" led to an average of 7.4. Participant P6 scored low with a 2 and added the comment "[There are] still few good blueprints available that I can use as a starting point or framework." Three participants gave a score of 10, with the comments "HORA, in particular the business function model, is a useful guideline to check whether you are complete in your advice" and "I always use HORA (business function model, information objects, etc.)."

The score of the last statement is ambiguous and therefore indicated by an asterisk. Four participants did abstain in answering, because they already used HORA (scoring on average an 8 on the third statement). One participant scored a 10 on the third statement and a 1 on the fourth. But this participant was not supposed to vote on that statement. It should have been stated more clearly to the participants that the statement was only to be answered when statement 3 had a low score. In the GSS application it was not possible to restrict a statement based on earlier input. Only one participant scored low on statement 3 (a score of 2) and gave an 8 on the last statement. For the next iteration of the model, this statement should be reformulated.

Table 10

Statements on the Modelling Process

Function	Average score	Spread	Abstentions
I write advice for stakeholders regarding potential disruptive innovations.	6.8	46%	0
I make models to support that advice.	7.8	36%	0
I use HORA as input for these models.	7.4	57%	0

[5] Spread is calculated by Meetingwizard, and is based on establishing a % value between 0% (no disagreement) and 100% (the most disagreement possible). The calculation involves calculating the maximum possible standard deviation for a group given the number of participants submitting non-abstaining values for an evaluation method, calculating the actual standard deviation for the step results and dividing the two values.

Function	Average score	Spread	Abstentions
I do not use HORA for these models yet, but I would like to.	5.3*	65%*	4*

Note. On a scale 1 to 10, participants were asked whether they agreed with the statements. The results of the last statement, indicated by the asterisk, are ambiguous. See the explanation above.

Results Step 3: Assess the Use of HORA

The innovations the participants provided in step 1 were input for step 3. On a scale from 1 till 10 participants were asked whether HORA is useful for making models about those disruptive innovations. Participants were asked to look at the available models and see if elements might be missing to describe the reality or a potential future reality (quality attribute K4 “Perceived semantic quality” from CMQF) and if a type of model is missing (quality attribute K1 “Perceived model–domain appropriateness” from CMQF). Participants were asked to give comments about missing elements or models if the participants scored lower than 8. It took the participants 21 minutes to fill in this part. The result of the scoring is shown in Table 11. The complete set of comments can be found in Appendix E (in Dutch).

De average scores range from 2.3 till 6.4 on a scale of 10. Many concerns scoring 5 or higher on the usability of HORA are related to flexibility of education. When clustered by the themes from Table 9 it shows in Table 12 that the scoring is the higher for “Flexible education” (containing 10 concerns), scoring an average of 5.6.

Table 11

Usability of HORA per Perceived Stakeholder Concerns, Sorted by Scoring

#	Concerns	Scoring	Spread	Abstentions
17	More cooperation between institutions, and between institutions and sector partners, such as Studielink and DUO	6.4	43%	3
11	Integral "customer view"	6.0	31%	2
4	Modularization of educational offerings	5.8	34%	2
15	Research data management: capture and manage data or metadata for archiving, publication, reuse	5.8	55%	3
16	Assessing qualification without following education	5.6	36%	3
9	Multiple starting times for educational modules	5.5	37%	2
1	Flexibility of education	5.4	31%	1
18	Follow education at another educational institution	5.4	38%	3
8	Combining regular and commercial students in class groups	5.2	45%	3
12	Just-in-time learning from Lifelong Learning	5.2	43%	3
13	Further developments in blended learning	5.0	27%	4
7	Data Driven	4.8	24%	4
14	Exchange of achieved results (micro-credentials)	4.8	39%	4
21	Low coding	4.3	47%	2
3	Collaboration with researchers outside own institution (Identity & Access Management)	4.0	48%	3
6	The impact of AI in general	3.7	43%	1
10	Registration and review of research plans with recommendations for follow-up	3.3	32%	4
23	Faster changing content of the working field	3.3	32%	4

#	Concerns	Scoring	Spread	Abstentions
2	Wide use of ChatGPT for educational purposes	3.0	42%	3
22	Data engineering: pipelines for data processing and analysis	3.0	31%	4
5	The impact of open science	2.8	32%	4
19	What will quantum computing bring?	2.7	27%	5
20	Cloud native high-performance computing	2.3	28%	4
	Total	4.6		

Note. On a scale 1 to 10, participants were asked whether how well HORA helped with modelling about those innovations. The spread is the score provided by Meetingwizard.

Table 12

Usability of HORA per Perceived Stakeholder Concerns, Grouped by Theme, Sorted by Scoring

Theme	Scoring
Flexible education	5.6
Learning	5.0
Research	4.1
Data	3.9
Technology	3.4
Society	3.3

Note. On a scale 1 to 10, participants were asked whether how well HORA helped with modelling about those innovations. This clustering is made after the meeting, see Table 11 for the original list.

Where participants gave a score lower that 8, participants were asked to enter a comment about what should be added in HORA to make it more useful for making models about disruptive innovation. With 23 innovations and 8 participants, the possible number of scores was 184. In total, 113 scores were given (61%), of which 103 were lower than 8. See Table 13. The number of comments within those 103 scores were 63, so 40 times (39%) a participant scored low but did not provide a comment. 3 comments were given with a score of 8 or higher or with a missing score, making the total of comments 66.

Table 13

Scores Given by the Participants

Score	Times given	Number of comments
1	14	12
2	1	0
3	25	8
4	12	6
5	17	12
6	23	18
7	11	7
8	9	1

Score	Times given	Number of comments
10	1	1
Empty	71	1
Total	184	66

Of those 66 comments, 11 of them were about the question whether HORA should be expected to cover that specific innovation. 8 of those comments were given about 6 technology themed innovations (quantum computing, ChatGPT, cloud native high-performance computing, low coding, AI in general, and data engineering). The other three were given about "Collaboration with researchers outside own institution," "Further developments in blended learning," and "Faster changing content of the working field." Those 9 innovations scored a 3.5 on average on usability. The rest of the innovations, where no participant mentioned this question, scored on average a 5.2.

Of the 55 remaining comments, 15 of them were not specific enough of what was missing. Either the comment was that indeed attention was needed, or the comment indicated what the problems were regarding the subject. This leaves 40 entries about specific items that were missing in HORA. 8 of them were references to an earlier entry about "Flexible education": A number of innovations can be seen of part "Flexible education," so the participants referred to there first entry on that subject.

The missing elements that were mentioned by the participants were extracted from the comments and can be found in Table 14. In the third column, the related quality attribute from CMQF is show. This is added after the meeting.

- K1 is the "Perceived model–domain appropriateness," about whether the type of model is appropriate for modelling about disruptive innovation in higher education. This quality attribute applies if a type of model is missing, or a specific layer.
- K4 is the "Perceived semantic quality." The semantic quality is about the accurate representation of reality in the HORA models, when using it to make models on disruptive innovation. This is both about the existing reality of higher education in the Netherlands and the possible scenarios for adjustments to that reality in the near future. This quality attribute applies if elements are missing, or element descriptions do not represent reality sufficiently.
- K7 is the "Perceived empirical quality," which is about the readability of the conceptual representation itself. This quality attribute applies if the participants of the meeting mentioned that improving the readability would be needed.
- An asterisk is added, when the comment is not about a quality attribute of CMQF but related to the use of the reference architecture.
- A double asterisk is added, when the comment is not about the models, but the architecture principles in HORA.
- A hyphen is added when the comment is a reference to another comment, or when no comment about missing elements was given.

Table 14

Missing Elements in HORA, According to the Participants

Concern	Missing elements	CMQF
1. Flexibility of education	Adjustment of definition of information objects, such as exam programme; adjust processes; make the views visually more attractive (see MORA)	K4, K7
	Different wording	K4
	Capability layer	K1
	Elements to describe 'modular' and 'learning outcomes' based education	K4
	Customer perspective; aspects of demand-driven education; definitions of programme, module, learning and assessment activity too limited; N-to-N relationships between study programme, module, learning and assessment activity	K4
	Less freedom for institutions to deviate; follow mandatory guidelines	*
	Demand response; customer journey; application services; integration interfaces and standards; make explicit why certain choices have been made; cooperation between institutions; relationship between process and data; update of the business objects; difference between student and professional is shrinking (lifelong learning)	K1, K4
2. Wide use of ChatGPT for educational purposes	Principles about using AI	**
3. Collaboration with researchers outside own institution (Identity & Access Management)	Elements of research business process for different forms of collaboration in the preparatory phase, executive phase and final phase; functionality required for this; technology that can fulfil this	K4
	More depth in the business and application functions outside education and research	K4
	Collaboration with other institutions; more elaboration of IAM; EDU-ID	K4
4. Modularization of educational offerings	Adapt business processes more to modularization	K4
	Less freedom for institutions to deviate	*
	See ‘Flexibility of education'	-
5. The impact of open science	Elements about Open Science	K4
	FAIR principles	**
6. The impact of AI in general	More support at application layer and data layer modelling in relation to impact AI	K4
7. Data Driven	More layering in information objects (like ‘participant’)	K4
	Extension of information objects	K4
8. Combining regular and commercial students in class groups	Distinction between regular and commercial students	K4
	Further breakdown of the SIS applications objects	K4
9. Multiple starting times for educational modules	See ‘Flexibility of education'	-

Concern	Missing elements	CMQF
10. Registration and review of research plans with recommendations for follow-up	Preparatory phase research (registration and assessment - data management plans and impact on functionality and technology to be used, taking into account RDM policy and frameworks)	K4
11. Integral "customer view"	'Integral customer view' in the principles	**
	Customer perspective	K1
	More holistic approach, linking application to data and interfaces	K4
12. Just-in-time learning from Lifelong Learning	See 'Flexibility of education'	-
13. Further developments in blended learning	-	-
14. Exchange of achieved results (micro-credentials)	-	-
15. Research data management: capture and manage data or metadata for archiving, publication, reuse	Models on data management of the research cycle	K1
16. Assessing qualification without following education	Business object 'learning outcomes.' See also Flexibility of education'	K4
	Disconnect assessment from education	K4
17. More cooperation between institutions, and between institutions and sector partners, such as Studielink and DUO	(Open) standards for data exchange	K4
	More focus on exchange services	K4
18. Follow education at another educational institution	See 'Flexibility of education'	-
19. What will quantum computing bring?	-	-
20. Cloud native high-performance computing	Technology layer	K1
	Elaborations regarding working environments for data processing and analysis that meet RDM frameworks and privacy and security requirements in which collaboration is possible and computing power and storage capacity can be added in a flexible manner	K4
21. Low coding	Technology layer	K1
22. Data engineering: pipelines for data processing and analysis	-	
23. Faster changing content of the working field	See 'Flexibility of education'	-

Results Step 4: Assess the Effect of HORA on Return on Modelling Effort

In step 4, the participants were asked to reflect how effective HORA helped them in making models about disruptive innovation. In line with the Assessment Model, the statements were about the direct effect on making the models, on the value created during the modelling process, and the value it has for the stakeholder. The last two statements were

about the sustainable of the model. See Table 15 for the scoring. There were no abstained answers. Filling in the information costed 6 minutes.

Table 15

Effectiveness of HORA According to the Participants of the Expert Meeting

Statements	Scoring	Spread
Thanks to HORA, my models about disruptive innovation have more effect.	6.0	41%
Thanks to HORA I spend less time making models about disruptive innovation.	6.1	32%
Thanks to HORA I get more value from the above modelling process.	7.1	30%
Thanks to HORA, the model I made about disruptive innovation has more value for the stakeholder.	6.1	43%
Thanks to HORA, the model I made about disruptive innovation remains relevant for longer.	6.1	32%
Thanks to HORA, the model I made about disruptive innovation remains up to date for longer.	4.9	41%

Note. On a scale 1 to 10, participants were asked whether they agreed with the statements.

Participants were asked to give comments about missing elements or models if they scored lower than 8. In total, 26 comments were made, which is 62% of the total 42 possible entries. 31 entered scores ware lower than an 8, of those entries 24 comments (77%) were filled in.

Most of the participants indicated that the models about disruptive innovation have more effect thanks to HORA, with 6 of them scoring this statement 6, 7, or 8. Participant P3 mentioned this was “because HORA is probably seen as a reliable foundation.” Participant P1 gave a 5 and mentioned that “An elaboration of relevant disruptive innovations in HOSA seems to me to have more value than in HORA.” Participant P6 scored a 2, mentioning, “I make little use of HORA for these innovations because it still offers insufficient support.”

Most of the participants gave the same or a higher score for the statement about the effect on the time making a model. Participant P7 mentioned, “The first drafts are faster,” and participant P6 mentioned, “I can copy basic things, so that speeds up modelling.” Only participant P5 scored lower (a 4 instead of 7), because there is not enough yet in HORA about cross-institutional processes.

“Value from the above modelling process” scored highest, with an average of 7.1. 5 participants scored an 8, the other 2 scored a 5. Participant P6, one of the latter, mentioned, “[It] helps not to forget important things, but for now HORA is less useful for elaboration.”

The statement about stakeholder value scored a 6.1, with the highest spread of 43%. Participant P5, who scored this statement a 7, mentioned, “It does provide added value to name it, not directly on the modelling itself.” Participant P8, also scoring a 7, mentioned that “this depends on the stakeholder's familiarity with HORA.”

The two statements on the sustainable of the models got two different outcomes. While the statement about how long the models remain relevant thanks to HORA received an average score of 6.1 the statement about the models remaining up to date for longer received

a 4.9. The participant gave this lower score because of the changing nature of innovation. Participant P2 stated, “This depends on external factors and the extent to which HORA is up to date,” and participant P6 stated, “That has much more to do with the life cycle management of your models, HORA will not take that off your hands.” And as participant P8 stated, “It does depend on the speed with which the disruption recedes into the background. HORA does not help with that.”

Results of the Reflection on the Assessment Model

Participants were asked to reflect on the Assessment Model and how it was used in the expert meeting. The reflection was base only on this session, the participant did not receive or use the Assessment Model beforehand. Filling in the information took 4 minutes. The reflection was guided by three statements, the scoring can be seen in Table 16. In Table 17 all the comments are listed.

Table 16

Reflection on the Assessment Model by the Participants of the Expert Meeting (Scoring)

Concerns	Scoring	Spread
Thanks to this model I can assess HORA in a better way.	6.4	31%
This model allows me to assess HORA from more perspectives.	7.0	23%
Thanks to this model I can assess HORA more efficiently.	6.6	37%

Note. On a scale 1 to 10, participants were asked whether they agreed with the statements.

Table 17

Reflection on the Assessment Model by the Participants of the Expert Meeting (Comments)

Concerns	Comments
Thanks to this model I can assess HORA in a better way.	I think it applies not only to disruption, but to all kinds of issues.
	I cannot judge this properly at the moment, so I would have to get started with it myself in practice. Hence 3 x 6 score.
	Requires more depth, from this point of view I have not looked enough at HORA and this meeting helps with this but requires follow-up.
	Structured viewing always helps. Due to the different types of disruptions, it is difficult to look at it unambiguously.
	The applicability of HORA at business function level has become more transparent for me through the model.
This model allows me to assess HORA from more perspectives.	Yes, this perspective will more strongly be considered in the future.
	You do focus better because of the question of where the different models of HORA are useful.
Thanks to this model I can assess HORA more efficiently.	It might be good for [us as producers of HORA] to do this once in a while, for example after an update.
	I hope so! This of course depends on the clearness of the feedback.
	Yes, I can now see more quickly from this perspective (through awareness) whether HORA can help me with this.
	You do focus better from the question of how HORA is useful.

Concerns	Comments
	It is not so much more efficient, but it does help to mention it earlier.

As part of the feedback during the meeting, participant P3 suggested that in applying the model in a session like this, it might by useful to give the participants a limit in naming potential disruptive innovation, because of the duration of step 3.

Results of the Evaluation Expert Meeting With HORA Representatives

The results of the main expert meeting were presented to HORA representatives on 2 August 2023. In preparation of the meeting on 2 August, the representatives received a file beforehand with some of the results: a list with the 26 stakeholders, a list with the 23 disruptive innovations, the feedback on the missing elements per disruptive innovation, and the feedback on the return on modelling effort. Three representatives were present at the meeting. One of them participated in the trail expert meeting, two of them participated in the main expert meeting.

Next to the received feedback, additional information about the scoring was presented to the representatives during the expert meeting. After the presentation of each step, they were asked to react via Meetingwizard on statements about whether they thought that step was useful in improving HORA. The results are presented in Table 18.

Table 18

Reflection on the Usefulness of Each Step in the Assessment Model by the HORA Representatives

Statement	Scoring step 1	Scoring step 2	Scoring step 3	Scoring step 4
This step provided useful information about HORA.	6.3	7.3	8.3	7.0
This step provided useful information about HORA and disruptive innovation.	6.0	6.3	6.7	7.3
The information obtained from this step will help to improve HORA.	8.3	7.3	8.7	6.7
With the information obtained, HORA will become more useful in disruptive innovation.	7.0	6.3	7.7	7.0

Note. On a scale 1 to 10, the HORA representatives were asked whether they agreed with the statements.

With each statement, the representatives could also add comments. 22 comments were provided in Meetingwizard. They can be found in Appendix F. In the discussion that followed, the points in the next subsections were of interest for the research questions.

Focus of HORA on Future Development

There was a discussion about the focus of HORA regarding the time horizon. Should HORA only contain elements and models that represent things that are already existing in the current world, or should it also contain elements and models about the near future? One of the representatives mentioned, “[...] you actually see a kind of need that HORA is not just

about the here and now, because if you were to describe the current situation, you would get all those innovations that are simply not in there. [...] And I notice that it is almost necessary from a HORA perspective to always actually be a little ahead of where the institution itself is." Part of the discussion was about whether the current elements would be sufficient to model for the future: If an architect wants to see the effect of an innovation on the institution, the architect can use HORA to describe the current world where the innovation has an effect on, and combine that with its own added elements regarding the innovation. The conclusion was that this was not the case: Elements representing future developments do have value in HORA, according to the representatives.

The representatives saw a role of HORA in describing innovations and the possible effects in the near future. One of the reasons given by the representatives was the need of collaboration between institutions. One of the representatives said, "There should be more cooperation between institutions with other parties and that means that I think the role of HORA will also change in that it must support the standardization that is required for this." Another representative stated, "I think that ultimately, we will not be able to adequately answer the question that comes from the sector or from the institution. Because I would very much like to know from an institutional perspective, what flexibilisation will look like for me in the future, and if I then only base it on the steps that have currently been taken, then I think I will get different outcomes, different models." Even then, the challenge is still if there is enough knowledge to model about the future scenarios. One of the representatives mentioned, "[…] it is impossible for us to come up with everything ourselves [...]. You don't have that knowledge at all, so you cannot get ahead of it, but you can keep up with it."

Overall, the representatives indicated that thanks to the expert meetings, they gained more insight on the use of HORA in relation to disruptive innovation. One of the representatives commented, "In my opinion, the figures also show that the improvements of HORA seem especially necessary on disruptive topics." Another commented, "[…] it is important that HORA should include innovation in its further development."

The Usefulness of the Output of Missing Elements

In step 3, the participants from the main expert meeting were asked to indicate what needed to be changed in HORA to make it more useful to model about the innovations named in step 1. According to the HORA representatives, this step scored high on the statements "This step provided useful information about HORA" (8.3) and "The information obtained from this step will help to improve HORA" (8.7). It scored lower on the statements "This step provided useful information about HORA and disruptive innovation" (6.7) and "With the information obtained, HORA will become more useful in disruptive innovation" (7.7). On average, the specific statements on disruptive innovation scored 0.7 points lower. Reasons giving by the representatives indicated that specifically on disruptive innovation, the feedback was not always detailed enough. One of the representatives added as comment, "Limited, the information is too summarily for that." Another comment that was made was: "Gives a general picture rather than specifically about disruptive innovation." Other comments were more positive: "Gives a good idea of where HORA needs improvement" and "The responses from the participants contained a number of valuable contributions that we (the HORA developers) had not yet considered."

Brainstorm on the Application of the Assessment Model

The final part of the meeting with the HORA representatives was a brainstorm about the application of the Assessment Model during the main expert meeting. 7 comments were provided, see Table 19 below. A few comments mentioned a follow-up session and how the results from the main expert meeting would tie into that. According to one representative, a follow-up session could be used to look for a trend over time, but there was also a question on what to do when part of the output of a follow-up session is the same. Other suggestions were about the setting of the meeting itself, on how the statements might be made more concrete, so that more substantial results can be obtained, or whether the 10-point scale was the most appropriate. Finally, one of the representatives mentioned that up till now the stakeholders themselves were not involved.

Table 19

Result of the Brainstorm on the Application of the Assessment Model

Statement
Add questions that provide a more concrete answer. For example, which information objects are missing.
In follow-up session you might also want to take results from a previous session and consider a trend over time.
Many thematic elements now seem to have been mentioned that are missing from HORA, but it is not yet clear how these themes should be reflected in HORA in order to actually be useful for the stakeholders mentioned.
Perhaps you could send the questions in advance and then use the session to discuss the results. Then the result might be more correct and/or complete and the session more efficient.
Involve the mentioned stakeholders. It seems that HORA is not only intended for architects (that is what the architects themselves say (and I think so too)), but not all the stakeholders mentioned are involved. As a result, there is still no insight into how HORA in its implementation is sufficiently or really in line with the stakeholders.
I would change the scores from 1-10 to 1-5 and/or strongly agree-strongly disagree where appropriate. Scale 1-10 suggests a precision that cannot always be there.
The question for me is, what if you repeat this approach regularly, for example annually. How do you ensure that you do not get all kinds of duplications in results compared to last time, or are those duplications interesting? In other words, how useful is the method of applying it repeatedly?

Note. This feedback was provided by the three HORA representatives. The original statements were in Dutch.

The output of the main expert meeting provided useful insights on missing elements in HORA that can help to improve the next version (both for HORA in general and for using it to address disruptive innovation). Next to that, the representatives gained new insights on how to use HORA as a reference architecture in the context of disruptive innovation. At the end of the meeting, the representatives concluded that they were interested to organise follow-up meetings using the Assessment Model, so that trends in innovations can be examined on the effect on HORA.

Summary

The main expert meeting of 12 July 2023 was productive in delivering information about HORA itself and about the use of the Assessment Model. The output of the meeting

gave the HORA representatives a new perspective on HORA as a means in dealing with disruptive innovation. Thanks to the trail expert meeting, the main expert meeting was more effective in focussing on the missing elements for modelling about potential disruptive innovation. The interview about the case practice from research from the working group IT from the DCC Applied Research gave insight in a process with a comparable type of outcome (see Figure 17 and Table 6 on page 51).

In the main expert meeting, 8 architects worked with the Assessment Model, helped by the application Meetingwizard. In step 1, 26 types of stakeholders were identified (see Table 8 on page 54). A list of 23 innovations were identified where stakeholders are having (of might be having) concerns about the potential disruption that can be caused by them (see Table 9 on page 55). 5 of them were technological, the rest were about changes in the market and the way of working. 10 concerns were related to flexibility of education. In step 2 it was validated that the participants did make models regarding potential disruptive innovations and did use HORA in this process.

In step 3, the usability of HORA was assessed using the list of innovations from step 1. On average, the usability scored a 4.6 on a scale of 10 (see Table 11 on page 57). But, as some participants pointed out, in some cases HORA is not meant to support models for those specific innovations. 6 of the 9 innovations with a comment about the intended purpose of HORA were about technology, like low coding or quantum computing. When those 9 innovations are not taken into account, the average score on usability would be a 5.2. The 10 concerns about flexible education scored a 5.6 on average.

Via comments the participants were asked to indicate what elements were missing. This led to the summary of missing elements in Table 14 (see page 60). All the input from this step can be found in Appendix E, in the original Dutch language. The elements were shared with the producers of HORA, who are currently working on an update of the reference architecture. The comments were mainly about “Perceived semantic quality” (K4 in CMQF), followed by “Perceived model–domain appropriateness” (K1 in CMQF). So, the participants mainly named elements and relations that were missing to describe models about disruptive innovation, next to naming types of models that were missing, or missing layers in them. One time a comment was about K7, the “Perceived empirical quality,” related to readability of the models. Main points from the feedback:

- Elements and relations were missing to describe the different innovations in flexible education. Some are specifically named by the participants (CMQF quality attribute K4).
- Some layers in the metamodels were missing: customer journey, capability layer, and technology layer (CMQF quality attribute K1).
- Some indicated that HORA and other standards should be more mandatory in use (not a CMQF quality attribute).
- Making layers or hierarchy in information objects would make HORA more useful, as well as more relations between information objects and processes (CMQF quality attribute K4).
- Specific research processes about the preparation phase of research and the collaboration processes were missing (CMQF quality attribute K4).

In step 4, the effect of HORA on return on modelling effort was assessed, specifically for modelling about disruptive innovation. The fist five indicators were scored around 6, with 1 scoring a 7.1 (see Table 15 on page 62). Participants indicated that a reason for scoring lower that an 8 was that HORA is at this moment not up to date. But overall, the participants were positive about HORA as a means for making models. 1 statement scored lower, with a 4.9, about HORA helping to keep models on disruptive innovation up to date for a longer period of time. Participants indicated that this was mostly a result of external factors, mainly how quickly innovations develop or disappear.

At the end of the main expert meeting, the participants were asked to score the usefulness of the Assessment Model itself, on the basis of three statements (see Table 16 on page 63). All three statements score between 6.4 and 7.0. The higher score concerned the way the model allowed to view HORA from a different perspective. The participants appreciated the view via the innovation lens, one of the participants specifically mentioned that this changed his way of looking at HORA. The producers of HORA, who were also present at the main expert meeting, were proposing to use the Assessment Model once in a while to keep HORA up to date. But some participants also pointed out that using it once during the main expert meeting did not yet give enough insight in the Assessment Model's usability. Also, a participant mentioned because of the different types of disruptions it was "difficult to look at it unambiguously."

When comparing the results from the main expert meeting in Table 14 (page 60) with the results from the modelling process from the working group IT from the DCC Applied Research in Table 6 (page 51), the results of the latter are more concrete and succinct. One possible explanation for that can be that the main expert meeting was an open brainstorm session, and the working group IT was making a specific model where there could be precisely indicated wat was missing during the modelling process.

On 2 August 2023, the results were presented to the HORA representatives. Overall, they found all the steps useful: Statements of the usefulness of the different steps were on average scored between 6.3 and 8.7 (see Table 18 on page 64). The scores were on average 0.7 points higher when asked for the usefulness of HORA in general compared to the use in the context of disruptive innovation. In a brainstorm session, a number of suggestions were given to improve the application of the Assessment Model (see Table 19 on page 66). The representatives indicated that they gained new insights on how HORA might be helpful at disruptive innovation and were interested in follow-up sessions using the Assessment Model, so that trends in innovations can be examined on the effect on HORA.

Wrap-up: HORA Addressing Disruptive Innovation

In this final chapter, the results of the assessment of HORA are presented, as well as the results of the design process of the Assessment Model. This research started by stating that there are innovations that may affect higher education institutions. The discussion on how disruptive those innovations will be in higher education is still open. But since there are stakeholders who have concerns regarding potential disruptive innovations, architects can try to help them in addressing those concerns. The first research question looked at how HORA can help the architects in this context. To support this research question, an Assessment Model was constructed. The Assessment Model was made via Design Science, going through multiple cycles (see Figure 1 on page 10).

The first research question will be answered below by assessing HORA on its usefulness in addressing disruptive innovation and by proposing changes to improve that. The second research question will be answered by evaluating the use of the Assessment Model during the expert meetings and proposing options for further development of the model (page 73).

After the research questions are answered, I will reflect on the implication of this research for the use of reference architecture in the context of disruptive innovation (page 76), which will be summarized in the conclusion (page 78).

Research Question 1: HORA and Disruptive Innovation

The first research question was: “How can HORA support the challenges of disruptive innovation in higher education in the Netherlands?” To answer this question, 4 subquestions where formulated. Below, each subquestion will be addressed, after which the main question will be answered.

Subquestion 1.1: Disruptive Innovation in Dutch Higher Education

Innovation can lead to people and organisations doing things better or do new things. When it forces companies to do things different on a strategic level, because otherwise they might be forced out of the market, this is called disruptive innovation (Christensen, 1997). The first subquestion was: “What is the effect of disruptive innovation on the Dutch higher education?” The research for answering the question is presented in chapter “The Effect of Disruptive Innovation on Higher Education in the Netherlands” (page 14). The literary research showed that there is a discussion whether the dynamics Christensen described can happen in higher education, where there is still a high threshold for entering the market (Tierney & Langford, 2016).

From the main expert meeting, a series of potential disruptive innovations were gathered (see Table 9 on page 55). Most innovations were related to flexible education. The innovations were not always sharply defined whether it was an innovation that could be disruptive. For example, the concept microcredentials was named, but this will probable be not something that leads to a disruption in the way presented by Christensen (1997). It is a technology that is being developed in the existing sector, with existing higher education institutions. On the other hand, the development of microcredentials is part of a wider movement, like other innovations that were mentioned by the participants: “modularization of

educational offerings," "just-in-time learning from lifelong learning," and "assessing qualification without following education." If smaller educational offerings can be provided more easily, than this might lower the threshold for newcomers. In that case, damping effects mentioned in this research might be smaller. When the damping effects are smaller, the potential disruption might be stronger. In that case, some technologies mentioned in the main expert meeting, like "wide use of ChatGPT for educational purposes" and "the impact of AI in general," could have a stronger disruptive impact.

In the end this question cannot be answered definitively. The literary research did show different possible scenarios. The research also showed that the ex-post research that has been done up until now, cannot be used to make predications ex ante. In other words: We cannot predict whether an innovation will be disruptive or not for the higher education in the Netherlands.

Nevertheless, research did show how disruption might work. This can be taken into account when an architect is making an architecture description for a stakeholder with concerns about potential disruptive innovation.

Subquestion 1.2: The Intended Use of HORA

The second subquestion was: "What is the intended use of HORA?" This question was researched via an interview with a representative of HORA, via discussions in the final expert meeting with three representatives of HORA, and was based on information on the HORA website and in the starting assignment for the update of HORA.

First and foremost, the intended use of HORA is for it to be used by architects working in higher education to make local architecture products. The reference models in HORA are supposed to be used as a starting point for making local models. In this way, it is a reference architecture according to the definition in this research: an architecture which is intended by its producer to be used in supporting the construction of another architecture.

This is a broad description of its use and this does not indicate what kind of architectures can or should be made. At this moment, a set of 8 types of models is available (see Table 2 on page 25), limiting its potential use for other types of models. For example, there is no complete technology layer: The only technology model is about application platforms. As the expert meeting showed, other types of models are missing as well, like the user journey (see Table 14 on page 60).

The representative of HORA that was interviewed mentioned in that interview that HORA is also used as a representation of how higher education institutions work. This is for example used by sector partners. Formally, HORA was never assessed whether it accurately presents the way all higher education institutions work, but there is enough trust in HORA for those users to give it the affordance of being a model of reality.

The time horizon was also discussed. When HORA was first published in 2013, it was supposed to be a generalised representation of how higher education institutions organised their business and their IT landscape. It provided a common ground based on the input of representatives of those institutions. The focus was on the generalised existing architecture, so upcoming innovations and their potential effects were not in scope. Also, the process of gathering information about the different existing architectures and combining them to a

generalised version takes time. Because of this process, the latest developments in the higher education architecture are not taken into account.

In the assignment for HORA 3.0, the proposed use of HORA is still as a reference to be used by architects in the higher education institutions. The assignment focusses on updates for existing situations like what is already published in the HOSA products and to connect HORA with existing trends on security, public values, and FAIR principles. But in the topics named in the assignment, there is a clear need for making HORA more relevant for recent discussions, including monitoring the impact of new technologies.

The conclusion is that HORA is a reference architecture, supposed to be used as a reference by architects to make local architectures. In the latest assignment HORA is expected te be more up to date and more focussed on new developments. But for now the assignment is focused on getting HORA up to date to the current situation.

Subquestion 1.3: Usefulness of HORA for Addressing Disruptive Innovation

The third subquestion was: "How useful is HORA to address the challenges of disruptive innovation?" This was assessed during the expert meetings with architects working in higher education that have been using HORA. The participants were asked to score the usefulness of HORA based on their stakeholders' concerns regarding disruptive innovation.

The assessment of the participants of the usefulness is presented per potential disruptive innovation in Table 11 (page 57) and per theme in Table 12 (page 58). On average, the score was 4.6 on the scale of 10. There was a difference in score between themes. "Flexible education" scored 5.6, and "Technology" 3.4. When looking at the different quality attributes from CMQF, the reason the participants gave for the low scoring where mostly about K4 "Perceived semantic quality." This quality attribute applies if elements are missing or element descriptions do not represent reality. Another quality attribute was K1 "Perceived model–domain appropriateness." This quality attribute applies if a type of model is missing, or a specific layer in a model.

There were some positive scores as well, where the experts indicated that they could use HORA to see how a new innovation would fit in their architecture. It that case, the reference architecture is used to model the current situation, where the innovation has an effect on. As long as HORA is up to date, for this method of working HORA is perceived as useful.

The experts were also asked to give their ideas on the return on modelling effort. Because HORA is seen as a reliable foundation, models about disruptive innovation do have more effect. The participants also scored it 6.1 on the scale of 10, whether the models about disruptive innovation would stay relevant for longer. But they did not expect it to be longer up to date, because of the fast-moving nature of innovation.

Based on the interview with the HORA representative, the assignment for the new HORA, and the input of the experts during the expert meetings, the usefulness of the current version of HORA appears to be low.

Subquestion 1.4: Improving HORA for Addressing Disruptive Innovation

The final subquestion was: "How can HORA be enhanced to make it more effective in addressing the challenges of disruptive innovation?" The main expert meeting provided a list of comments on missing elements during the voting (See Appendix E for the complete list of the original texts in Dutch). A summary of those results, only naming the missing elements, is provided in English in Table 14 (page 60). Those findings were presented to the HORA representatives during the evaluation expert meeting on 2 August 2023. Their response to these findings can be found in subsection "The Usefulness of the Output of Missing Elements" (page 65). A part of the input was a confirmation of what was already known. The elements can be related to known issues with the current version, as was told by the representative of HORA in the interview, and to the desired function of HORA according to the assignment. Although feedback was given that the information was not specific enough, one of the representatives also stated that it contained a number of valuable contributions that they had not yet considered. On average, the results were seen as useful by the HORA representatives, scoring on different statements between 6.7 and 8.7 on a scale of 10.

For some of the participants of the meetings, it was an eye-opener to look at HORA from the point of view from disruptive innovation. Using the Assessment Model in the meetings gave them a new perspective on the possible use of HORA. The conclusion of the meetings was that the reference architecture should have an expanded use and therefore an extended time horizon.

This poses a challenge: Where originally HORA was made by generalising the existing architectures, now scenarios must be included about potential new elements in the architecture. These can be new applications, new processes, or new information objects, but the common denominator is that it is not clear yet whether those new elements will be part of the architecture of higher education institutions in the future. Or whether the definition or other metadata will be "predicted" correctly. Also, there might be scenarios, were there are possible variations in the options. On a later moment, those new elements have to be assessed on their "truthfulness."

Conclusion on Research Question 1

At this moment, HORA is considered to be not very useful for addressing the concerns about disruptive innovation. For one part, this can be improved by making HORA up to date, to include the latest developments. The other part involves adding new types of models. Participants from the main expert meeting mentioned a capability layer, costumer journey, and the technology layer. Regarding some aspects the participants wanted to see extra principles, on AI, "integral customer view," and FAIR. A summary of both the missing elements and the missing model types can be found in Table 14 (page 60).

Adding the new elements will be a temporarily solution, especially for the perceived semantic quality issues. HORA should be updated more frequently to keep up with the changing world and to keep HORA relevant for the architects and their stakeholders. The same applies to the new model kinds: The moment that they are published, they are at risk of being out of date by new developments.

The proposition that a reference architecture will be of better use when it is kept up to date is of course no surprise. So, for HORA to be especially relevant for potential disruptive innovation, the way HORA is looked upon should be changed. Its core should still be that it is a representation of the real world, of how higher education institutions organise education and their IT landscape. This is needed so HORA remains the trusted source for a common ground. But to help architects make models about the impact of potential disruptive innovation, HORA should contain elements about those new innovations as well. Even if they are not yet part of the current generalised entity of interest. How this can be applied and managed, will be reflected on in subsection “Reflection” (page 76).

Research Question 2: The Assessment Model

For supporting the first research question, an Assessment Model has been made (see Figure 16 on page 46). This model was based on a ISO/IEC/IEEE 42010:2022 frame of reference (see Figure 7 on page 29 and Figure 8 on page 31) and various quality frameworks. Part of the insights gained from those frameworks are not in the visual representation of the model but have been used in preparing the statements for the expert meetings (see appendices A and B), for discussing the Assessment Model with the experts, and in analysing the results.

Below, the application of the Assessment Model during the expert meetings is discussed. This is based on the feedback from the experts during the expert meetings, the scoring by the HORA representatives during the evaluation expert meeting op 2 August 2023 (see Table 18 on page 64), and on the analysis of the results.

Step 1: Validating the Concern

The goal of step 1 is to validate the concern. Participants of the expert meetings were asked in a brainstorm to reflect which stakeholder had concerns about potential disruptive innovations and what those innovations were. Judging on the expert meetings, this was a good way to start the session. It sparked the conversation about potential disruptive innovations and there was a discussion about whether the items collected could be disruptive or not, or even were to be seen as innovations at all.

There might have been a more coherent list of innovations that matches more with the definition of potential disruptive innovation, when in this step criteria were used about what kind of innovations should be on the list. This can be added in the next cycle of the design process of the Assessment Model. Another possible improvement would be to switch the questions about the stakeholders and the innovations. Then, for every innovation, the participant can be asked to indicate which stakeholder has that concern. In this way, extra information is gained on the relation between the concerns and the stakeholders. This also ensures that the participants only name stakeholders with those specific concerns and not just all their stakeholders.

Even so, the step provided useful information according to the HORA representatives. Not only about the innovations themselves, but also about the wide range of stakeholders that architects are making architecture descriptions for.

Step 2: Validating the Modelling Process

The goal of this step was to validate whether the architects were indeed making models and were using HORA for that. If not, an assessment of HORA would be useless in this setting, since in the next step, architects were supposed to have had experience with HORA.

The HORA representatives found this step useful, to get an indication about how often HORA is used. They saw the scoring, which they deemed as too low, as an incentive to make HORA better and to ensure more architects will use HORA to make architecture descriptions.

Although this step does not say much about how HORA can be used or how it can be improved, it does provide information about the proliferation of the use of HORA. So, this step is useful not only as preparation for step 3, but also for the assessment of the use of HORA by itself.

Step 3: Assess the Use of HORA

Step 3 is the main step of the model, where participants are asked to score the usefulness of HORA in addressing the concerns of disruptive innovation. If they score it lower than an 8 of the scale of 10, they are asked to indicate what should be added to HORA to make it more useful.

This step had been revised drastically in the relevance cycle after the trial expert meeting, see Appendix B. In the first iteration, the quality attributes of CMQF were used for making the statements. During the trail expert meeting, it was discovered that applying those quality attributes needed much more understanding of CMQF. Participants got confused by the terminology of CMQF and needed extra help to score the statements. The other problem was that it did not relate to specific innovations. Because of this, the input was very generic and did not provide enough information on how HORA should be improved. So, the set-up was changed: The innovations provided in step 1 would be used in step 3, asking the participants for a general score on the usefulness per innovation.

In the new set-up, participants were able to vote on the statements and provide extra input via the comments without much extra help. In comparison, the scoring was more general and lacked the depth the CMQF could have offered. But it did provide useful information for the representatives of HORA, giving them new insights on missing elements. The scoring on usefulness was lower when the statements were specifically about usefulness regarding disruptive innovation. This might be related to the issue addressed at step 2: The list with innovations had items on them, that might not be about disruptive innovation. The missing elements were still useful: Adding these in the update will improve HORA and make it more useful in addressing the concerns named by the participants.

In the presented case practice from the Digital Competence Centre (DCC) Applied Research (see subsection “A Case Practice From HORA and Research” on page 49), the results were more concrete. This was because it resulted from modelling work, were the working group made the model they needed and wrote down every element they could not find in HORA. This is of course a different set-up. This can only be done if participants have a concrete idea of what they want to model and the model must be about a possible disruptive

innovation. Next to that, a modelling session could cost more time then has been spend in the main expert meeting of this research (depending on the detail level and scope of the model).

Step 4: Assess the Effect of HORA on Return on Modelling Effort

In this last step, participants were asked to vote on statements about return on modelling effort (Proper and Guizzardi, 2022; see also Frank, 2006). This step was added to get a perspective on the value of HORA and how to maximize its return on modelling effort.

This step proved to be useful in sparking a discussion about the value of HORA and how to profit from it as a higher education institution. The HORA representatives found this step useful. The fact that the participants saw that by using HORA their models stayed relevant for a longer period of time, indicated that HORA is not only useful for an efficient modelling process, but also for having a model that will be relevant (and brings value to the organisation) for a longer period of time.

The Application of the Assessment Model in the Expert Meetings

Apart from the output of the different steps, the application of the Assessment Model in an expert meeting setting seemed to generate useful insights on how to use HORA in addressing disruptive innovation. The experts participated actively in the discussion and were committed to give proper input. Thanks to the expert meetings, they were inspired to look at HORA from a fresh perspective.

Meetingwizard proved to be an effective tool to gather information and reuse that in the meeting. During a brainstorm, different innovations were provided by the participants. Then, those results were presented back to the participants. Together with the participants, the results were checked on duplicates or on entries that were unclear or did not fit the assignment. Later in the meeting that information could be used directly by the participants to score on the usefulness of HORA for that specific innovation. All the interaction provided by Meetingwizard led to an interactive and useful discussion with the participants.

Conclusion on Research Question 2

The presented Assessment Model was seen as useful by the participants of the expert meetings. In general, it did provide information that was deemed useful and inspirational by the HORA representatives.

With the three expert meetings, two iterations of the relevance cycle have been done. The first iteration was during the trail expert meeting and the preparation for the main expert meeting, the second iteration was after the main expert meeting during with the evaluation of this model. Propositions for the next version of the Assessment Model will be done in this section based on the experience during the expert meetings, the analyse of the results, and the evaluation expert meeting with the HORA representatives.

The HORA representatives were interested in reusing the Assessment Model and repeating the main expert meeting. In September 2023 work on that will start by first deciding what is learned from the last iteration of the design cycle and what changes should be made at the Assessment Model and the set-up of the meeting.

Possible enhancement of the Assessment Model and the set-up of the meeting:

- Formulating criteria about the kind of innovations could be considered for step 1. Some concerns that were give by participants were not innovations themselves but are about a *response* to innovations. Also, it should be assessed if an innovation *might* be disruptive or it is more likely about a sustaining innovation based on how higher education institutions are already working on them.
- Asking participants to name the stakeholders after the brainstorm on innovations and connect them to the innovations. During the meeting this will mean the cleaning of the list with innovation should take place before naming the stakeholders and connecting them to the innovations.
- In step 3 the results might be more coherent if criteria are given here as well. If a participant is asked to indicate if an comment is about a missing element, a missing model kind or a missing principle, the results would more structured. This might ask for more advanced options in Meetingwizard or using a different application.
- For now the method and the criteria are not part of the presented model in Figure 16. A more structured Way of Working can be added to the model, based on the experience with the expert meetings. Appendices A and B can be used as a starting point for that.

Reflection

The journey for this research started by stating that higher education institutions are facing challenges because of the emergence of new technologies (see page 7). There is debate on whether that will lead to disruptive innovation or "just" sustaining innovation. In my experience, the discourse about disruptive innovation will create a higher sense of urgency than sustaining innovation. But it will also trigger a discussion about that same urgency, creating two sides: people who think that quick action is needed before institutions will fail and people who think that the developments will not go that fast. In the end, it depends on different factors how an innovation might disrupt the market and only time will tell whether innovations will be disruptive or not.

Still, a lot is going on in the higher education world. There are for example many initiatives related to the flexibilisation of education. It is seen as part of disruptive innovation: Because students demand more flexibility and other companies or institutions might offer that, market share can be lost. The desk research showed multiple reports from the Acceleration Plan Educational Innovation with ICT (in Dutch: Versnellingsplan Onderwijsinnovatie met ICT[6]) that focus on making education more flexible (Brinkman et al., 2022; Huizinga et al., 2022; Scheers & Pinchetti, 2020; Versnellingsplan Onderwijsinnovatie met ICT, n.d.).

This research showed a nuanced view on the concept of disruptive innovation in higher education. The discussion in the expert meetings seemed to indicate that many aspects that were named as disruptive innovation are already experimented with by the major institutions themselves. Via initiatives like the Acceleration Plan higher education institutions work together to incorporate innovations. This is a scenario that is missing in the model of

[6] Some of the projects of that Acceleration Plan are now part of the new initiative Npuls. The website https://npuls.nl/en/ provides more information.

Kilkki et al. (2018; Figure 13 on page 43). In the higher education market, all the current institutions are working together to avert a possible disruption by external parties. They are not working on being disrupters themselves. This has an influence on the use of reference architecture. Since working together is key, it is even more important to use a common ground for designing processes, information models, and information systems.

Furthermore, not all potential disruptive innovations seams to lead to major changes in the essential model of institutions. This was shown in the example of the case study at the AUAS (see chapter "Case Study: Disruptive Innovation at the Amsterdam University of Applied Sciences (AUAS)" on page 17). A future scenario that from one perspective looked like a whole different way of organising education did not change much in the enterprise ontology. When the *structure* of the organisation of education is changed, but the *elements* stay roughly the same, the product of a higher education institution does not change much on an abstract level. The same statement was given in the interview about the case practice on applied research: The participant indicated that in essence the way research is being done will not change significantly. Here we see an important factor that Christensen (1997) already mentioned: The companies in the research were focussed on the current needs of the current population of customers and looked for improvement in their current product portfolio. This seems to be what is happening in the higher education world in the Netherlands as well. That might be the underlying factor why HORA did not score too bad on its use for potential disruptive innovation regarding flexibility. When the elements stay roughly the same, an architect can use those elements from the reference architecture to model scenarios for a new structure.

Some innovations may lead to more changes in the elements than that would happen in the scenario from the case study at AUAS. That was also shown in the expert meetings: Elements are missing at this moment, because HORA is not up to date. So, in some other scenarios the elements and models in HORA need to be changes more significantly.

This research was about the use of a specific reference architecture in addressing disruptive innovation. The research focussed on higher education in the Netherlands but the insights gained by this research have broader implications. A reference architecture is mostly seen as an architecture based upon best practices, representing the generalised knowledge of different instances of the entity of interest. The insight from this research is that it is more useful in a fast-changing world when it also includes elements about a near future, where it is not certain yet how those new elements will settle in the generalised entity of interest. Constructing and managing those elements is different from elements representing the current reality. Version management might include faster iteration cycles on those elements, with the possible consequence that they need to be changed or removed already in the next cycle. Maintaining a high standard on a trustworthy reference architecture on one side and catering to the fast-changing world on the other side, can be an interesting challenge.

In this way, HORA will be a *bimodal reference architecture*. A significant part of the reference architecture will still be the trustworthy and stable description of the current organisation of higher education. But another part will consist of new and experimental elements, that might change or disappear quickly. See the differences between the classic and the bimodal reference architecture in Table 20. It is important for architects to recognize the

experimental elements when making local models, because of there changing nature. It might mean that their local model should be updated as well when those elements change.

Table 20

Classic Versus Bimodal Reference Architecture

Attribute	Classic	Bimodal
Time horizon	Now	Now + near future
Trust	This is the truth	This is the truth + scenarios
Maintenance	Regular updated based on new developments	Regular updated based on new developments + incorporating upcoming innovations and scenarios
Status of the elements	All elements are part of the current architecture	Some elements are labelled as being part of a scenario, or experimental
Changing and changing elements	Most of the elements will stay stable for a long time (legacy architecture)	Experimental elements can change quickly or can be discarded when an innovation does not stick

Conclusion

HORA in its current form scores low on its usefulness in addressing the challenges of disruptive innovation. For some themes, this is meanly because HORA is out of date at the moment. When new elements are added in the next version, the usability will most likely be higher, especially for the types of innovations where the enterprise ontology does not change much. But for the types of potential disruptive innovations that do introduce new concepts, HORA needs to contain those elements to make it more useful. Those concepts are needed in the reference architecture for a common ground in modelling, because higher education institutions work together on most innovations.

For the introducing of those new elements a bimodal reference architecture can be used. Certain new and experimental elements can be added in the reference architecture, in a higher pace than the previous updates. Those new elements should be labelled as being experimental, so it is clear that they might change in next version, or even disappear.

The Assessment Model constructed during this research can be used to guide those sessions. This model helps in focussing on the problem area and to set the mindset to innovation. When the recommendations on improving the Way of Working from the previous section are followed, the results of the sessions will likely be even more effective.

Working on a reference architecture will become more than just describing the current structures and the best practices. It will become a job where an architect has to look into the future and analyse what innovations are promising enough to add to the reference architecture, and keep an eye on the developments to see if those innovations will persevere. In short, it will become the responsibility of the architect to ensure that the reference architecture can support the challenges of disruptive innovation.

Further Research

This exploratory research has gained insights that can be build upon in further research. Some of them have been stated above in the reflection. The concept of bimodal reference architecture should be studied further on its implications. How can this be modelled and maintained? Will it be effective in practice? Next to that, the Assessment Model can be iterated to a next version, especially in the Way of Working how to organise successful meetings.

The concepts of RoME, ViA and RiME were added to the Assessment Model, to get a complete assessment of the use of HORA. Due to the scope of the thesis and because the RoME-ViA-RiME is still in development, the return of investment of HORA and using HORA were not studied in detail. It can be highly beneficial for SURF, the higher education institutions and the architects working in the sector to do more research on this topic. With more understanding about the factors influencing the return on investment, the models and the modelling process and the use of the models can be altered to elevate this return on investment.

For the scope of this research, an objective analyse of the models in HORA was not included. For answering the research questions about the quality of HORA, the research relied on the input of the experts and their knowledge and opinions. This is due to time restraints, but also because it is hard to assess the objective quality aspects in line with the CMQF methods: The method depends on variables that assess completeness, in a context where the possible options are very large. The quality aspects related to the knowledge of architects and stakeholder is a practical surrogate (Nelson et al., 2012). But it would be interesting to see how CMQF could be applied in a practical setting like an evaluation of HORA.

The framework from Frank (2006) was not used in making the Assessment Model, since the CMQF and Return on Modeling Effort seemed to lead to a comprehensive enough framework. In a next iteration cycle the framework from Frank might be studied further upon, to see if certain elements can provide extra insights.

The level of flexibility is not determined in this research. It was just stated that higher education needs “more” flexibility, without specifying the current or desired level of flexibility. And overview of different possibilities of flexibilisation in Dutch higher education, and research done is this area, can be found in the report from Huizinga et al. (2022). To assess the level of flexibility, a recent conference proceeding by Rizun and Pańkowska (2022) proposed a maturity model. Further research could be done on specifying with forms of flexibility and which maturity level is wanted by the stakeholders, and what that means for the requirements for the architecture and reference architecture of the IT landscape supporting the organisation of education.

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General Definitions

In defining the main concepts used in this thesis, several terms are used where formal definitions may vary. In this paragraph, these terms are specified as to how they are used in this thesis.

Conceptual model	Shorthand for "A conceptual complex that is used as a model of a concrete complex" (Dietz & Mulder, 2020, p. 76). In this thesis, when a model is mentioned, it is always about a conceptual model.
Enterprise architecture	"A coherent whole of principles, methods, and models that are used in the design and realisation of an enterprise's organisational structure, business processes, information systems and infrastructure" (Lankhorst, 2005).
Framework	A frame of reference, that is, "a set of ideas, conditions, or assumptions that determine how something will be approached, perceived, or understood" (Merriam-Webster, n.d.).
Innovation	**"**A new idea, method, or device" (Merriam-Webster, n.d.).
Model	A complex that is used or is intended to be used to obtain knowledge of another complex without directly interacting with that complex (Dietz & Mulder, 2020, p. 73). In this thesis, when a model is mentioned, it is always about a conceptual model.
Sector architecture	The term is coined by SURF in the name "Higher Education Sector Architecture" (HOSA). Their definition is based on their view on the concept "sector": a collaboration of suppliers and partners working on communal IT services. In this thesis, sector architecture is considered a specialisation of a reference architecture, focussed on a specific sector, but not necessarily associated with communal IT services.
Standard	In the context of information systems, a standard is considered to be a "technical standard": an established norm or requirement for a repeatable technical task (Wikipedia, n.d.). This definition combines the construction and the function of a standard. A standard is considered as a specialisation of a reference architecture. The OOAPI website reference to "a set of definitions," which is considered a specific type of standard.

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Appendix A: Trail Expert Meeting

The 4 Steps of the Assessment Model

Introduction

The case is introduced by showing an animated video, with the following script (translated to English, original was in Dutch):

> The case is based on the situation that you, as an architect, are asked for advice by a colleague with a concern about disruptive innovation. This colleague can be a staff member, a dean or a member of the Executive Board.
>
> Your colleague is concerned about the innovations that organisations outside of higher education are working on. Will these developments force higher education to organise education differently? What can we as an institution do with these innovations?
>
> You will work as an architect to help your colleague. You will write some advice, including models that provide a good picture of the possible scenarios for setting up a future-proof organisation of education.
>
> As an architect in higher education, you have HORA at your disposal. A reference architecture that you can use as a template to adapt where necessary to the specific situation of your institution.
>
> We will now look at how well HORA helps with this, and what can be improved on HORA in that context.
>
> First, let us look at the issue. What kind of disruption are we talking about? Which stakeholders are working on this question? And what questions do they have?
>
> Then we look at the process. Do you advise on these issues, and do you use HORA for this, or would you like to use HORA for this?
>
> In step 3 we look at HORA itself. How well does HORA work, and how could it be improved?
>
> Finally, we ask the question: Does HORA help you as an architect to advise more effectively on this issue?

Step 1: Validating the Concern

Step 1 is introduced as followed:

> We first look at the stakeholder's question. What innovation does this stakeholder see coming, and to what extent are they potentially disruptive?
>
> We speak of disruptive innovation when an organisation has to adapt its strategy in order to survive. When it comes to innovation that can be implemented without a significant adjustment of the strategy, we speak of sustaining innovation.

> Whether or not an innovation could be disruptive does not matter much for this step. The point is that the stakeholder is concerned about this and therefore asks you for advice.

After this introduction, the experts are asked to answer the following question: "Which stakeholders ask you for advice?" and "Which disruptive innovations are we talking about?" This is done in a brainstorm, where participants can type in as many stakeholders and concerns as they want in Meetingwizard. The results are then shared with the group to discuss the results and to get a shared idea of what the experts are talking about.

Step 2: Validating the Modelling Process

Step 2 is introduced as followed:

> We now turn to the modelling process. Do you use HORA when drawing up your advice, or would you like to use it?

Three statements are then asked, where via voting the experts can indicate on a scale from 1 till 10 how much the agree. If wanted, participants can add comments at each statement.

- I write advice for stakeholders regarding potential disruptive innovations.
- I make models to support that advice.
- I use HORA as input for these models.

The results are then shared with the group to discuss the result and to get a shared idea of what the experts are talking about.

Step 3: Assess the Use of HORA

Step 3 is introduced as followed:

> We now come to step 3, the analysis of HORA itself. We focus on the models that are available and will look at this on the basis of a number of criteria based on the Conceptual Modeling Quality Framework (CMQF).

Then a list of statements is presented. Those statements are based on the quality attributes from the Conceptual Modeling Quality Framework: K3, K4, K6, K7, L1, L2, L3, L4, D3, D5, and D6. The statements were shown as listed below, without further explanation. Via voting the experts can indicate on a scale from 1 till 10 how much the agree. The participants could ask questions during the voting, and participants were asked to add comments when they scored a statement lower than an 8.

- Do you think the modelling language is consistently applied within HORA models?
- Does HORA have a positive influence on the syntactic quality of your own models?
- How well does HORA describe the current organisation of higher education?
- How well does HORA describe possible scenarios for adapting this organisation?
- Does HORA have a positive influence on the semantic quality of your own models?

- How consistently do HORA models meet the principles of the type of model?
- Does HORA have a positive influence on the intentional quality of your own models?
- How readable are the HORA models? Do the models comply with what you would expect in terms of layout and colour use?
- Does HORA have a positive influence on the empirical quality of your own models?
- How well do the HORA models help to understand disruptive innovations and their effects on higher education institutions?
- How well do the HORA models help to understand the type of models used?
- How well do the HORA models help to understand the modelling language used?
- How well do the HORA models help to understand the HORA models?
- How well do the HORA models help to make the local models understandable for stakeholders?
- Do the HORA models have a positive influence on the domain knowledge you use when making the local models about disruptive innovation?
- Do the HORA models have a positive influence on the domain knowledge you use when making the local models?
- Do the HORA models have a positive influence on the language knowledge you use when making the local models?

The results are then shared with the group to discuss the result and to get a shared idea of what the experts are talking about.

Step 4: Assess the Effect of HORA on Return on Modelling Effort

Step 4 is introduced as followed:

> The following statements are about assessing the effectiveness of HORA. You can give a score for each perspective. If you give less than an 8, can you indicate how HORA should be improved for a higher score.

Six statements are then asked, where via voting the experts can indicate on a scale from 1 till 10 how much the agree. If wanted, participants can add comments at each statement. The participants could ask questions during the voting, and participants were asked to add comments when they scored a statement lower than an 8.

- Thanks to HORA, my models have more effect.
- Thanks to HORA I spend less time making my models.
- Thanks to HORA I get more value from the modelling process.
- Thanks to HORA, the model I created has more value for the stakeholder.
- Thanks to HORA, the model I made remains relevant for longer.
- Thanks to HORA, the model I made remains up to date for longer.

The results are then shared with the group to discuss the result and to get a shared idea of what the experts are talking about.

Evaluating the Assessment Model

As last part of the expert meeting, the participants were asked their opinion on the Assessment Model:

Indicate whether you thought this model contributed to HORA's assessment.

Three statements are then asked, where via voting the experts can indicate on a scale from 1 till 10 how much the agree. If wanted, participants can add comments at each statement. The participants could ask questions during the voting, and participants were asked to add comments when they scored a statement lower than an 8.

- Thanks to this model I can better assess HORA.
- This model allows me to assess HORA from more perspectives.
- Thanks to this model I can assess HORA more efficiently.

The results are then shared with the group to discuss the result and to get a shared idea of what the experts are talking about.

Appendix B: Main Expert Meeting: Amendments to the Trail Expert Meeting

The 4 Steps of the Assessment Model

Introduction

[No changes]

Step 1: Validating the Concern

[No changes in the introduction. In the assignment, the bold text is added.]

After this introduction, the experts are asked to answer the following question: "Which stakeholders ask you for advice?" and "Which disruptive innovations are we talking about?" This is done in a brainstorm, where participants can type in as much stakeholders and concerns as they want in Meetingwizard. **The participants are told that the list of disruptive innovations will later be used to score HORA on usability to make models about those innovations. Participants are asked to type in one innovation per entry in the brainstorm session.** The results are then shared with the group to discuss the result and to get a shared idea of what the experts are talking about.

Step 2: Validating the Modelling Process

In stead of three, four statements are asked. The fourth one in the list below is added.

- I write advice for stakeholders regarding potential disruptive innovations.
- I make models to support that advice.
- I use HORA as input for these models.
- [NEW] I do not use HORA for these models yet, but I would like to.

Step 3: Assess the Use of HORA

[This step is changed completely.]

Step 3 is introduced as followed:

> We now come to step 3, the analysis of HORA itself. We focus on the models that are available, and will look at this on the basis of a number of quality aspects:
>
> - Semantic quality: how well do the current HORA models fit with reality and the possible scenarios for the future when it comes to modelling potential disruptive innovation?
> - Model–domain appropriateness: how well are the current types of models (such as the business function model, the information model and the application function model) useful when it comes to modelling concerning potential disruptive innovation?

The results are then shortly shown to the group to discuss the result and to get a shared idea of what we are talking about. Cause of the length of the list of innovations, an in-depth discussion is not possible in the ninety minute timeframe of the meeting.

Step 4: Assess the Effect of HORA on Return on Modelling Effort

The statements were too general about HORA, not specifically on HORA for making models about disruptive innovation. The new statements are:

- Thanks to HORA, my models about disruptive innovation have more effect.
- Thanks to HORA I spend less time making models about disruptive innovation.
- Thanks to HORA I get more value from the above modelling process.
- Thanks to HORA, the model I made about disruptive innovation has more value for the stakeholder.
- Thanks to HORA, the model I made about disruptive innovation remains relevant for longer.
- Thanks to HORA, the model I made about disruptive innovation remains up to date for longer.

Evaluating the Assessment Model

[No changes]

Appendix C: Literature on Quality Attributes on Enterprise Architecture and Models

This list is based on literary research, in accordance with the method described in section "Frameworks to Assess the Usability of Reference Architectures in Responding to Disruptive Innovation" (page 31). The table contains 110 entries.

Title	Year	Authors	Input for model
Understanding quality in conceptual modeling	1994	Lindland, O. I., Sindre, G., & Sølvberg, A.	●
Defining quality aspects for conceptual models	1995	Krogstie, J., Lindland, O. I., & Sindre, G.	
Requirements of the generic enterprise reference architecture and methodology	1997	Bernus, P., & Nemes, L.	
MITRE's Architecture Quality Assessment	1997	Hilliard, R. F., Kurland, M. J., & Litvintchouk, S.	
Enterprise architecture: The issue of the century	1997	Zachman, J. A.	
The Guidelines of Modeling – An approach to enhance the quality in information models	1998	Schuette, R., & Rotthowe, T.	
Architectures for evaluating the quality of information models – A meta and an object level comparison	1999	Schuette, R.	
Evaluating the quality of reference models	2000	Misic, J., & Zhao, J.	
Understanding the roles of signs and norms in organizations – A semiotic approach to information systems design	2000	Stamper, R. K., Liu, K., Hafkamp, M. P. J., & Ades, Y.	
Enterprise models for enterprise architecture and ISO9000:2000	2003	Bernus, P.	
Enterprise model verification and validation: An approach	2003	Chapurlat, V., Kamsu-Foguem, B., & Prunet, F.	
QFD in the architecture development process	2003	Erder, M., & Pureur, P.	
Classification of reference models: A methodology and its application	2003	Fettke, P., & Loos, P.	
Ontological evaluation of reference models using the Bunge-Wand-Weber model	2003	Fettke, P., & Loos, P.	
ISO quality standards for measuring architectures	2004	Losavio, F., Chirinos, L., Matteo, A., Lévy, N., & Ramdane-Cherif, A.	
Understanding the requirements on modelling techniques	2005	Hoppenbrouwers, S., Proper, H. A., & Van Der Weide, T.	
Theoretical and practical issues in evaluating the quality of conceptual models: Current state and future directions	2005	Moody, D. L.	
Evaluation of reference models	2006	Frank, U.	●
Understanding the term reference model in information systems	2006	Thomas, O.	
Exploring modelling strategies in a meta-modelling context	2006	Van Bommel, P., Hoppenbrouwers, S., Proper, H. A., & Van Der Weide, T. P.	
An instrument for measuring the quality of enterprise architecture products	2006	Van den Berg, M., Bos, R., & Brnkkemper, B.	
Potential critical success factors for enterprise architecture	2006	Ylimäki, T.	

Title	Year	Authors	Input for model
Quality management activities for enterprise architecture	2006	Ylimäki, T.	
Towards critical success factors for enterprise architecture: AISA project report	2006	Ylimäki, T.	
Quality evaluation of architectural documentation and models: AISA project report	2007	Hämäläinen, N.	
Analysis of the current state of enterprise architecture evaluation methods and practices	2007	Hoffmann, M.	
Formalizing analysis of enterprise architecture	2007	Johnson, P., Nordström, L., & Lagerström, R.	
Enterprise architecture: A framework supporting system quality analysis	2007	Närman, P., Johnson, P. J., & Nordström, L.	
Architecture principles – A regulative perspective on enterprise architecture	2007	Van Bommel, P., Buitenbuis, P., Hoppenbrouwers, S., & Proper, H. A.	
QoMo: A modelling process quality framework based on SEQUAL	2007	Van Bommel, P., Hoppenbrouwers, S., Proper, H. A., & Van Der Weide, T.	●
Using enterprise architecture models for system quality analysis	2008	Närman, P., Schönherr, M., Johnson, P. J., Ekstedt, M., & Chenine, M.	
Stakeholder perception of enterprise architecture	2008	Van Der Raadt, B., Schouten, S., & Van Vliet, H.	
Relevance and usability of enterprise architectures during post merger IT integrations	2008	Van Houwelingen, J. W.	
Towards a generic evaluation model for enterprise architecture	2008	Ylimäki, T.	
Measuring the effectiveness of enterprise architecture implementation	2009	Bonnet, M. J. A.	
Classifying enterprise architecture analysis approaches	2009	Buckl, S., Matthes, F., & Schweda, C. M.	
The concept of reference architectures	2009	Cloutier, R., Muller, G., Verma, D. C., Nilchiani, R., Hole, E., & Bone, M.	
A new AHP-based approach towards enterprise architecture quality attribute analysis	2009	Davoudi, M. R., & Aliee, F. S.	
Characterization of enterprise architecture quality attributes	2009	Davoudi, M. R., & Aliee, F. S.	
A new approach towards enterprise architecture analysis	2009	Davoudi, M. R., Aliee, F. S., & Mohsenzadeh, M.	
Question framework for architectural description quality evaluation	2009	Hämäläinen, N., & Markkula, J.	
A comparative analysis of enterprise architecture frameworks based on EA quality attributes	2009	Lim, N., Lee, T. H., & Park, S. M.	
Quality enhancement in creating enterprise architecture: Relevance of academic models in practice	2009	Nakakawa, A., Van Bommel, P., & Proper, H. A.	
Adapting the DeLone and McLean model for the enterprise architecture benefit realization process	2009	Niemi, E., & Pekkola, S.	

Title	Year	Authors	Input for model
Modern QFD-based requirements analysis for enterprise modelling: Enterprise-QFD	2009	Özdağoğlu, G., & Salum, L.	
Anti-patterns as a means of focusing on critical quality aspects in enterprise modeling	2009	Stirna, J., & Persson, A.	
Concepts and strategies for quality of modeling	2009	Van Bommel, P., Hoppenbrouwers, S., Proper, H. A., & Roeloefs, J.	
A conceptual framework for enterprise architecture design	2010	Buckl, S., Matthes, F., Roth, S., Schulz, C., & Schweda, C. M.	
The relation between EA effectiveness and stakeholder satisfaction	2010	Van Der Raadt, B., Bonnet, M., Schouten, S., & Van Vliet, H.	
Comprehensive measurement framework for enterprise architectures	2011	Dube, M. R., & Dixit, S.	
Qualitative characteristics of enterprise architecture	2011	Khayami, R.	
An AHP-based approach toward enterprise architecture based on enterprise architecture quality attributes	2011	Razavi, M. S., Aliee, F. S., & Badie, K.	
An approach towards enterprise architecture analysis using AHP and fuzzy AHP	2012	Davoudi, M. R., & Sheikhvand, K.	
Goal-oriented requirements engineering and enterprise architecture: Two case studies and some lessons learned	2012	Engelsman, W., & Wieringa, R.	
Realizing benefits from enterprise architecture: a measurement model	2012	Lange, M., Mendling, J., & Recker, J. C.	
A conceptual modeling quality framework	2012	Nelson, H. J., Poels, G., Genero, M., & Piattini, M.	●
Quality marks, metrics, and measurement procedures for business process models: The 3QM-framework	2012	Overhage, S., Birkmeier, D., & Schlauderer, S.	
On the categorization and measurability of enterprise architecture benefits with the enterprise architecture value framework	2012	Plessius, H., Slot, R., & Pruijt, L.	
A model to assess the usability of enterprise architecture frameworks	2013	Bijarchian, A., & Ali, R.	
Enterprise architecture quality attributes: A case study	2013	Niemi, E., & Pekkola, S.	
Enterprise architecture evaluation using utility theory	2013	Österlind, M., Johnson, P., Karnati, K., Lagerström, R., & Valja, M.	
Enterprise architecture documentation: Current practices and future directions	2013	Roth, S., Hauder, M., Farwick, M., Breu, R., & Matthes, F.	
Measuring and visualising the quality of models	2013	Storch, A., Laue, R., & Gruhn, V.	
Usability elements as benchmarking criteria for enterprise architecture methodologies	2014	Bijarchian, A., & Ali, R.	
Measuring enterprise architecture effectiveness: A focus on key performance indicators	2014	Günther, W. A.	
A new approach based on genetic algorithm for prioritizing quality scenarios in enterprise architecture evaluation	2014	Karimi, M., Sharafi, S. M., & Dehkordi, M. N.	
A unified framework for enterprise architecture analysis	2014	Langermeier, M., Saad, C., & Bauer, B.	

Title	Year	Authors	Input for model
PRIMROSe: A graph-based approach for enterprise architecture analysis	2014	Naranjo, D., Sánchez, M. E., & Villalobos, J.	
Exploring enterprise architecture evaluation practices: The case of a large university	2015	Andersen, P., Carugati, A., & Sorensen, M. G.	
The critical success factors of enterprise architecture	2015	Hope, T.	
Investigating the usage of enterprise architecture artifacts	2015	Kotusev, S., Singh, M., & Storey, I.	
SEQUAL as a framework for understanding and assessing quality of models and modeling languages	2015	Krogstie, J.	●
Enterprise architecture adoption method for higher education institutions	2015	Syynimaa, N.	
UNITA: A reference model of university IT architecture	2016	Chen, S., Tang, Y., & Li, Z.	
An empirical analysis of the factors and measures of enterprise architecture management success	2016	Lange, M., Mendling, J., & Recker, J. C.	
Stakeholder's expected value of enterprise architecture: An enterprise architecture solution based on stakeholder perspective	2016	Puspitasari, I.	
Measuring the quality of enterprise architecture models	2016	Spence, C., & Michell, V.	
Understanding the benefits and success factors of enterprise architecture	2017	Jusuf, M., & Kurnia, S.	
Eight essential enterprise architecture artifacts	2017	Kotusev, S.	
Using enterprise architecture artefacts in an organization	2017	Niemi, E., & Pekkola, S.	
A hybrid method for evaluating enterprise architecture implementation	2017	Nikpay, F., Ahmad, R., & Kia, C. Y.	
Quality framework for quality assuring enterprise architecture model	2017	Rumapea, S. A., & Sitohang, B.	
A first literature review on enterprise reference architecture	2017	Sanchez-Puchol, F., & Pastor-Collado, J. A.	
Towards an unified information systems reference model for higher education institutions	2017	Sanchez-Puchol, F., Pastor-Collado, J. A., & Borrell, B.	
Towards a quality framework for enterprise architecture models	2017	Timm, F., Hacks, S., Thiede, F., & Hintzpeter, D.	
Towards a method for developing reference enterprise architectures	2017	Timm, F., Sandkuhl, K., & Fellmann, M.	
An overview of process model quality literature-the comprehensive process model quality framework	2018	De Meyer, P., & Claes, J.	
A framework for descriptive models quality assessment	2018	Ernadote, D.	
Planning for digital transformation: Implications for institutional enterprise architecture	2018	Kar, S., & Thakurta, R.	
A situational method for creating shared understanding on requirements for an enterprise architecture	2018	Nakakawa, A., Van Bommel, P., Proper, E., & Mulder, H.	

Title	Year	Authors	Input for model
Enterprise modelling in the age of digital transformation	2018	Van Gils, B., & Proper, H. A.	
Diseño de un framework de arquitectura empresarial para instituciones públicas de educación superior	2019	Fuentes, I. M., Bernal, W. N., Trillos, S. M., & Julio, Y. H.	
A reference model for digital transformation and innovation	2019	Gomes, S., Santoro, F. M., Da Silva, M. M., & Iacob, M.	
Understanding challenges of applying enterprise architecture in public sectors: A technology acceptance perspective	2019	Guo, H., Li, J., & Gao, S.	
Understanding and assessing quality of models and modeling languages	2019	Krogstie, J.	
Generic analysis support for understanding, evaluating and comparing enterprise architecture models	2019	Langermeier, M.	
Framework, model and tool use in higher education enterprise architecture: An international survey	2019	Lethbridge, T., & Alghamdi, A.	
How enterprise architecture improves the quality of IT investment decisions	2019	Van Den Berg, M., Slot, R., Van Steenbergen, M., Faasse, P., & Van Vliet, H.	
Towards a comprehensive understanding of digital transformation in government: Analysis of flexibility and enterprise architecture	2020	Gong, Y., Yang, J., & Shi, X.	
A model for evaluation of enterprise architecture quality	2020	Mirsalari, S. R., & Ranjbarfard, M.	
Quality attributes of enterprise architecture models	2020	Schoonderbeek, J.	
Enterprise architecture measurement: A systematic literature review	2021	Abdallah, A., Abran, A., & Khasawneh, M. A.	
Enterprise architecture in higher education: processes, principles, challenges, success factors and agility	2021	Alghamdi, A.	
Enterprise architecture artifacts facilitating digital transformations' strategic planning process	2021	Grave, F., Van De Wetering, R., & Kusters, R. J.	
Enterprise architecture artifacts for digital transformation	2021	Hammou, S. O.	
The theoretical basis of enterprise architecture – A critical review and taxonomy of relevant theories	2021	Kotusev, S., & Kurnia, S.	
De rol van EA in strategische planning voor digitale transformaties in de geestelijke gezondheidszorg	2022	Mooijman, J.	
Enhanced digital transformation supporting capabilities through enterprise architecture management: A fsQCA perspective	2022	Pattij, M., Van De Wetering, R., & Kusters, R.	
Modeling for enterprises; let's go to RoME ViA RiME	2022	Proper, H. A., & Guizzardi, G.	●
Maturity model for assessment of personalization of higher education	2022	Rizun, M., & Pańkowska, M.	

Appendix D: Literature on Disruptive Innovation in Higher Education

This list is based on literary research, in accordance with the method described in section “Frameworks to Assess the Usability of Reference Architectures in Responding to Disruptive Innovation” (page 31). The table contains 14 entries.

Name	Year	Authors	Input for model
Disruptive technology reconsidered: A critique and research agenda	2004	Danneels, E.	●
The usefulness of measuring disruptiveness of innovations ex post in making ex ante predictions*	2006	Govindarajan, V., & Kopalle, P. K.	●
Assessment of the “Disrupt-O-Meter” model by ordinal multicriteria methods	2016	Gavião, L. O., Ferraz, F. a. P., Lima, G. B. A., & Sant’Anna, A. P.	
Transformational and transactional factors for the successful implementation of enterprise architecture in public sector	2016	Lee, S., Oh, S. M., & Nam, K.	
Business development in the early stages of commercializing disruptive innovation: considering the implications of Moore’s life cycle model and Christensen’s model of disruptive innovation	2017	Giglierano, J. J., Vitale, R., & McClatchy, J. J.	●
Digital transformation in higher education – The role of enterprise architectures and portals	2017	Sandkuhl, K., & Lehmann, H.	
MOOCs, disruptive innovation and the future of higher education: A conceptual analysis	2019	Al-Imarah, A. A., & Shields, R.	
Digital doesn't have to be disruptive: The best results can come from adaptation rather than reinvention	2019	Furr, N., & Shipilov, A.	
Challenges to implementing disruptive and digital technologies	2020	Ghawe, A. S.	
The significance of enterprise architecture in driving digital transformation on public sectors	2021	Makovhololo, M. L., Makovhololo, P., & Sekgweleo, T.	
Assessing the personalization of higher education: Maturity framework development	2021	Rizun, M.	
Digital government transformation: A structural equation modelling analysis of driving and impeding factors	2021	Tangi, L., Janssen, M., Benedetti, M., & Noci, G.	
The role of enterprise architecture for digital transformations	2021	Van De Wetering, R., Kurnia, S., & Kotusev, S.	
Enabling disruptive innovations in high growth organizations when architecting an enterprise	2022	Niday, T.	

Appendix E: Comments Provided in Step 3 of the Main Expert Meeting

These are the comments provided by the participants during the main expert meeting. The participants were asked to score the usefulness of HORA to model about the innovation mentioned, on a scale of 1 to 10. They were asked to add comments on what was missing, if they scored lower than an 8. The comments were given in Dutch and are presented below without adaptions. The resulting scoring on the statements can be found in Table 11 (page 57).

1. Flexibilisering van het onderwijs
    - Capability laag is denk ik ook nodig om meer naar de toekomst te schrijven.
    - De huidige HORA is gemodelleerd rond 'opleidingen' en sluit daardoor minder aan op 'modulair' en 'leeruitkomsten' gebaseerd onderwijs.
    - De huidige HORA is opgebouwd vanuit instellingsaanbod. Maar vraagsturing en relatie naar customer journey ontbreken. Applicatieservices ontbreken volledig. Interfaces en standaarden zijn niet geïntegreerd. Waarom de huidige inrichting van de HORA gedaan is zoals die gedaan is, is niet expliciet, waardoor ik minder goed kan inschatten welke overwegingen ik in beschouwing zou moeten nemen.
      De samenwerking met andere instellingen is moeilijk te beschouwen met de huidige HORA. De relatie tussen proces en gegevens is nog niet geduid.
      De business objecten zijn denk ik ook verouderd. Flexibilisering vraagt waarschijnlijk een andere view op dezelfde business objecten. Denk aan het verschil tussen studenten en professionals dat steeds kleiner wordt waardoor nu meer over (leven lang) lerenden gesproken wordt.
    - Definities van informatie objecten sluiten niet altijd aan (bv examenprogramma). Processen zijn niet aangepast.
      Visuele weergave is niet aantrekkelijk (vergeleken met de MORA).
    - Klantperspectief ontbreekt. De huidige HORA gaat uit van het aanbod met de opleiding als hét onderwijsproduct. Vraaggestuurd onderwijs in al zijn aspecten kan nu niet goed worden gemodelleerd.
      Sommige informatieobjecten die het onderwijsaanbod beschrijven (opleiding, onderwijseenheid, leer- en toetsactiviteit) zijn te beperkt gedefinieerd en de relaties ertussen zouden N-op-N-relaties moeten zijn.
    - Onze instelling zit hier middenin maar gebruikt op verschillende HORA-lagen andere bewoordingen.
    - Te veel vrijheid voor de instellingen om het op de eigen manier te doen. Verplichte landelijke/Europese richtlijnen zijn m.i. noodzakelijk.
2. Breed gebruik van ChatGPT voor onderwijsdoeleinden
    - HORA gaat niet in op onderwijsinhoudelijke zaken.
    - Opnemen als onderdeel van de verschillende soorten principes.
    - Prima voor een stakeholderanalyse, maar minder voor een gedetailleerd model.
    - Weet niet of dit een echt een architectuurvraagstuk is.
3. Samenwerking met onderzoekers buiten eigen instelling (IAM)
    - De samenwerking met andere instellingen ontbreekt in het model.
      IAM is maar heel beperkt uitgewerkt, zeer arm!
      EDU-ID en dergelijke ontbreekt.

- HORA is niet diep genoeg uitgewerkt voor bedrijfs en applicatiesfuncties buiten domein onderwijs en onderzoek.
- Met name in de HOSA.
- Samenwerking en verschillende vormen van samenwerking in de voorbereidende fase, uitvoerende fase en afrondende fase worden niet meegenomen bij de bedrijfsprocessen, laat staan welke functionaliteit daarvoor nodig is en welke technologie daaraan invulling kan geven.

4. Modularisering van onderwijsaanbod
   - De bedrijfsprocessen vanuit HORA zijn opleidingsgericht derhalve niet passend bij modularisering.
   - Ook hier te veel keuzevrijheid.
   - Zie flex.
   - Zie Flexibilisering van het onderwijs.
   - Zie flexibilisering.
5. De impact van open science
   - FAIR-principes, en andere architectuurkaders worden niet meegenomen in de modellen om aan 'Open Science' (transparantie, verantwoording, hergebruik van data) te kunnen voldoen.
   - Opnemen graag.
6. De impact van AI in het algemeen
   - "in het algemeen" geeft het idee van een hoog-over visie. HORA kan dan hooguit op het hoogste niveau ondersteuning bieden.
   - Hier is nog geen aandacht voor binnen de HORA.
   - Is denk ik niet vanuit een referentie architectuur te beantwoorden.
   - Met behulp van het bedrijfsfunctiemodel is een aardige inschatting te maken van waar AI potentieel impact kan hebben (voor de informatiekamer is dat op deze manier gedaan). Maar de applicatieve en gegevensimpact zijn minder goed ondersteund.
   - Opnemen graag.
7. Data Driven
   - Beperkte informatie-objecten.
   - Informatieobjecten zijn soms te generiek en zouden gelaagder kunnen zijn (b.v. deelnemer).
   - Nu te veel versnippering van de data. Hoe voorkomen we dit? Is er een landelijk datalake nodig?
8. Combineren van reguliere en commerciële studenten in lesgroepen
   - Hier wordt geen onderscheid in gemaakt.
   - HORA gaat uit van een groot SiS. Het verder uitsplitsen van Student Administratie en Student Volg is daarbij gewenst.
   - HORA kan hier heel goed helpen de impact op verschillende bedrijfsfuncties en -processen te bepalen.
9. Meerdere startmomenten voor onderwijsmodules
   - Zie Flexibilisering van het onderwijs.
   - Zie flexibilisering.
10. Registratie en toetsing onderzoeksplannen met aanbevelingen voor vervolg

- De hele voorbereidende fase van onderzoek (registratie/beoordeling - datamanagement- plannen en impact op te gebruiken functionaliteit/technologie rekening houdend met RDM beleid/kaders etc.) die doorloopt in vervolgfasen is onvoldoende uitgewerkt in de HORA.
- Dit soort zaken worden nu in de Waardeketen Onderzoek van het DCC-HBO uitgewerkt, maar is niet opgenomen in de HORA.
- Ja opnemen.

11. Integraal "klantbeeld"
    - Het klantperspectief ontbreekt in het onderliggende metamodel.
    - Omdat HORA al gemodelleerd is vanuit een centraal beeld, geeft dit al weer hoe dit eruit zou kunnen komen te zien, inclusief de eindverantwoordelijkheid. En dit ook nog op verschillende architectuur-niveaus.
    - Toevoegen aan principes.
    - Vanuit de HORA, maar ook vanuit de instellingen zelf, wordt vaak in systemen gepraat. Denk bijvoorbeeld aan het SIS. En dat wordt dan door architecten doorvertaald naar de applicatiecomponent SIS. Maar een systeem is niet alleen een applicatiecompenent, want een systeem bestaat uit alle structurele componenten, dus ook bijvoorbeeld data en de interfaces die er zijn. De holistische impactsview kan nu nog niet gemaakt worden met de HORA.
12. Just-in-time learning vanuit LLO
    - Door de bedrijfsobjecten uit HORA te gebruiken is de inzet van Low coding wel redelijk te ondersteunen.
    - Zie Flexibilisering van het onderwijs.
13. Verdergaande ontwikkelingen op blended learning
    - Misschien niet heel erg dat dit niet heel goed ondersteund wordt met de HORA. Maar blended learning vraagt om een mix van applicatieservices, leermaterialen, etc die in de onderwijsuitvoering gecombineerd moeten kunnen worden. Die relaties zitten nu niet sterk in de HORA. Verder gaat blended learning denk ik vooral impact hebben op de manier waarop onderwijs wordt ontworpen. Dat is een onderwijsinhoudelijk issue en ligt grotendeels bij de onderwijskundigen, hoewel de combinatie van technologie en onderwijs steeds verder in elkaar opgaan vermoed ik.
14. Uitwisselen van behaalde resultaten (microcredentials)
    - Op uitwisselingsvlak is er weinig in de HORA.
15. Research datamanagement: vastleggen/beheer (meta)data voor archief, publicatie, hergebruik.
    - Er zijn geen modellen die het datamanagement (beheer en opslag van -meta-data) over de gehele onderzoeks-/datacyclus heen beschrijven.
16. Toetsen van bekwaamheid zonder onderwijs te volgen
    - Binnen HORA is Toetsing nog rechtstreeks verbonden aan Onderwijs en kan daardoor niet gezien worden als losstaande functie.
    - Zie Flexibilisering van het onderwijs. Het hiervoor noodzakelijke bedrijfsobject Leeruitkomsten ontbreekt nu nog.
17. Meer samenwerking tussen instellingen onderling en van instellingen met sectorpartners, zoals Studielink en DUO.
    - Aangevuld met (open) standaarden voor uitwisseling van gegevens lijkt me dat HORA per definitie hier het uitgangspunt zou moeten zijn.

- Meer aandacht in de HORA voor uitwisselingsservices zou helpen bij dit soort vraagstukken.
- Zeer nodig!

18. Onderwijs volgen bij andere onderwijsinstelling
    - Zie Flexibilisering van het onderwijs.
19. Wat gaat quantum computing brengen?
    - Hoort dit in de HORA?
20. Cloud native high performance computing
    - Er zijn geen uitwerkingen binnen de HORA betreffende (online) werkomgevingen voor dataverwerking/-analyse die voldoet aan RDM-kaders en privacy/security eisen waarin kan worden samengewerkt en rekenkracht/ opslagcapaciteit op flexibele wijze aan toegevoegd kan worden.
    - Hoort dit in de HORA?
    - Technologielaag is niet uitgewerkt.
21. Low coding
    - De technologische laag is in de HORA beperkt uitgewerkt, waardoor een impact analyse op technologisch niveau niet te maken is.
    - Dit is zo'n technologie die je organisatie kan binnensluipen zonder dat je het merkt en veelal processen probeert te automatiseren door handwerk "na te doen" (zeker bij RPA). Door het procesmodel en functiemodel er naast te houden behoed je jezelf voor het knutselen ipv echt integreren van systemen (met hier en daar een procesaanpassing).
    - Hoort dit in de HORA?
    - Is meer een oplossing en niet een vraagstuk vanuit referentie architectuur.
22. Data engineering: pipelines voor data-verwerking/-analyse
    - Hoort dit in de HORA?
    - Technologielaag is niet uitgewerkt.
23. Snellere veranderingen van de inhoud van het vakgebied
    - "de HORA gaat niet over de inhoud van een vakgebied, maar ik zou de veranderende inhoud wel relateren aan onderwijsontwikkeling en onderwijs uitvoeren.
    - De impact op de IT is wel groot omdat nieuwe technologieën belangrijk worden. Ik zie dat niet terugkomen in de HORA.
    - Hier is ook een link met de technische architectuur en hoe die goed te 'governancen'."
    - Is denk ik niet een architectuurvraagstuk.
    - Relatie met flexibilisering en en het onderwijs modulair inrichten.

Appendix F: Comments Provided by HORA Representatives

These are the comments provided by the HORA representatives during the evaluation expert meeting. The representatives were asked to score the statements about the usefulness of the different steps in the Assessment Model and add comments to elaborate on the score. The original comments were in Dutch and are presented below in English. The resulting scoring on the statements can be found in Table 18 (page 64).

With every step, the same four statements were provided. Not all statements received comments at every step. There were three representatives, so the maximum number of comments for any step/statement-combination is three.

Comments

Step 1: Validating the Concern

- This step provided useful information about HORA.
    - The enormous variety of stakeholders mentioned can help to determine characteristics in order to determine stakeholder groups and to better align the HORA information with those groups.
    - The outcome indicates the broad group of stakeholders for which HORA should or could be relevant. It does not yet provide any information about the practical usability of HORA.
- This step provided useful information about HORA and disruptive innovation.
    - -
- The information obtained from this step will help to improve HORA.
    - -
- With the information obtained, HORA will become more useful in disruptive innovation.
    - -

Step 2: Validating the Modelling Process

- This step provided useful information about HORA.
    - In particular, this confirms the impression that HORA needs a major update and that we are running into the issue of how we position HORA in time. Now the approach is to display the current setting, while it now appears that the wish is that HORA will also partly look ahead.
- This step provided useful information about HORA and disruptive innovation.
    - -
- The information obtained from this step will help to improve HORA.
    - The conclusion that HORA is not always used as a source of input for modelling is reason to find out how we can improve HORA in such a way that this will happen and HORA can therefore better assist in accelerating the development of institutional architectures.
- With the information obtained, HORA will become more useful in disruptive innovation.
    - -

Step 3: Assess the Use of HORA

- This step provided useful information about HORA.
    - The step clearly shows where there is improvement potential.
    - Gives a good idea of where HORA needs improvement.
- This step provided useful information about HORA and disruptive innovation.
    - And in addition to the comment to 'this step contains useful information about HORA', the useful information is of course specifically about points for improvement with regard to the impact of disruptive innovations.
    - Gives a general picture rather than specifically about disruptive innovation.
    - Especially understanding that things are not in order now.
- The information obtained from this step will help to improve HORA.
    - The responses from the participants contained a number of valuable contributions that we (the HORA developers) had not yet considered.
    - Yes, but the conclusions match the picture we already had.
- With the information obtained, HORA will become more useful in disruptive innovation.
    - Limited, the information is too summarily for that.
    - in combination with the previous question. In the way that HORA can improve with this. It should be noted that it raises a question about the positioning of HORA (here and now versus future-oriented).
    - Certainly, among other things due to the comment 'make the display more visually attractive'. We were already working on that, but a confirmation from the group of users is a confirmation that we are on the right track with the further development of HORA.

Step 4: Assess the Effect of HORA on Return on Modelling Effort

- This step provided useful information about HORA.
    - The fact that HORA now gets a 6.1 shows that there is still a lot of room for improvement.
    - In particular about the fact whether the actuality of HORA is important for the application of HORA (seems to be an open door, but it turned out not to be, given its maintenance in recent years).
    - For me, all this information obtained gives an idea, but is not concrete enough for targeted improvement of HORA.
- This step provided useful information about HORA and disruptive innovation.
    - In my opinion, the figures also show that the improvements of HORA seem especially necessary on disruptive topics.
    - Especially that it is important that HORA should include innovation in its further development.
- The information obtained from this step will help to improve HORA.
    - I do see opportunities to further expand the functionality of HORA. For example, by publishing faster about current developments and the impact on architecture.
- With the information obtained, HORA will become more useful in disruptive innovation.

- When we process current topics more quickly in HORA, HORA will also become more useful.
- It is difficult for me to make a statement about this based on the results.