Factors involved in successful multi-mode standardization in case of phosphorus recovery in form of struvite from municipal wastewater

Thesis report

By

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Executive summary

Phosphorus is an essential and non-renewable resource for the growth of a living organism. Within the recent years, phosphorus recovery from municipal wastewater has been marked as a major contributor to obtain phosphorus. A possible method for phosphorus recovery from municipal wastewater is through the formation of struvite. However, barriers such as different qualities of the produced struvite due to different types of struvite installations and regulations about trading of struvite hamper implementation of these struvite installations. Through standardization towards one type of struvite installation, the barrier of different types of quality could be solved. Standardization has been as subject which has been broadly studied by scholars. Multiple studies can be found in which a standards battle is analyzed, from a market-based. Within multiple technological fields, relevant factors and their importance has been identified to predict or analyze the winner of the standards battle. However, current trends show that actors from different backgrounds with different strategies come together in the standardization process. This causes a multi-mode standardization process, where the following three perspectives come together: market-, committee- and government-based standardization. At this moment, literature lacks deeper insight in this multi-mode standardization. In addition, the possible standardization of struvite installations shows characteristics of multi-mode standardization. As the market-based perspective is present with the different technology providers delivering the technologies. In addition, the government-based perspective is present with the regulations about produced struvite. This leads to the main research question of this research: "*Which are factors of influence in order to achieve success within the multi-mode standardization process in the context of phosphorus recovery through struvite formation from municipal wastewater according to experts?"*

This research was conducted in three phases to answer the main research question. In the first phase of this research all the necessary data was collected. Here, the goal was to answer the following two sub-questions: *"What are the factors for success in the multi-mode standardization process?"* and "*What are the relevant factors for phosphorus recovery in form of struvite from municipal wastewater according to literature and experts?"*. The data was collected by the means of a literature study and by expert interviews. For the expert interviews, people were interviewed who were involved in the purchasing of already present struvite installations within the Netherlands. The second phase focused on determining the importance of the relevant factors, answering the third sub-question of this research: *"What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?"*. The importance of the factors was calculated by employing the Best Worst Method. In this case, the global weights of factors were calculated by making use of the results of obtained local and category weights via the Best Worst Method. In addition, this method was applied two times where the factors were divided within different types of categories, which resulted in different global weights for the factors. The results of the obtained global weights of a factor were determined if significantly different by a statistical analysis. During the third and final phase of this research the interpretation of the gathered data was performed. By discussion all the obtained data and thus the answers of the three sub-question, the main research question was answered.

In this research the first sub-question was answered by constructing a framework including factors for success within multi-mode standardization. The framework builds on previous published framework including factors for success within standardization from a market-perspective. In total the proposed framework included 45 factors divided into seven different categories. From this proposed framework, eleven factors were deemed as relevant, thus answering the second sub-question of this research. The identified relevant factors were: 'financial strength', 'technological superiority', 'compatibility',

‘complementary goods’, ‘pricing strategy’, ‘appropriability strategy’, ‘market communications’, ‘financial support’, ‘agenda setting’, ‘current installed base’ and ‘suppliers’. For the third sub-question the weights were successfully determined by the Best Worst Method. Additionally, through the statistical analysis a significant difference was observed in the obtained weights for ‘financial strength’, ‘appropriability strategy’, ‘market communications’, and ‘suppliers’. These factors were therefor not classified as high, medium of low important factors. Overall, from the results it was concluded, as answer for the main research question, that ‘technological superiority’ and ‘compatibility’ were seen as the high scoring factors by experts. The factors ‘pricing strategy’, ‘agenda setting’, and ‘current installed base’ were identified as the medium important factors. The factors ‘complementary goods’, ‘market communications’, ‘financial support’ and ‘suppliers’ were classified as the low important factors.

Within this research multiple theoretical contributions were made. First, it gives a broad definition of understanding what successful multi-mode standardization is. Furthermore, it emphasizes the importance that an author should always clearly mention his or her understanding of a standard and successful standardization. Second, a framework was built including factors for success in multi-mode standardization. Third, this research shows directly the relevance of this newly proposed framework as two newly identified factors in the framework were considered relevant in the studied case. Additionally, this also shows and agrees with earlier research that the studied case indeed is a multi-mode standardization problem. Fourth, this research builds on earlier comparable published research which analyzes the importance of relevant factors which influence successful standardization via the Best Worst Method. Furthermore, this is the first record in the field of phosphorus recovery and wastewater management. Finally, this research contributes towards the Best Worst Method local and category weights were used. Also, some practical contributions were made as well. First, the results of this case could be compared to the current testing method when a municipal wastewater treatment plant selects a struvite installation. Accordingly, the testing method could be adapted to include all factors and their importance. Secondly, via this proposed framework and the Best Worst Method a test could be made and applied for purchasing other technologies. This not only applies to municipal wastewater treatment plants but is also applicable for other firms which use similar testing methods as well. Finally, the knowledge of the proposed framework could be used by firms to adapt new strategies which are involved around multi-mode standardization.

For further research of standardization, it is recommended that the proposed framework in this study will be used. This is because it is a more comprehensive framework and has shown it relevance in the studied case. Further testing of this framework with familiar cases of multi-mode standardization is recommended to analyze if the framework is indeed complete. In addition, when local and category weights are used when applying the Best Worst Method, it is recommended to use comparable numbers of factors within a category. Recategorization should be applied when there is unequal distribution or if there is a fear of a high scoring category which could lead to biased results.

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List of acronyms

Adenosine triphosphate (ATP)
American Standards Association (ASA)
Analytic Hierarchy Process (AHP)
Analytic Network Process (ANP)
Bayerische Motoren Werke (BMW)
Best worst method (BWM)
Core and peripheral categories (CPC)
European Commission (EC)
European Sustainable Phosphorus Platform (ESPP)
General Motors (GM)
Intellectual property rights (IPR)
International Electrotechnical Commission (IEC)
International Organization for Standardization (ISO)
Multi-Criteria Decision-Making (MCDM)
Municipal wastewater treatment plant(s) (MWWTP(s))
Original categories (OC)
Phosphorus (P)
Phosphorus-cycle (P-cycle)
Phosphorus-recovery (P-recovery)
Phosphorus-removal (P-removal)
Polyphosphate-accumulating organisms (PAOs)
Society for Automotive Engineers (SAE)
Standard setting organization(s) (SDO(s))
United States of America (USA)

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1. Introduction

The element phosphorus (P) is an essential and non-renewable resource for growth of a living organism. It is used among others in cell membranes and in the energy carrier adenosine triphosphate (ATP) (Buckwell & Nadeu, 2016; Butusov & Jernelöv, 2013). Within Figure 1 the natural phosphorus-cycle (P-cycle) is given with human interactions. Naturally phosphorus ends up in the soil and water through weathering of phosphate rocks. However, this process is irrupted by humans, e.g. by harvesting of phosphate rocks for usage as fertilizer. By uptake and through organic decompensation by plants, micro-organism, animals and humans the phosphorus ends up in a dissolved form in water (Ashley, Cordell, & Mavinic, 2011; Buckwell & Nadeu, 2016; Cisse & Mrabet, 2004). Through marine sedimentation phosphate rock is created with the dissolved phosphorus compounds, this is a process which takes place over millions of years (Steen, 1998). At this point it is not known when exactly phosphate rocks reserves will be depleted. In the meantime, phosphorus has already been marked in Europe as critical raw material (European Commission, 2014). Furthermore, mining of the remaining phosphate rocks has become less attractive. This is due to the lower concentration of phosphorus and higher amount of contaminations which are found in the phosphate rocks. Additionally, the remaining phosphorus is more difficult to access. Finally, the mining of these rocks have a more negative effect on the environment (Ashley et al., 2011; Cordell, Drangert, & White, 2009).

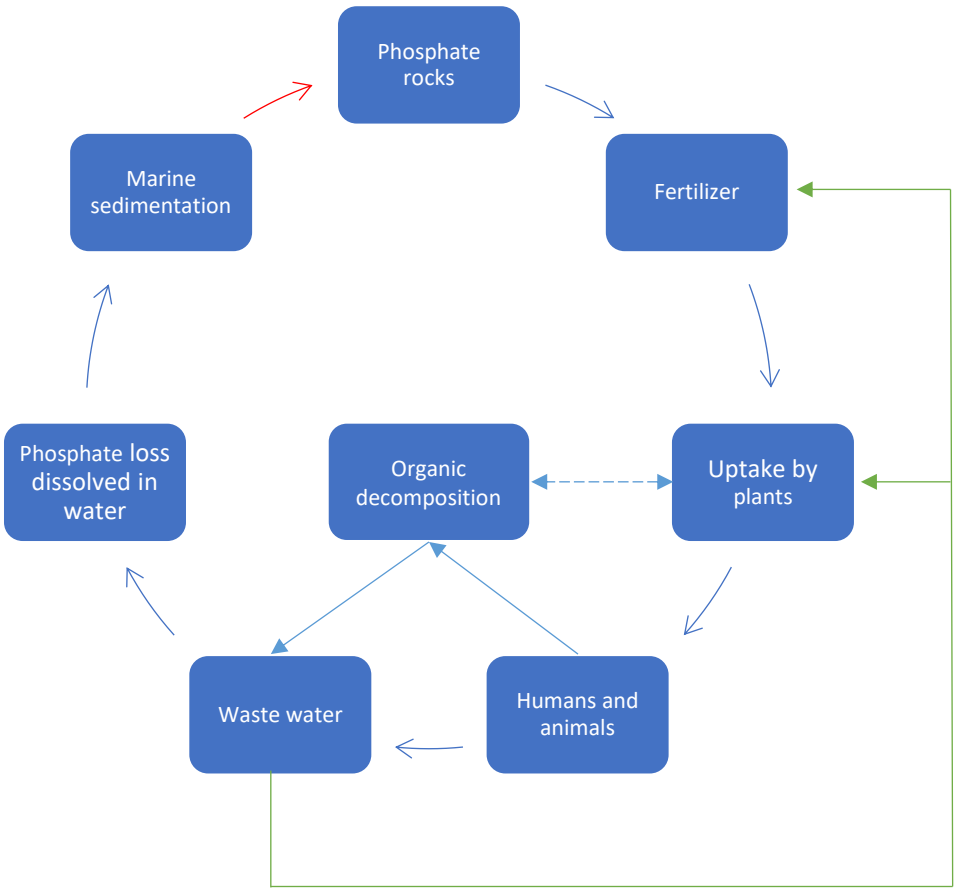

Figure 1: A simplified P-cycle with human interactions. The green arrows represent P-recovery, the red arrow represent phosphate rock production with can take over millions of years.

In the Netherlands the government plans to achieve a circular economy by 2050 (Bos, 2016). Meaning by no longer treating products as waste, but through recycling and reusing products using them as secondary raw material to extend the life cycle of products (Ghisellini, Cialani, & Ulgiati, 2016). Within recent literature, phosphorus-recovery (P-recovery) from municipal wastewater has been identified as a major contributor for closing the P-cycle (de Ruijter, Van Dijk, Curth-van Middelkoop, & van Reuler,

2015; Lukas Egle, Zoboli, Thaler, Rechberger, & Zessner, 2014; Zoboli, Laner, Zessner, & Rechberger, 2016a; Zoboli, Zessner, & Rechberger, 2016b). Furthermore, actions from the industry and government to help closing the P-cycle have been made. Namely, in 2011 the 'Ketenakkoord Fosfaatkringloop' was signed by 20 actors involved within the phosphate industries in the Netherlands. This accord has as goal to reuse phosphorus as much as possible (Ketenakkoord Fosfaatkringloop, 2011).

Clearly, the importance of phosphorus has arisen the last few years. Simultaneously the number of techniques for P-recovery has increased and improved as well. One possibility of P-recovery from municipal wastewater is through the formation of struvite. However, this method is only applicable when biological removal of phosphorus is applied in the municipal wastewater treatment plants (MWWTPs). Furthermore, the amount of recovered phosphorus is small compared to other P-recovery techniques, such as P-recovery from the sludge ash (Amann et al., 2018; L Egle, Rechberger, Krampe, & Zessner, 2016; Remy & Jossa, 2015). Still, this method has as its advantages as it can be combined with the P-recovery method via sludge ash. Secondly, it brings down the operational costs of a MWWTP. Finally, this method can be applied at the MWWTP, while P-recovery from the sludge ash is done elsewhere (Arcadis Nederland B.V., 2017). Within the Netherlands, in 2016 a total of 327 MWWTPs could be found. Of these 327 MWWTPs, only 120 qualify for P-recovery via struvite as they apply have biological P-removal system (CBS, 2016). However, not all 120 MWWTP can implemented a struvite installation, they can only be applied at the larger MWWTPs. These larger MWWTPs can, however, collected and process sludge from smaller MWWTPs (I4, 2019). Currently there are only seven struvite installations and one is under construction and of these seven installed struvite installations four different techniques are applied at this moment as presented in Table 1 (Arcadis Nederland B.V, 2017; I7, 2019). These different installations produce different qualities of struvite. The quality differs, amongst others, if the struvite can be used directly as fertilizer or as raw material for fertilizer. Furthermore, the quality diverges in the type of status the struvite obtains, this type of status might hinder possible trading of the struvite. The different type of qualities of the produced struvite were identified as a barrier hampering the implementation of struvite as fertilizer. Another important identified barrier at this time is the regulation around struvite, blocking the trading process with other countries (Arcadis Nederland B.V., 2017; Verhulst, 2017). Within this research the aim is to gain further insight about standardization towards one type of struvite installation. This, hopefully, could lead to higher implementation of struvite installations as the quality of produced struvite is the same. More background information, technical details, and regulation information about this case can be found in Appendix A.

Table 1: Overview of current struvite installations within the Netherlands (Arcadis Nederland B.V., 2017)

Type of installation	**Location of MWWTP**
Airprex	Echten and Amsterdam-West
NuReSys	Land van Cuijk and Apeldoorn
Phospaq	Olburgen and Tilburg-Noord
Pearl	Amersfoort

1.1 Multi-mode standardization

In literature there has been a focus on the identification for factors which are relevant for success within a standardization process. A standardization process or standards battle can be described as a process or battle were multiple proposed technologies battle to become the standard, e.g. most implemented or most newly bought. In one literature review of van de Kaa, van den Ende, De Vries, and van Heck (2011) a framework is presented including factors relevant in a standards battle from a market perspective. Following this, more research has been conducted with the framework to identify the importance of the relevant factors within a standards battle (van de Kaa, Fens, & Rezaei, 2018; van de Kaa, Kamp, & Rezaei, 2017; van de Kaa, Scholten, Rezaei, & Milchram, 2017). By determining the importance, a possible winner could be predicted or analyzed of a standards battle. To calculate the

importance of the factors, a Multi-Criteria Decision-Making (MCDM) was used called the Best Worst Method (BWM). This research has been applied in different technical domains, e.g. biomass thermochemical conversion technology, battery and fuel cell powered electric vehicles, and residential grid storage (van de Kaa, Fens, et al., 2018; van de Kaa, Kamp, et al., 2017; van de Kaa, Scholten, et al., 2017). However, as earlier mentioned, van de Kaa et al. (2011) only identified factors from the market perspective, while other literature discusses the possibility of the existence of other perspectives. In Wiegmann, de Vries, and Blind (2017) multi-mode standardization is introduced. This multi-mode standardization includes three different types of perspectives which can be involved in a standardization process, these three perspectives are:

- Market-based standardization (e.g. Schilling 2002; van de Kaa, 2017a);
- Committee-based standardization (e.g. Jain 2012; Leiponen 2008)
- Government-based standardization (e.g. Farina, Gutman, Lavarello, Nunes, & Reardon, 2005).

Furthermore it is stated in Wiegmann et al. (2017) that standardization literature mostly focusses on only one of these three perspectives. Some literature can be found were the influence of multiple perspectives on the standardization is discussed, e.g. Gao, 2014; van den Ende; van de Kaa, den Uijl, & de Vries, 2012. However, this literature still lacks theoretical insight on multi-mode standardization (Wiegmann et al., 2017). Meanwhile, current trends are observed where previously unrelated stakeholders from different background are getting together within standardization processes. These stakeholders bring different strategies to the table based from individuals' perspectives of standardization. This leads to a multi-mode standardization process. Consequently, it can be expected that multi-mode standardization is becoming more important (Kenney & Zysman, 2016; Porter & Heppelmann, 2014; Wiegmann et al., 2017).

1.2 Research problem

As discussed above, in the recent years multiple standards battles from different technological fields have been analyzed. However, the research done mostly focusses on only one possible perspective of standardization and is lacking theoretical insight from a multi-mode standardization (Wiegmann et al., 2017). In order to be able to analyze technology battles in a more complete form, Wiegmann et al. (2017) suggest further research to identify the factors which are of relevance within a multi-mode standardization process. Such research would be building on published literature about multi-mode standardization.

To test such composed framework, the standardization process of P-recovery via the formation of struvite from municipal wastewater seems suited. As pointed out there are some regulation and application barriers at this moment (Arcadis Nederland B.V., 2017; Verhulst, 2017). As the regulation barriers stems from the government, it can be expected that government has an influence within this standardization process. Additionally, some collaboration between different stakeholders can already be identified. For example, there is the European Sustainable Phosphorus Platform (ESPP) where amongst the members are: the Dutch government, companies who offers P-recovery technologies, and fertilizer producing companies (European Sustainable Phosphorus Platform, 2018). Another example of collaboration is Aquaminerals who sells struvite, has waterboard "Aa en Maas", a struvite producer, enlisted as one of its shareholders (Aquaminerals, 2018). Finally, a recent study from Germany about standardization in the German municipal wastewater sector found interdependencies between governmental regulation and committee-based standardization (Freimuth, Oelmann, & Amann, 2018). As of now, limited research is available on possible standardization which solely focusses on P-recovery via the formation of struvite is available. Research which is available compares different P-recovery techniques from different phases, for example P-recovery from water via struvite

formation versus sludge ash, are available. However, such studies still fall short on implications like infrastructures, and legal frameworks (Amann et al., 2018; Remy & Jossa, 2015).

1.3 Research objective

This research objective consists out of two parts. The first objective of this research is to develop a framework consisting factors influencing success in multi-mode standardization. This framework will build on the existing framework of market-based standardization from van de Kaa et al. (2011). The expansion and adaptation of this framework will be done via the identifications of factors from literature. The second objective of this research will focus on identification and importance of the relevant factors from the multi-mode standardization framework for the P-recovery techniques in form of struvite formation from municipal wastewater. By using a MCDM method the importance of the factors can be determined. This will be done by interviewing experts who were involved in the installation of struvite installations within the Netherlands.

1.4 Main research question and sub-questions

To solve the above described research problem, the following main research question is proposed:

"Which are factors of influence in order to achieve success within the multi-mode standardization process in the context of phosphorus recovery through struvite formation from municipal wastewater according to experts?"

To answer this question, first the following sub-question will be answered:

1. *"What are the factors for success in the multi-mode standardization process?"*
2. *"What are the relevant factors for phosphorus recovery in form of struvite from municipal wastewater according to literature and experts?"*
3. *"What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?"*

1.5 Research approach

The research will be conducted in three phases: information gathering, determining weight of the key factors and statistical analysis, and interpretation of gathered data. The goal of these three phases is to answer the first two sub-question in the first stage, sub-question three in the second stage. Finally the main research question then could be answered in the third and final stage. An outline of the research is given in Figure 2.

1.5.1 Phase 1 – Information gathering

In the first stage will focus on answering the first two sub-questions by gathering information through literature and interviews. To answer the first sub-question: *"What are the factors in multi-mode standardization process?"* the previously constructed framework by van de Kaa et al. (2011) will be expanded and modified. The factors to broaden this framework will identified by means of a literature study. The review article published by of Wiegmann et al. (2017) was used as a starting point identify the first set of articles which would be studied. For some of these articles a forward research was conducted to expand the literature study. This was done until it was clear that the framework was saturated, and no new factors were identified anymore. Identified factors will be classified by overlapping in meaning or when factors are closely related. By classifying these factors, a shorted and unique list of factors and their explanation will be obtained.

Once a complete framework of factors which have an influence within a multi-mode standardization process is obtained, the second sub-question *"What are the relevant factors for phosphorus recovery in form of struvite from municipal wastewater according to literature and experts?"* will be answered

by content analysis of available literature and expert interviews. As previously mentioned, there is a limited amount of literature available on this subject. Therefore, the content analysis will be complemented with expert interviews. A total of three experts were interviewed who work at a MWWTP which have implemented a struvite installation. A factor was considered relevant when it is found in these secondary resources. This is comparable with previous research which used the framework constructed by van de Kaa et al. (2011), e.g. van de Kaa, Scholten, et al. (2017) and van de Kaa, Fens, et al. (2018).

1.5.2 Phase 2 – Determining weight of the key factors and statistical analysis

The second stage of the research follows up on the identified factors by literature and experts from the first phase. This phase focusses answering the third sub-question *"What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?"*. To answer this question a MCDM method will be applied to determine the importance of each found relevant factor. There are multiple MCDM methods to choose from such as Analytic Network Process (ANP), Analytic Hierarchy Process (AHP) and the earlier mentioned BWM. The recently developed BWM by Rezaei (2015,2016) was chosen for this process for multiple reason. First, it gives more reliable and consistent results. Secondly, it is simpler and needs less comparison than previously mentioned methods. Finally, the effectiveness of this method has been proven previously in similar research where technology battles from a market perspective were analyzed (van de Kaa, Fens, et al., 2018; van de Kaa, Kamp, et al., 2017; van de Kaa, Scholten, et al., 2017). To conduct a BWM a second round of interviews with experts were held. Here, interviewees from the first round were interview for a second time. Furthermore, contact details were obtained in the first round of interviews for possible experts who could be interviewed in the second round. In total seven persons were interviewed. The BWM exists out of a total of five steps. In the first step the criteria must be determined, in this case the relevant factors which found in the first phase of this resource. For the second step the worst and best criterion are identified. Once the best criterion has been selected, the third step can follow. Here a pair-wise comparison with the other criteria were made with the best criterion. Step four is a replication of step three, but instead of comparing criteria to the best criterion, now the comparison is made with the worst criterion. The final step, step five, is solving a mathematical model from which the optimal weights will be obtained (Rezaei, 2015, 2016).

Additionally, a statistical analysis was performed during this research as the BWM was applied two times. The first time it was applied with factors divided in categories following the literature research. The second time factors were redistributed in new categories on which the BWM was employed. This was done in response to observations made in the first round of interviews. The obtained weights of a factor were compared through a statistical analysis to conclude if the two obtained weights for one factor were significantly different.

1.5.3 Phase 3 – Interpretation of gathered data

In the final phase the gathered data will be analyzed. By looking how each factor overall scored it could be concluded which factors seem to be most relevant factors within this case. Furthermore, the results of the statistical analysis were discussed. This was because a significant different in weights of a factor can lead to biased results. Once all the information is gathered, the main research question "*Which factors affect the success of phosphorus recovery in form of struvite from municipal wastewater within a multimode standardization process?"* can be answered.

1.6 Structure of thesis

In Figure 2 an overview of the structure of this thesis is given. Before focusing on answering the main and sub-questions of this research, a further elaboration about multi-mode standardization is given in Chapter 2. In Chapter 3 the research methodology will be discussed. Following the research methodology will be the results in Chapter 4 and Chapter 5. First in Chapter 4 the newly constructed

framework for factors for success in multi-mode standardization will be given. Then in Chapter 5 the relevant factors involved when choosing a struvite installation will be given and their weights will be determined. The interpretation of the results given in Chapter 5, will be further discussed in Chapter 6. Finally, the conclusion and recommendations will be given in Chapter 7.

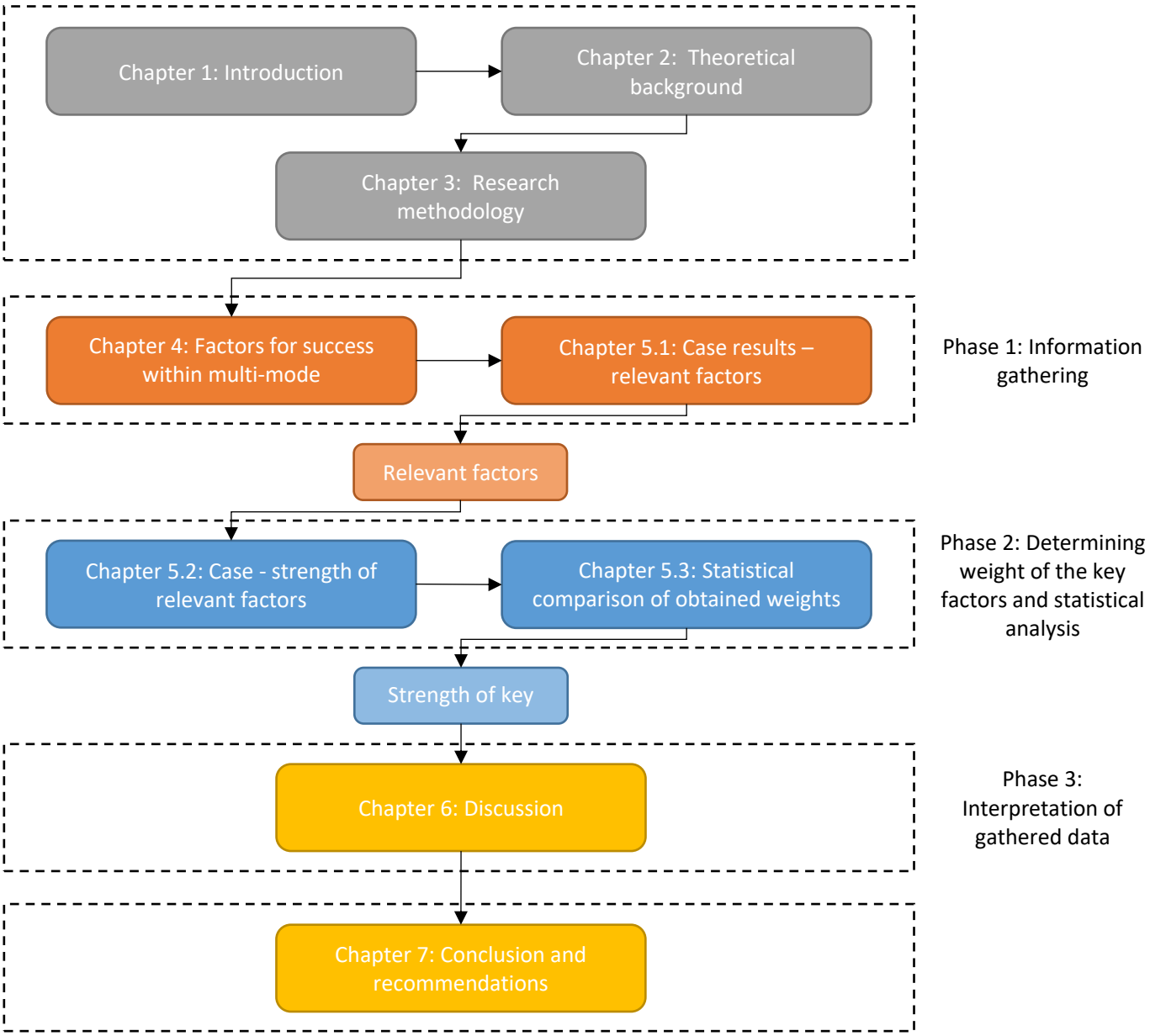

Figure 2: Research outline

2. Theoretical background

Before further elaboration and examples are given about multi-mode standardization, the meaning of the word standard is discussed, as the word standard can be linked to multiple definitions within literature, which may lead confusion. As example Krechmer (1996) defines four different classes of technical standards: 1) units, 2) similarity,3) compatibility, and 4) etiquette. While in a more recent article of Ho and O'Sullivan (2018b) five types of standards are distinguished depending on their roles, namely: 1) terminology and semantic standards, 2) measurement and characterization standards, 3)quality and reliability standards, 4) compatibility and interface standards, and 5) variety-reduction standards. Even more, sometimes different terminology is used to identify the same type or class of standard. For example, compatibility standards is defined in Krechmer (1996) as "the interface between two or more mating elements that are compatible rather than similar, e.g. a plug and a socket, a transmitter and a receiver". Other scholars refer to these compatibility standards as interface specification (van de Kaa et al., 2011). Furthermore, the result of market-based standardization is sometimes referred to as a de-facto standard, of which there are again different understandings (Wiegmann et al., 2017). Within den Uijl (2015) a definition of a de-facto standard is given which includes the concepts of compatibility standard, dominant design and platform to describe a de-facto standard. The concept of a compatibility standard is the same as explained above by Krechmer (1996). While dominant design is described as "design specifications that define a product category's architecture (i.e. >50% market share) and platform is described as "Technological systems that facilitate interaction between demand and supply network". These three concepts together describe the term de-facto standard as "a compatibility standard, platform, or product design specification that has obtained widespread acceptance (>50% market share in terms of worldwide yearly unit sales) through market competition" (den Uijl, 2015). However, during the review of the article about multi-mode standardization of Wiegmann et al. (2017) it was noticed that no definition of a standard given. Furthermore, Wiegmann et al. (2017) also recognizes that in literature different concepts are given for dominant designs, platforms, and de-facto standard. Additionally, these concepts are not specified within the terms of multi-mode standardization by Wiegmann et al. (2017). This review article goes over many different cases of multi-mode standardization processes, of which most articles were read for this thesis as well. Here, it was noticed that the meaning of a standard, if given, differs in each article. Therefore, it can be said that the definition of each standard is case dependent and thus, in view of multi-mode standardization, there is not just one definition that satisfies the word standard. The analyzed case in this research about struvite installations can be described as a compatibility standard. These installations must work together with the other elements present at a MWWTP, like a plug and a socket. In this chapter first more theoretical insight about multi-mode standardization is given. Furthermore, the different meaning of success within multi-mode standardization obtained during the literature study will be given at the end of this chapter.

2.1 Multi-mode standardization

In Wiegmann et al. (2017) multi-mode standardization is discussed. The identified perspectives of multi-mode standardization, as mentioned in Chapter 1.1, are: market-, committee- or government-based standardization (Farina, Gutman, Lavarello, Nunes, & Reardon, 2005; Leiponen, 2008; van de Kaa, Kamp, et al., 2017; Wiegmann et al., 2017). Different characteristics can be used to describe each perspective individually. The first mentioned perspective, market-based standardization, is also referred to in literature as de facto standardization. These types of standards arise after competition between two or multiple standards within a market. Wherein the standards are offered by different parties within the market. The outcome of the battle is determined when one standard reaches market dominance (van de Kaa, Kamp, et al., 2017; van de Kaa et al., 2011; Wiegmann et al., 2017). A very familiar example of a market-based standard was the battle between Betamax and VHS. The second mode of standardization, committee-based standardization, is also known within literature as de jure standardization. Here, stakeholders cooperate to find one fitting standard to the proposed problem. The cooperation of the multiple stakeholders can find place within committees of standard developing

organizations (SDOs), consortia, professional associations, trade associations, or in open source initiatives. One standard will only diffuse if consensus between the different stakeholders is reached. From this point it can be said that the standardization process was successful (Leiponen, 2008; Wiegmann et al., 2017). One widely recognized SDO which manages committees were voluntary standards are designed is the International Organization for Standardization (ISO). Finally, the third mode of standardization is the government-mode. Here the government makes use of its hierarchical position to enforce standards. Within market-based standardization a standard dominance is result of a battle and with committee-based standardization a standard is set through consensus within a committee. Meanwhile, in government-based standardization the government can intervene within standardization development battle or obligate usage of certain existing voluntary standards (Farina et al., 2005; Wiegmann et al., 2017). One might think of safety standards through regulation as a government-based standardization.

Although these individual types of standardization are easily recognized. Multi-mode standardization, where two of these perspectives or all three of these perspectives interact together, is expected to be becoming more relevant. Since unrelated stakeholders nowadays cross paths within the standardization battles, as mentioned in Chapter 1.1. These stakeholders have different experiences and strategies originating from one these perspectives for standardization, leading to multi-mode standardization (Kenney & Zysman, 2016; Porter & Heppelmann, 2014; Wiegmann et al., 2017). Following, examples are given to create a better understanding of a multi-mode standardization process.

2.1.1 Committee- and market-based standardization

The case used to explain a committee- and market-based standardization is the HD-DVD versus Blu-ray. Initially this battle started as a market-based standardization. However, it turned into a committee- and market-based standardization process when the DVD-Forum became involved. The battle started in 2002 when an alliance between Toshiba and NEC was established to develop the HD-DVD as standard. This can be seen as a reaction to the already growing alliance of Sony and Philips who started in 2000 with the development of Blu-ray. To gain more and diverse support from other companies, the HD-DVD project was proposed to the DVD-Forum. Additionally, this DVD-Forum was chaired by Toshiba employee. The DVD-Forum was at that time the existing organization for support of the DVD standard. However, the DVD-Forum was built up with stakeholders who were involved in Blu-ray and in the HD-DVD project. Initially, support from the DVD-Forum was declined due to resisting of the stakeholder who were involved within the Blu-ray development. To gain eventually the support of the DVD-Forum, Toshiba changed the manner of voting. Simultaneously, it broadened the support towards HD-DVD by addition of new members. The involvement of the DVD-Forum caused that the standardization battle no longer was a purely market-based, but multi-mode standards battle of committee- and market-based standardization. Despite the efforts of the alliance supporting HD-DVD and gaining the support DVD-Forum, Blu-ray was eventually the winner of this standards battle (den Uijl & de Vries, 2013; van den Ende et al., 2012).

Within studied literature about the committee- and market-based standardization one problems arises. Which can be explained by the following example; Wiegmann et al. (2017) identifies the article of Axelrod, Mitchell, Thomas, Bennett, and Bruderer (1995), which studies standard-setting alliances, as committee- and market-based standardization literature. However, the same article is identified as market-based standardization literature by Dan (2018). This shows there are contradicting views between scholars about committee- and market-based standardization when there are alliances or consortia involved. The chosen example above, about the HD-DVD and Blu-ray, shows these difficulties as there was committee formed by the DVD-Forum. However, the DVD Forum might not be recognized as an official SDO, such as ISO. Furthermore, both HD-DVD and Blu-ray where alliance-based initiatives, thus it can be argued whether from which moment it could be said it there was a committee- and

market-based standardization process. The problem where there is no clear sign that a committee stemming from an official SDO was involved but a alliance of stakeholders was involved occurred more often with the studied literature which was classified as committee- and market-based standardization. Blind and Mangelsdorf (2016) even concluded within their research that the formal standardization can be seen as a form of strategic alliance.

During literature study, standard setting by a committee or consortia or by an alliance was compared and one similarity arose. A proposed standard must first reach consensus within the group of stakeholders before diffusion of the standard can take places. There are different opinions when it could there could be spoken of a true committee- and market-based standardization. However, the same factors which were identified for consensus reaching and diffusion of a standard within an alliance or committee showed strong similarities. This can be partly explained as committees and consortia both are group of stakeholders trying to design one standard as solution to a problem. The goal during the literature review was to identify multi-mode factors and not individual factors committee- or market-based factors. Thus, the found factors where a group of stakeholders are collaboration towards one standard are all described under committee-standardization for simplicity.

2.1.2 Committee- and government-based standardization:

The standards battle of standardized sizes for shipping containers describes a committee- and government-based standardization. Although the first containers were used early in the 19th century, it wasn't until the mid-1950s before the standardization process was started. A sectional committee established by the American Standards Association (ASA) started here the standardization process. Therefore, this process can be originally identified as a committee-based standardization. However, the first standards which were published by the ASA were not in the advantage of the two biggest stakeholders, namely Sea-Land and Matson. These two stakeholders had roughly about 70% of the market share within the shipping containers transport in the United States of America (USA). By successfully gaining government support, the standard dimensions of the shipping containers were rewritten into the advantages of Sea-Land and Matson. This action turned it into a committee and government-based standardization. However, this was not the end of the battle as it continued on a global level. Once the USA had set their standard, subsidies were given to their proposed standard to gain a large installed base. When the ISO got involved to set a global standard, the American standard based containers had already a head-start with respect to Europe. Furthermore, the USA was identified as a driving force within the ISO committee for shipping containers. Finally, the USA had stricter regulation about possible container dimensions for the road, where these containers would be used as well. This resulted in the ISO accepting the standard dimensions for shipping containers which were proposed by the USA (T. Egyedi & Spirco, 2011; T. M. Egyedi, 2000; Meyer, 2012).

2.1.3 Government- and market-based standardization:

There is limited literature available with discusses cases within a government- and market-based standardization compared to other multi-modes. (Wiegmann et al., 2017). The example chosen within the government- and market-based standardization is about the competition between railway track gauges. This standardization process originally standard as a market-based standardization process. Here the builders determined which gauge would be used when building a railway. These engineers made their choice in what they believed was best practice and with which gauge they used with previous build railways. This caused for high diversity of gauges, in 1860s the eastern half of North America could be divided in nine major regions which had different gauges. Within Europe, a lack of interest of international standardization was clearly evident as well. Although countries had adopted gauge standards, differences in gauges between the neighboring counties such as Germany and the Netherlands could be observed in late 1830s and 1840s. The early choices of which gauge to implemented where generally made by governments or by the companies who owned the railways. Thus, the choices where market-or government-mode based showing government- and market-based

standardization. The lack of coordination and foresight of possibilities which the railways could offer between regions or countries hindered the standardization process. Later a resolution in diversity in gauges, towards one standard, was facilitated by railways companies working togethering (Puffert, 2000, 2002).

2.1.4 Committee-, market-, government-mode based standardization:

Finally, it is possible to have standardization where all three modes are involved in. The case to illustrate this multi-mode standardization is the electric vehicle recharging plug. The most important formal committee stakeholder here is the International Electrotechnical Commission (IEC), from which several working groups were established. It accepted three physical designed plugs standards in 2011 which has arose during the years before. The first standard, the Yazaki plug, was designed through collaboration which was initiated by the Society for Automotive Engineers (SAE) which was led by General Motors (GM). The designed standard, however, was not suited for Europe as there was a difference in power grids between USA and Europa. Partly because of this, leading automakers including Bayerische Motoren Werke (BMW), Ford, GM, Mitsubishi, and Volkswagen designed the second standard: the Mennekes plug. However, not all parties in Europe agreed with this standard. It was indicated there was a lack in safety in this standard. An initiative taken by French and Italian electrical equipment manufactures designed the third standard: the Scame plug. These Mennekes and Scame plug were both available in Europe and incompatible with each other. Stakeholders pushed the European Commission (EC) to choose one standard, however it was not until 2013 before a the Mennekes plug was chose as the European standard. The development of the different types of plugs could be seen a market- and committee-based standardization. While the involvement of the EC between the Mennekes and Scame plug can be seen as government-based standardization (Bakker, Leguijt, & van Lente, 2015). Overall, leading that this above described case shows characteristics of a multi-mode standardization process.

2.2 Success within standardization

Like the different type of definitions of a standard as explained at the beginning of this chapter. There are also different understandings when it can be said standardization is successful. As almost none of the reviewed article within multi-mode standardization gave a clear explanation what is their exact understanding is for successful standardization. Van de Kaa et al. (2011) is one of the few authors who describes successful standardization as dominance, which is described as it reaches at least 50% of the market share for a significant amount of time. This description of dominance will be followed when applicable. However, this definition of successful standardization was made in the context of market-based standardization. To identify factors for success within a multi-mode standardization a broad meaning of success is applied. This definition depends on what type of standardization process is going one. The overall following explanation of standard success is based on the read literature about standardization and can be described as followed:

- Committee-based standardization: standardization is successful when a committee reaches consensus about a standard.
- Market-based standardization: standardization is successful when a standard reaches market dominance.
- Government standardization: standardization is successful when a government actively enforces a standard.
- Committee- and market-based standardization: A combination of successful agreement about standard within the committee and deployment in market so that standard reaches market dominance.
- Committee- and government-based standardization: A combination of successful agreement about standard within the committee and deployment in market with help of the government.

- Government- and market-based standardization: A combination of standards battling in the market for dominance and through help of government one standard reaches market dominance.
- Committee-, market-, and government-based standardization: A combination of successful agreement about standard within the committee, a battle for market dominance with multiple standards where the government can help reaching market dominance.

During the identification of factors leading to success within standardization, these broad explanations where followed. When a combined explanation is given, factors were considered relevant when it influenced a part of the given explanation above. In addition, similar like authors should give their definition of a standard within their research, researchers should also give their understanding of successful standardization. As described in the Chapter 1.2 influences are expected from all three perspectives. Thus, the case of phosphorus recovery in form of struvite from municipal wastewater the understanding of successful standardization which will be followed is described under the committee-, market-, and government-based standardization.

3. Research methodology

3.1 Framework construction

In the first part of this research a framework will be constructed which consists out of factors influencing success in multi-mode standardization. As mentioned before this framework will build on a previously constructed framework by van de Kaa et al. (2011). Within this framework a total of five categories were identified, namely 'characteristics of the format supporter', 'characteristics of the format', 'format support strategy, other stakeholders', and 'environmental factors'. Newly identified factors will be listed in the existing or in new categories. Furthermore, general description will be given about the factors and the categories.

Factors and their description will be gathered through a literature study. A total of 51 articles were reviewed to construct the new framework. The first set of articles which were reviewed were extracted from tables enlisting literature on interaction between different modes within multi-mode standardization from Wiegmann et al. (2017). Expansion of the literature study was done via forward search of some studied literature from Wiegmann et al. (2017) and suggested additional literature. The articles which were selected to perform a forward research can explained with help of the following example: Funk and Methe (2001) was selected based on that they were mentioned in Wiegmann et al. (2017) as well as other articles read from Wiegmann et al. (2017). Articles which were only mentioned Wiegmann et al. (2017) and not discussed within other studied literature mentioned in Wiegmann et al. (2017) were not selected to perform a forward search on. This was done until it was clear that the framework was saturated, and no new factors were identified. Articles which were selected for further studies can be explained as followed: The first selection of additional articles was done based on the title, where specially was looked for titles mentioning standardization. From these selected articles the abstract was read. Then, based on the gained information from title and article it was decided if the article could be relevant for further expansion of the framework. The total approach described in this subchapter for the search of factors for success within multi-mode standardization is similar to the approach of the framework building of van de Kaa et al. (2011).

3.2 Data collection

For the first step of the BWM the criteria must be determined. From the constructed framework, consisting out of 45 number of factors in total, relevant criteria were identified via interviews and content analysis of available literature. Three employees involved with four different types of struvite installations at MWWTP within the Netherlands were interviewed to determine the relevant factors (Table 2). These interviews were open ended. The interviews with I1 and I2 were done in person while the interview with I3 was done over the telephone. Before the interviews about identifying possible relevant factors was started with I1 and I2, the following questions were asked:

- What was the reason to take a struvite installation?
- Where their specific requirements set when choosing a struvite installation?
- Where their other parties involved, and if so what was there influence?
- Is there information exchange between different and the same type of struvite installations?
- What do you think are the barriers for the further implementation of struvite installations within the Netherlands?
- Why is there not one specific struvite installation within the Netherlands?
- What could be your role as MWWTP towards standardization to one struvite installation?

Following up the questions the constructed framework was reviewed together to identify relevant factors. When an interviewee identified that a factor was relevant, it was asked to give a further explanation. At the end of the interviewee it was asked if the interviewee thought factors were missing. Due to limited time the interview with person I3, which was done by telephone, only the list of factors was discussed. Furthermore, available literature was studied to identify relevant factors from the constructed framework. All three interviews were held in Dutch and recorded, transcripts are available

of these interviews upon request. Factors are considered to be relevant when it was mentioned as by the interviewee or found in literature.

Table 2: Background of interviews for identification of relevant factors

Interviewee	Organization	Type of struvite installation
I1	Waterschap Vallei en Veluwe	NuReSys and Pearl Ostara
I2	Waterschap Amstel Gooi en Vecht	Airprex
I3	Waterschap Tilburg-Noord	Phospaq

3.3 Best Worst Method

Within the research approach in the introduction is explained that the BWM is used to rank the relevant factors. A broader explanation of the steps in order to determine the weight of these factors in given in this part (Rezaei, 2015, 2016).

Step 1

A set of decision criteria must be determined. These criteria (c_1, c_2 , … , c_n) are equal to the relevant factors determined in the previous paragraph.

Step 2

Through a second round of interviews, experts must determine the best and the worst criteria in general.

Step 3

Once the best criteria is determined, the experts were asked to compare the best criteria with the other criteria. To express their preference, they are asked to assign a number between a range of 1 to 9. Where 1 means this criteria j is equally important as the best criteria and 9 means that criteria j is extremely more unimportant than the best criteria. This will result in Best-to-Others vector:

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$$

Step 4

The next step in the interview was to ask the experts to compare the worst criteria with the other criteria. Similar like step three, the expert was asked to express their preference by assigning a number between a range of 1 to 9. Now, 1 means this criteria j is equally important as the worst criteria and 9 means criteria j is extremely more important than worst criteria. This will result in Worst-to-Others vector:

$$A_w = (a_{1w}, a_{2w}, \dots, a_{nw})^T$$

Step 5

In the final step the optimal weights are calculated. The optimal weights of each criteria is when $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_W} = a_{jW}$. Thus the optimal weights can be calculated when the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ for all j is minimized.

This leads to the following model to solve:

$$\min max_j \left\{\left|w_B - a_{Bj} w_j\right|, \left|w_j - a_{jW} W_w\right|\right\}$$

s.t.

$$\sum_j w_j = 1$$

$$w_j \geq 0, for\ all\ j$$

Which is equal to the following linear programming model

$$\min \xi^L$$

s.t.

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi^L, for\ all\ j$$
$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi^L, for\ all\ j$$
$$\sum_j w_j = 1$$
$$w_j \geq 0, for\ all\ j$$

By solving this problem, the optimal weight can be calculated. In which ξ^L is defined as the consistency ratio. The closer to zero this ξ^L is, the better the consistency in the results are, thus the more reliable the obtained results are. Within similar previous research, scores were said to be consistent if the ξ^L when the scores were not higher as 0.20 (van de Kaa, Scholten, et al., 2017). Therefore, within this research scores are considered consistent if they do not score above the 0.20.

3.4 Global and local weights determination

Once the relevant factors were identified in step 1 of the BWM, the importance of these factors can be determined. During the second round of interviews, the interviewee was first asked to make the comparison between the different categories (the category weights). Then, the interviewee was asked to compare the different factors within the category (the local weights). After the interviews, the global weight of the factors was determined through multiplication of the local weights against the category weights. This method is similar in earlier applied research using the BWM (van de Kaa, Fens, et al., 2018; van de Kaa, Kamp, et al., 2017).

3.5 Comparing outcome of BWM

During this research, the BWM was applied two times with the identified relevant factors divided within different categories. Interviews were first asked to rank factors and categories according to the proposed framework. The second time they were asked to rank factors and categories, were the factors were recategorized in new categories. These new categories were made in response to the first round of interviews were the relevant factors were determined. To examine if the obtained weight of a factor is significantly different, the paired samples T-Test or a Wilcoxon signed-rank test was employed. The paired samples T-Test was used if the obtained data is normally distributed otherwise the alternative, the Wilcoxon signed-rank test, was used (Sekaran & Bougie, 2016; Uva Wiki Methodologiewinkel, 2014a). The following two steps were followed with help of IBM SPSS Statistics 25 to determine if the obtained weights of one factor were significantly different:

Step 1

First the obtained weights of each factor were verified to be normally distributed. This was done via the Kolmogorov-Smirnov test, were the following hypotheses were assumed:

H_0: The data is normally distributed

H_a: The data is non-normally distributed

If a p-value of lower than 0,05 is obtained than the H_0 would be rejected (UvA Wiki Methodologiewinkel, 2014b).

Step 2

Following the results of step 1 it was chosen if the paired samples T-Test or Wilcoxon signed-ranked test to test for significance of the obtained weights of one factor. If the both weights of a factor following the BWM applied with the framework categories and newly made categories were considered normally distributed the paired samples T-Test was used. It was concluded that the difference in weights of the specific factor is significantly different if a p-value is smaller than 0,05 is obtained (Sekaran & Bougie, 2016; Uva Wiki Methodologiewinkel, 2014a). When from the same factor one or both weights were non-normally distributed, the Wilcoxon signed-rank test was used. Here, it was also assumed that if the p-value falls below 0,05 the difference between in weights of that factor is significant (Sekaran & Bougie, 2016; UvA Wiki Methodologiewinkel, 2014c).

4. Factors for success in multi-mode standardization

During the literature review a total of 51 articles were reviewed. Hereby the broad explanation given in Chapter 2.2 of successful standardization was used to identify factors. The reviewed articles resulted in extending and reforming the existing framework of van de Kaa et al. (2011) with 29 factors to 45 factors in total. The factors were categorized, based on their similarities, in one of the following categories: 'characteristics of the standard supporter', 'characteristics of committee composition', 'consensus reaching committee characteristics', 'characteristics of the standard', 'standard support strategy', 'other stakeholders', and 'environmental factors'. In the following part of this chapter the categories and the classified factors within these categories following the literature study will be shortly elaborated. The full explanation of the multiple ways how the identified factors can influence the standardization process is given Appendix B. Additionally, in Appendix C a full list of studied literature and in which type of multi-mode the article could be described as is given.

4.1 Characteristics of the standard supporter

The first group of factors were categorized where the factors relate to the strength of the standard supporter or group of supports. A greater strength within the supporters enhances the chance of becoming successful within the standardization process. Standardization can be seen as a long process in which high costs are involved. To be able to participate firms and survive the standardization process, a firm or groups of firms need 'financial strength' to carry them through this period (Mattli & Büthe, 2003; van de Kaa et al., 2011). Another important aspect is to be able to create legitimacy around the proposed standard. Here previous made 'brand, reputation and credibility' help with creating this legitimacy (Bakker et al., 2015; T. Egyedi & Spirco, 2011; van den Ende et al., 2012). Furthermore, firms each have their own resources. By making better use of these resources by having a greater superior production capacity, in other words 'operational supremacy', helps to gain an advantage within the standardization process (van de Kaa et al., 2011). Not only good use of the resources is important. The 'learning orientation', thus the ability to learn from previous experiences is also highly important. This can help preventing making the same mistake twice within a standardization process by recognizing comparable situations (Funk & Methe, 2001; Meyer, 2012). In similar lines with learning from the past, the ability to estimate the future, 'foresight', is a valuable strength. For instance, a lack of 'foresight' can lead to multiple conflicting standards which is seen in most of the times as standardization failure (Abbate, 2001; Puffert, 2000, 2002). Finally, 'coordination through market leadership' is possible where a market leader uses its powers to steer the standardization process in its own advantages. Here, the market leaders can choose not to accept a proposed standard by a committee. Then, through lobbying, pushing the government to intervene within the standardization process. Resulting in an enforced standard by the government (T. Egyedi & Spirco, 2011; T. M. Egyedi, 2000).

4.2 Characteristics influencing the committee composition

The next group of factors are related to the composition of a committee. As explained in Chapter 2.1 factors description where a group of firms which are collaborating such as consortia, alliances, or committees are named will all be referred to as committees for simplicity. This due to one important observed similarity, they all work together to be successful within the standardization process. The composition of the committee can change over time. This not only influences if consensus about a proposed standard can be reached. It also influences the chances of a standard being successfully deployment. Here, 'size of a committee' and 'diversity within a committee' influences both consensuses reaching and the deployment of a standard. A larger committee has broader support towards the proposed standard, increases it chances of being successful deployed. Furthermore, the more diverse a committee, the better it fits with the needs of the buyers making it more likeable to be successful. However, the larger and more diverse a committee is, the more people needs to agree with the proposed standard. This makes it more difficult to control a committee and to reach consensus within a committee (Axelrod et al., 1995; Markus, Steinfield, & Wigand, 2006; van den Ende et al.,

2012). Firms might try to influence the size of a committee by 'distribution of employees of firm within standardization committees'. This can be done to gain an upper hand in the voting process to ensure the consensus is being reached or a proposal is steered toward a certain direction (Leiponen, 2008; van de Kaa & de Bruijn, 2015). When firms know that they can gain something by joining a committee, named the 'winners effect', there are more likely to join and stay in a committee. This causes directly a change in size and possible diversity of the committee. Furthermore, these firms might bring along essential information, like IPR, needed for successful design of a proposed standard (van de Kaa & de Bruijn, 2015; Vercoulen & van Wegberg, 1998). As mentioned earlier the larger and more diverse a committee is, the harder it might be to reach consensus. Controlling of the size and diversity of a committee can be done via 'exclusivity of a committee'. By having participants paying a participation fee, a committee because more exclusive for example (Axelrod et al., 1995; Markus et al., 2006). Lastly, committee formation does not occur spontaneously. The 'committee formation capabilities by stakeholder' can be important in order to reach technological superiority which increases the chances of being successful within standardization process (Dan, 2018; X. Gao, 2014).

4.3 Consensus reaching committee characteristics

Within committees there are factors identified which are only involved with the consensus reaching process. This is the next category which is being discussed, consensus reaching committee characteristics. Here, the first factor which is classified within this category is the 'rule of voting'. There are multiple ways, normally pre-discussed, how consensus is reached within a committee. The knowledge of how a standard is determined, can be used by companies through strategic voting to achieve or hinder the consensus reaching (Borraz, 2007; Gandal, Salant, & Waverman, 2003; Spulber, 2016). Furthermore, in some committees there is the presence of 'veto points'. Within the studied literature, usage of this veto points is done to cause delay or even standardization failure (Hail, Leuz, & Wysocki, 2010; Meyer, 2012). Another important aspect if consensus can be reached is 'coordination within a committee'. As there are multiple parties involved in committees who have their own private interest (Borraz, 2007; Garud, Jain, & Kumaraswamy, 2002). Finally, the 'timing of participation' of a firm to join a committee influences amongst other the position a firm can gain. By gaining an important position such as chair, the standardization process can be more easily influenced and thus if consensus about a standard is reached (Blind & Gauch, 2009).

4.4 Characteristics of the standard

The next category involves factors which relate to the characteristics of the standard itself. Here, the more superior proposed standard has a higher chance of being successful. There are two factors which are involved during the design phase of the standard. These factors are the 'flexibility of the standard during the standard design' and 'openness of standard during standard design'. The flexibility influences amongst others how much changes stakeholders can make within a proposed standard. A higher flexibility means that the standard is more easily changed to the stakeholders wishes or needs, leading to higher chances of being successful (T. Egyedi & Spirco, 2011; van den Ende et al., 2012). The openness revolves around if information about a standard is easily shared, such as the IPR. Here, for example, when this information is freely available it encourages compatibility between different systems (Abbate, 2001). Furthermore, 'compatibility' was identified as a factor as well. There is spoken of 'compatibility' when two interrelated entities can fit and function together. When a proposed standard is compatible it positively influences the chances of being successful. Furthermore, when a standard has 'technological superiority' it means it contains features which makes it better compared to other standard. These type of proposed standards also are more likely to be successful (van de Kaa et al., 2011). The final factor identified within this category is the 'complementary goods'. The number of these available 'complementary goods' which are used with a proposed standard influence the standardization process. Were a greater amount of variety of such 'complementary goods' positively influences it chances of success of the proposed standard (van de Kaa et al., 2011).

4.5 Standard support strategy

Once a possible standard is designed, stakeholders may apply different strategies to be successful within the standardization process. Within this category different factors around this standard support strategy are discussed. First, the 'pricing strategy' of possible standard is important as it influence the possible market share. Other examples of strategies which can be taken by firms are 'appropriability strategy' (e.g. protection of possible imitation), 'distribution strategy' (e.g. strategies used to increase distribution system strengths), or 'market communications' (e.g. early announcement in order delaying competitive products) (van de Kaa et al., 2011). These are all factors which influence the chances if a proposed standard is going to be successful. Furthermore, 'financial support' can be offered by different parties such as the government for example. This 'financial support' can help with the implementation of a proposed standard (Meyer, 2012). Besides the investment which must be made is of importance, the time when a standard is made available, i.e. 'timing of entry', is important. An early timing of a proposed standard can help creating an installed base. Which positively relates to success of a standard (van de Kaa et al., 2011). Furthermore, the 'possession of scare assets' can determine which standard can be successful. As these assets are essentially involved with the proposed standard. The possession of these assets can be owned by firms, but also by the government (Funk & Methe, 2001; P. Gao, Yu, & Lyytinen, 2014). Other support strategies which can be applied by the government are 'regulation by government' or 'control of the market by government'. Here, a standard can be obligated or through usage of immense purchase power which the government possesses (Cabral & Kretschmer, 2006; Rosen, Schnaars, & Shani, 1988). Firms can use the strategy 'lobbying' to gain government support. This strategy might also be used in committees to push stakeholders to make use of their veto point (T. Egyedi & Spirco, 2011; T. M. Egyedi, 2000; Meyer, 2012). The final two factors within this category are 'commitment' and 'agenda setting'. 'Commitment' is important as stakeholders within a committee for instance have to accept and adopted standards in order to be successful in standardization process (Funk & Methe, 2001). 'Agenda setting' can be done by different stakeholders. Through the alignment of interest and the raising awareness about possible standards, the chances of standardization being successful increases (Garud et al., 2002; Markard & Erlinghagen, 2017).

4.6 Other stakeholders

The next group of factors are factors related to other stakeholders than the standard support group. Other stakeholders involve the people or firms who can possibly purchase the proposed standard. This creates a 'current installed base'. Where a higher installed base increases the chances of a standard being successful. Furthermore, owners of previous similar standards give rise to a 'previous installed base'. If a newly proposed standard can be seen as an upgrade from an already established standard. This 'previous installed base' can help with adaptation of the new proposed standard (van de Kaa et al., 2011). Another important stakeholder which is identified within the category is a 'big fish', this can be for example a player who influences the availability of complementary goods or gives exclusive support. Support of such a player towards a proposed standard has a positive influence on the standardization process (Markus et al., 2006; van den Ende et al., 2012). Finally, there are the 'suppliers' within this category. Gaining support of broad range of suppliers who deliver services related to the standard is of influence of the possible success (van de Kaa et al., 2011).

4.7 Environmental factors

The last group of factors which is being discussed are the environmental factors. These are factors which are present in the standardization process. However, these factors cannot be influenced by firms. The first factor being discussed in this group is 'network externalities'. This factor can be described as the value of a product which increases with every new user. When there is a high installed base, the network externalities will be high as well. Thus, the chances of being successful are increased. During the standardization process it might be the case that users choose to implement a solution to their problem which has proven to work by other users. This is known as the 'bandwagon effect' and

positively effects the standardization process of that specific used solution (van de Kaa et al., 2011). Another factor which helps during standardization is a 'scandal or accident'. After such a 'scandal or accident' the need of certain standard arises, facilitating the standardization process (Delmas & Montiel, 2008; Trienekens & Zuurbier, 2008). Furthermore, there as some environmental factors which influence the possible standardization negatively. If there are 'multiple standards', it influences the possible market share which can be obtained. When there are more options of possible standards, this negatively influences the chance of being successful for each standard. Additionally, 'uncertainty in the market' has a negative effect like 'multiple standards'. The customers delay buying a possible standard due to uncertainty. As they do not want to take a risk attached by choosing a specific standard. Finally, there are the 'switching costs' which are the costs involved by switching between different standards. If these costs are high its negatively influences possible adaptation of a standard as well (van de Kaa et al., 2011).

5. Case results

5.1 Case analysis of relevant factors

During this research the possible standardization of struvite installations in a MWWTP for phosphorus recovery was further studied by applying the BWM. As mentioned in Chapter 3.3, the first step of this method is the identification of relevant factors. The relevant factors from the proposed framework in Chapter 4 were identified through interviews and by a content analysis of available literature. This resulted in a list of eleven factors in total, namely: 'financial strength', 'technological superiority', 'compatibility', 'complementary goods', 'pricing strategy', 'appropriability strategy', 'market communications', 'financial support', 'agenda setting', 'current installed base' and 'suppliers'. An overview of the identified factors and in which category they were assigned, according to Chapter 4 is given Figure 3 on the left side. The full justification of why factors were deemed to be relevant is given in Appendix D.1. Furthermore, during the interviews it was indicated by the experts that some identified factors were indeed relevant. However, these factors were influenced by other actors than the technology provider of the struvite installation (I1, 2019; I2, 2019; I3, 2019). Therefore, is was chosen to recategorize the factors in core and peripheral influence factors. Where the core influence factors can be described as the factors which have direct relevance with the technology provider. While the peripheral core influence factors are the factors were other actors than the technology provider play an important role. For example, the 'technological superiority' is categorized in the core influence as the technological aspects are designed by the technology provider. However, the price which is being paid for a struvite installation is not determined by the technology provider. As a total price is paid for installation of the struvite installation and all additional requirements. This price is determined by a main contractor and not by the technology provider. Thus 'pricing strategy' was

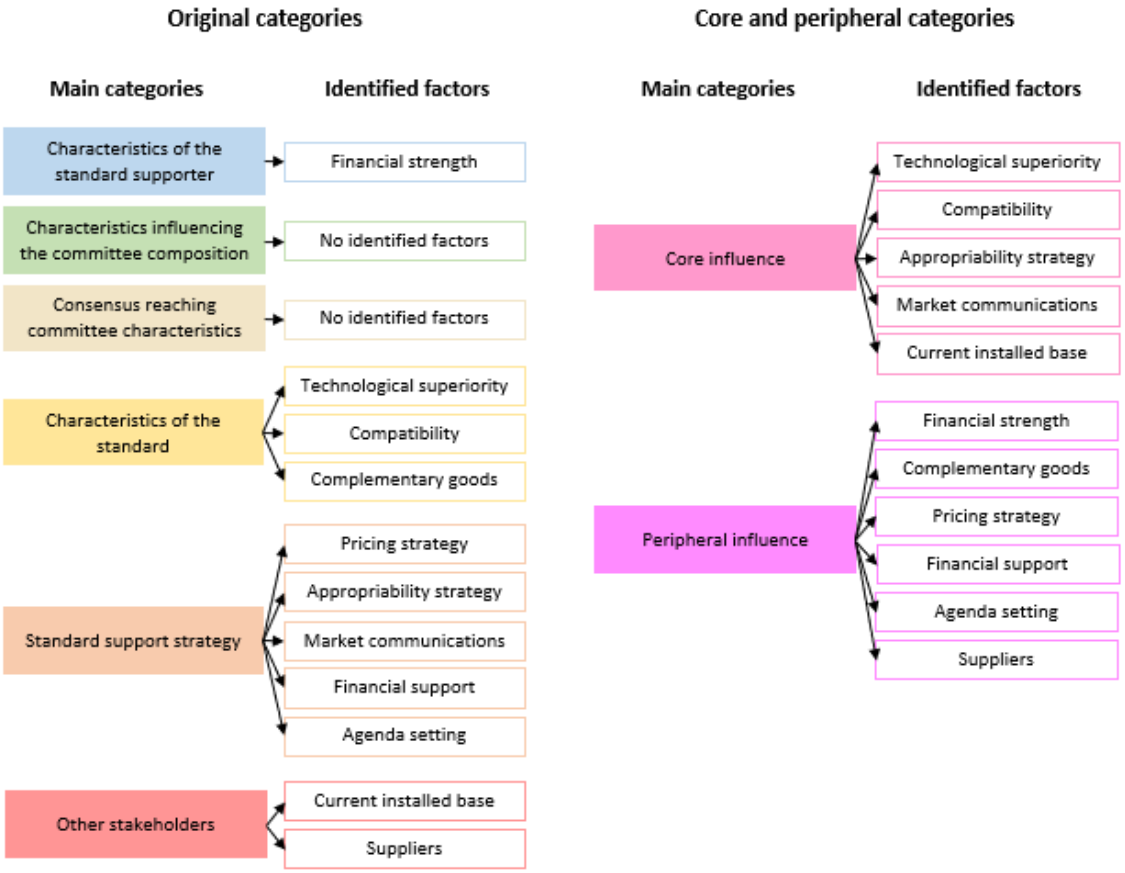

Figure 3: An overview of the identified relevant factors. On the left side the factors are represented with the categories as proposed in Chapter 4, on the right side the factors are given within core and peripheral influence factors categories as indicated by t

classified within the peripheral influence factors category. Following these examples, the factors 'compatibility', 'appropriability strategy', 'market communications', and 'current installed base' were recategorized within the core influence factors category. While the other factors 'financial strength', 'complementary goods', 'financial support', 'agenda setting', and 'suppliers' were classified within the peripheral influence factors category. The full explanation why these factors were assigned to core or peripheral category can be found in Appendix D.2. In Figure 3 on the left side an overview is given of the relevant factors within the core and peripheral influence categories.

5.2 Strength of relevant factors

Once the relevant factors were identified, the strength and the consistency ratio could be determined by applying the BWM. Step 2 up untill step 5 of the BWM according to Chapter 3.3 were applied two times. First the BMW was employed with the factors divided within the 'original categories', the categories according to the framework in Chapter 4 (Figure 3, left side). The experts were asked to make pairwise comparison between the categories. Furthermore, they were asked to only make pairwise comparisons of factors which were present within the same category. This resulted in the category and local weights, as explained in Chapter 3.3. Then the global weights were determined by multiplying the category weight with local weight of the factors present in that category. The results of the obtained local and global weights of the BWM employed with the original categories are given in Table 4. From these results it can be concluded that 'financial strength', 'technological superiority', and 'compatibility' form the top three most important factors. As these factors score the highest global weights. The second time the BWM was be applied with the 'core and peripheral categories' (Figure 3, right side). The experts were asked to make again a pairwise comparison between the categories and the factors classified within these categories. The obtained weights of this second round of the BWM are given in Table 6. Here the top three scoring factors were 'technological superiority', 'compatibility', and 'current installed base'. Thus, the results of the BWM employed with the 'original categories' and the 'core and peripheral categories' differs. Finally, within step 5 of the BWM the consistency ratio (ξ^L) was calculated. The ξ^L represented the consistency of the scores given by experts. The closer this number is to zero, the more consistent the answers of the experts were. The obtained ξ^L are given in Table 3 for the BWM employed with the 'original categories' and in Table 5 for the 'core and peripheral categories'. Overall none of the individual ξ^L scores higher as 0,18. These scores were not higher than the given limit of 0.2 given in Chapter 3.3. Thus it is concluded that the obtained results can be considered to be consistent.

5.3 Statistical comparison of the obtained weights

The global weight scores of the identified factors from the two BWM cases were compared in order examine if the difference is significant. For example, it was tested if the score of the factor financial strength obtained via the BMW applied with the 'original categories' significantly differs from the score obtained using the 'core and peripheral categories'. To test for significant differences a paired sample T-Test or Wilcoxon signed-rank test was used. To determine which test would be used, it was first checked if the data is normally or non-normally distributed, as explained in Chapter 3.4. By using the Kolmogorov-Smirnov test it was determined if the weight of a factor was normally distributed (Table 7). When the weights of one factor from both BWM outcomes was normally distributed, the paired samples T-Test was used. Else, the Wilcoxon signed-rank test was used to determine if the difference is significant. The used method to test for significant differences between weights of a factor is given in Table 7. The full SPSS results are displayed in Appendix E. In Figure 4 the global weights of the factors are given. Furthermore, it is indicated if there is a significant difference between scores within a factor. From the obtained data it can be concluded that the weights obtained from 'financial strength', 'appropriability strategy', 'market communications' and 'suppliers' are significantly different. For the other factors it can be said that 'technological superiority' and 'compatibility' are the highest scoring factors. As these are the only two factors which have a weight above 0.175. The factors 'pricing strategy', 'agenda setting', and 'current installed base' can be named as the medium important factors.

These factors have weights between 006-0.175. Finally, ‘complementary goods’, ‘market communications’, ‘financial support and ‘suppliers’ were classified as the low important factors. The scores of these factors do not rise above 0.06. The factors where the obtained weights were significantly different were not taken along while naming the high, medium, and low important factors.

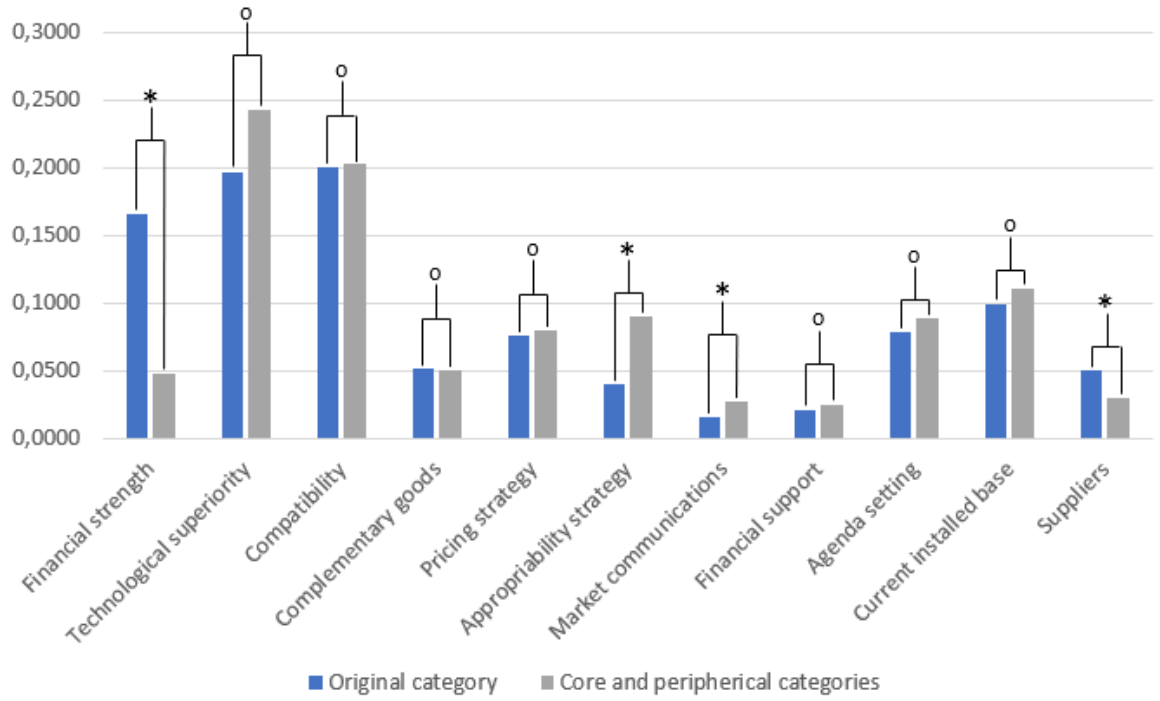

*Figure 4: Overview of global weights obtained via the BWM when factors were divided within the original category or within core and peripheral categories. If the difference in weight is significantly different it is marked with a * otherwise with a ᵒ.*

*Table 3: Consistency ratio (ξ^L) result of BWM applied with original categories according to Chapter 4. The ξ^L which have a score of 0 and are indicated with a * are as in these categories no comparison could be made or a comparison with only two factors were made, within this case it not possible to have an inconsistency.*

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Average
Categories	0,1622	0,1325	0,1667	0,1520	0,1579	0,0517	0,0517	0,1250
Characteristics of the standard supporter	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000
Characteristics of the standard	0,0600	0,1111	0,1724	0,0889	0,1731	0,1000	0,1000	0,1151
Standard support strategy	0,0822	0,1466	0,1182	0,1296	0,0754	0,0907	0,1001	0,1061
Other stakeholders	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000	0,0000

Table 4: Local and average global weight results of BWM applied with original categories according to Chapter 4

Factors	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Local average weight	Global average weight
Characteristics of the standard support	0,0676	0,1084	0,2464	0,0585	0,4737	0,1034	0,1034		**0,1659**
Financial strength	1,0000*	1,0000*	1,0000*	1,0000*	1,0000*	1,0000*	1,0000	1,0000	0,1659
Characteristics of the standard	0,5676	0,5181	0,5725	0,4444	0,3158	0,2586	0,4655		**0,4489**
Technological superiority	0,2400	0,4074	0,3793	0,6444	0,3654	0,5000	0,6000	0,4481	0,1964
Compatibility	0,6600	0,5185	0,5517	0,2444	0,5577	0,2000	0,2333	0,4237	0,2006
Complementary goods	0,1000	0,0741	0,0690	0,1111	0,0769	0,3000	0,1667	0,1282	0,0519
Standard support strategy	0,1216	0,3253	0,1232	0,2982	0,0526	0,4655	0,2586		**0,2350**
Pricing strategy	0,2466	0,1466	0,4136	0,5185	0,3579	0,2721	0,4186	0,3391	0,0767
Appropriability strategy	0,4110	0,2932	0,1773	0,0926	0,1083	0,0778	0,1729	0,1904	0,0402
Market communications	0,1233	0,0366	0,1064	0,0432	0,1444	0,0605	0,1037	0,0883	0,0165
Financial support	0,0548	0,0838	0,0369	0,1296	0,0314	0,1361	0,0455	0,0740	0,0220
Agenda setting	0,1644	0,4398	0,2659	0,2160	0,3579	0,4536	0,2593	0,3081	0,0796
Other stakeholders	0,2432	0,0482	0,0580	0,1988	0,1579	0,1724	0,1724		**0,1501**
Current installed base	0,8333	0,7500	0,8750	0,6667	0,7500	0,2500	0,6667	0,6845	0,0998
Suppliers	0,1667	0,2500	0,1250	0,3333	0,2500	0,7500	0,3333	0,3155	0,0503

*Table 5: Consistency ratio (ξ^L) result of BWM applied with core and peripheral influence categories. The ξ^L which have a score of 0 and are indicated with a * are as in these categories no comparison could be made or a comparison with only two factors were made, within this case it not possible to have an inconsistency.*

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Average
Categories	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*	0,0000*
Core influence	0,1385	0,0741	0,1455	0,1558	0,0947	0,0738	0,1304	0,1161
Peripheral influence	0,0870	0,1037	0,0781	0,1289	0,0852	0,1239	0,1181	0,1036

Table 6: Local and average global weight results of BWM applied with core and peripheral influence categories

Factors	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Local average weight	Global average weight
Core influence	0,8889	0,8333	0,6667	0,6667	0,6667	0,3333	0,6667		0,6746
Technological superiority	0,1692	0,3704	0,3134	0,4674	0,4736	0,4180	0,3913	0,3719	0,2422
Compatibility	0,3692	0,2222	0,4813	0,2077	0,2842	0,2459	0,2609	0,2959	0,2026
Appropriability strategy	0,1692	0,1481	0,0784	0,1246	0,0812	0,1639	0,1739	0,1342	0,0906
Market communications	0,0385	0,0370	0,0373	0,0445	0,0474	0,0492	0,0435	0,0425	0,0281
Current installed base	0,2538	0,2222	0,0896	0,1558	0,1137	0,1230	0,1304	0,1555	0,1112
Peripheral influence	0,1111	0,1667	0,3333	0,3333	0,3333	0,6667	0,3333		0,3254
Financial strength	0,0870	0,0855	0,3594	0,0403	0,3693	0,0437	0,0945	0,1542	0,0487
Complementary goods	0,0435	0,2137	0,1094	0,1160	0,1136	0,1846	0,2362	0,1453	0,0508
Pricing strategy	0,1739	0,3237	0,2188	0,4513	0,2273	0,1108	0,3543	0,2657	0,0806
Financial support	0,0870	0,0314	0,0625	0,1160	0,0909	0,0923	0,0394	0,0742	0,0256
Agenda setting	0,4348	0,2923	0,2188	0,1934	0,1515	0,4300	0,1575	0,2683	0,0892
Suppliers	0,1739	0,0534	0,0313	0,0829	0,0473	0,1385	0,1181	0,0922	0,0305

Table 7: Short overview of SPSS if the weight of factors is normally distributed and which type of test was applied in order to check for a significance difference between weights of one factor.

Factor	Normally distributed?	Type test applied	Factor	Normally distributed?	Type test applied
Financial strength OC Financial strength CPC	No No	Wilcoxon signed-rank test	Market communications OC Market communications CPC	Yes Yes	Paired samples T-Test
Technological superiority OC Technological superiority CPC	Yes Yes	Paired samples T-Test	Financial support OC Financial support CPC	Yes Yes	Paired samples T-Test
Compatibility OC Compatibility CPC	Yes Yes	Paired samples T-Test	Agenda setting OC Agenda setting CPC	Yes No	Wilcoxon signed-rank test
Complementary goods OC Complementary goods CPC	Yes No	Wilcoxon signed-rank test	Current installed base OC Current installed base CPC	Yes Yes	Paired samples T-Test
Pricing strategy OC Pricing strategy CPC	Yes Yes	Paired samples T-Test	Suppliers OC Suppliers CPC	Yes Yes	Paired samples T-Test
Appropriability strategy OC Appropriability strategy CPC	Yes Yes				

6. Discussion

6.1 Identified factors for success in multi-mode standardization

The first step within this thesis was composing a framework including factors for success within multi-mode standardization. This was done to answer the first sub-question of this research: "*"What are the factors for success in multi-mode standardization process?".* For this the framework of van de Kaa et al. (2011) was extended and reformed through a literature research. Therefore, articles stemming from already identified literature about multi-mode standardization by Wiegmann et al. (2017) and additional searched literature were used. Factors were identified within the theoretical background as well as through analyzed cases of the studied literature. In some studied literature the possible theory about multi-mode standardization was clearly discussed. However, this was not the case for all articles. While some factors were clearly indicated by the authors, other factors were named indirectly. Furthermore, the subjects of the studied cases were very divergent. Some cases could be seen in the industry context of information technology, other studied literature were involved within transportation, telecom, consumer electronic, financial services, manufacturing, or even environmental management (Wiegmann et al., 2017). This made identification of factors sometimes a challenge, as the knowledge within these fields was limited. This was especially the case for the indirect named factors. In the end, the answer of the first sub-question of this research led to a framework including 45 factors involved with success in multi-mode standardization.

In total, the framework from van de Kaa et al. (2011) was expanded from 29 factors within five categories to 45 factors within seven categories. Moreover, some factors from the existing framework were modified and moved to other categories within the new proposed framework. An overview of these modifications compared to the framework of van de Kaa et al. (2011) is given in Table 8. Within the first category, 'characteristics of the standard supporter', the framework was extended with two additional factors. The second and third category, 'characteristics influencing the committee composition' and 'consensus reaching committee characteristics', were added to the framework including 10 factors. Within the fourth category, 'characteristics of the standard', the factor 'flexibility' was split up into two different factors, namely 'flexibility of adaptation' and 'flexibility during standard design'. Additionally, in this fourth category one new factor was added. Resulting, that this fourth category was expanded from four factors to six factors. The next category, 'standard support strategy', a total of five factors were added. Hereof, the factors 'regulator' and 'antitrust law' were first categorized within the 'other stakeholders' category. These two factors were recategorized to the 'standard support strategy' and were redefined to 'regulation by government' and 'control of the market by government'. As within multi-mode standardization the government is identified as a standard supporter. Within the next category, 'other stakeholders', the most changes were made. As earlier discussed, the factors 'regulator' and 'antitrust laws' were redefined and moved to another category. Additionally, the factors 'effectiveness of the format development process' and 'network of stakeholders' were removed. The factor 'effectiveness of the format development' describes that a standard can be designed by a single stakeholder, group of stakeholders, or by SDO. Difference in amongst others management in these groups influences the effectiveness of a standardization process (van de Kaa et al., 2011). This factor is now covered by factors within the 'characteristics influencing the committee composition' and 'consensus reaching committee characteristics' categories. The factor 'network of stakeholder', which describers that several characteristics of the network of stakeholder could positively influence the standardization process, especially the diversity of the network of stakeholders (van de Kaa et al., 2011). This factor is amongst others covered by 'diversity within a committee' in the 'characteristics of committee outlook' category. Finally, the category 'environmental factors' was expanded with one factor.

Table 8: Overview of expanding and reforming framework of van de Kaa et al. (2011). Where the green square represented factors which were already identified, the blue square represents newly identified factors and the yellow square represent factors which has been reformed and possibly moved to another category.

Factor	van de Kaa et al. (2011)	Factor	van de Kaa et al. (2011)	Factor	van de Kaa et al. (2011)
Characteristics of the standard supporter		***Characteristics of the standard***		***Other stakeholders***	
1 Financial strength		17 Technological superiority		35 Current installed base	
2 Brand reputation and credibility		18 Compatibility		36 Previous installed base	
3 Operational supremacy		19 Complementary goods		37 Big fish	
4 Learning orientation		20 Flexibility of adaptation		38 Suppliers	
5 Coordination through market leadership		21 Flexibility of standard design			
6 Foresight		22 Openness of standard during standard design		***Environmental factors***	
				39 Bandwagon effect	
Characteristics influencing the committee composition		***Standard support strategy***		40 Network externalities	
7 Size of committee		23 Pricing strategy		41 Multiple standards	
8 Diversity within a committee		24 Appropriability strategy		42 Uncertainty in the market	
9 Committee formation capabilities by stakeholder		25 Timing of entry		43 Rate of change	
10 Winners effect		26 Market communications		44 Switching costs	
11 Exclusivity of a committee		27 Possession of scare assets		45 Scandal or accident	
12 Distribution of employees of a firm within standardization committees		28 Distribution strategy			
		29 Commitment			
Consensus reaching committee characteristics		30 Regulation by government			
13 Coordination within a committee		31 Control of the market by government			
14 Rule of voting		32 Financial support			
15 Veto points		33 Lobbying			
16 Timing of participation		34 Agenda setting			

6.2 Identified relevant factors and their strength when choosing a struvite installation

6.2.1 Identified relevant factors

The second step in this research was to identify the relevant factors from the proposed framework which include factors for success within multi-mode standardization. This part of information gathering was done to answer the second sub-research question: *"What are the relevant factors for phosphorus recovery in form of struvite from municipal wastewater according to literature and experts?"*. These factors were identified through a content analysis of available literature and through expert interviews. The second sub-research question can be answered with the total of eleven factors which were identified as relevant, namely: 'financial strength', 'technological superiority', 'compatibility', 'complementary goods', 'pricing strategy', 'appropriability strategy', 'market communications', 'financial support', 'agenda setting', 'current installed base' and 'suppliers'. From the total of eleven factors which were identified as relevant, only two factors (i.e. 'agenda setting' and 'financial support') were new in the proposed framework.

6.2.2 Strength of the identified relevant factors

The third step within this research was to employ the BWM to calculate the strength of the identified relevant factors. This was done to answer the third and final sub-question: "*What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?"*. During the first interviews, it was notified by the experts that relevant factors were influenced by different actors. Therefore, it was chosen that the BWM was applied two times in this research by dividing the factors in different categories. First the BWM was applied with factors divided in the 'original categories' according to the proposed framework. The second time the factors were divided in 'core and peripheral categories' according to if factors were influenced by technology providers (core influence category) or by other actors (peripheral influence category). The obtained global weights for the factors of the 'original categories' and the 'core and peripheral categories' are displayed in Table 4 and in Table 6. These weights showed significance difference as shown in Chapter 5.3, further elaboration on this significance difference will be given before answering the third sub-question of this research.

6.3 Significance difference within the factors

Within Chapter 5.2 it was observed that the top scoring factors when the BWM was applied with the 'original categories' differs in scores obtained from the 'core and peripheral categories'. Furthermore, in Chapter 5.3, it was shown that the obtained weights within the factors for 'financial strength', 'appropriability strategy', 'market communications' and 'suppliers' were significantly different, where, the obtained weights of the factor 'financial strength' deviate the most. The weight of 'financial strength' obtained by the BWM applied with 'original categories' scores at least three times higher than the score obtained via the BWM with 'core and peripheral categories'. Furthermore, the factor 'financial strength' was identified as one of the top three scoring factors from the BWM applied with the 'original categories' as shown in Table 4. In this table is can also be observed that this factor is categorized within the third scoring category 'characteristics of the standard supporter'. While the other two factors of the top three scoring factors are stemming from the most important identified category 'characteristics of the standard'. Meaning that none of the factors of the category which was identified as the second most important category 'standard support strategy' can be found in the top three scoring factors. In the following part of this subchapter two explanations are given for the obtained results that a significance difference between weights of factors were found.

6.3.1 Non-comparable number of factors in categories

The global weight of 'financial strength' is equal to the category weight of its category 'characteristics of the standard support', as it is the only factor within the category. Meanwhile in a category such as 'standard support strategy' the category weight must be divided over five factors for the calculations

of the global score. This is because with the BWM method the sum of the category weights is equal to one and the sum of all global weights is equal to one as well (Chapter 3.3). The different number of factors within a category can cause a biased distribution for the obtained global scores, observed with the factor 'financial strength'. As the top three scoring factors from the BWM applied with 'original categories' were stemming from the first and third scoring categories. When 'financial strength' was categorized in a category with other factors, as done with the BWM applied with 'core and peripheral categories', the obtained weight is lower. Hence, 'financial strength' is no longer a top three scoring factor (Table 6). A similar explanation can be applied to why the factor 'suppliers' gets a higher global score within the BWM with the 'original categories' when compared with BWM with 'core and peripheral categories'. As 'suppliers' is in a category with only two factors, as opposed to the other categories where more factors are present. Thus, the uneven distribution of factors within the categories causes biased results.

6.3.2 Advantages of a high scoring category

The other two factors where a significant difference is observed were the factors 'appropriability strategy' and 'market communications'. These two factors score higher with the BWM applied with the 'core and peripheral categories' than with the 'original categories'(Figure 4). A possible explanation for these higher scoring factors could be as follows: Both factors cannot be considered as high scoring factors when categorized in the 'original categories' (Table 4, 'standard support strategy') or in the 'core and peripheral categories' (Table 6, 'core influence'). However, the category weight obtained via the BWM is very high for the 'core influence' category when compared to the weight obtained for the 'standard support strategy' category. Thus, the high score of the category can have the effect that low scoring factors get a higher global weight assigned causing the significant difference. However, it is also crucial to notice that these factors still are not seen as the most important factors.

6.4 Top ranked factors

During this research and as earlier mentioned, the top-ranking factors from the two applied BWM differs. As discussed in Chapter 6.3 the unequal number of factors divided in categories can cause biased results. Furthermore, high scoring category weights can also lead to biased results of the lower scoring factors in that category. As some of the results are biased, due to the significant difference between the obtained weights, the third and final sub-question, which was "*What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?",* cannot be fully answered. Only the weights of the factors where no significant difference between the importance is found, can be accepted. It was chosen, here, to only give further elaboration on the two top ranking factors from the categories with the results of the BWM applied with the 'core and peripheral categories. As the number of factors in categories are comparable and by only assessing the top two scoring factors of each category, the possibility of advantages of high scoring category were also eliminated. The following factors which are considered as top scoring factors were: 'technological superiority', 'compatibility', 'agenda setting' and 'pricing strategy' (Table 6). Coincidentally these were also the top two scoring factors from the top two scoring categories from the results with the BWM applied to the 'original categories' (Table 4). Furthermore, these four factors show no significance difference in obtained weights within the factor (Figure 4).

6.4.1 Technological superiority

'Technological superiority', together with 'compatibility', were clearly indicated as the most important factors when choosing a struvite installation. This outcome came as no surprise, as during the interviews the experts did not need much time to indicate these two factors as most important, while they did need more time to rank the remaining factors. Furthermore, the explanation for this choice given by the experts was very similar.

For ‘technological superiority’ the high importance was indicated because a certain performance of the struvite installation is wanted. For example, each MWWTP has a certain amount of water which must be treated with a specific effluent concentration of phosphorus. If this performance cannot be met, one might question the relevance of taken on such installation. With other comparable and recently published BWM research, ‘technological superiority’ ended up in the top ranking factor three out of four times (van de Kaa, Fens, et al., 2018; van de Kaa, Janssen, & Rezaei, 2018; van de Kaa, Kamp, et al., 2017; van de Kaa, Scholten, et al., 2017). Giving a strong indicator that ‘technology superiority’ is very important within the standards battle field. Within van de Kaa, Kamp, et al. (2017) installations which treat biomass are discussed. This case has as similarity to the struvite installation case since it is not about a consumption good, but about an installation producing products which are being sold. In this research the following explanation about ‘technological superiority’ is given “It is important to what extent the technology can fulfill its purpose in an effective, efficient, and cost-effective way (van de Kaa, Kamp, et al., 2017)”. However, this argument does not hold in the struvite case. Experts have indicated that the mean purpose of such installation is to lower the operational costs of the MWTTP. Thus, not necessarily for the production and selling of struvite. There is high importance on phosphorus recycling, however this can also be achieved via other methods. As the main goal is to lower the operational costs the technological performance and the fit to the needs of the MWWTP, thus ‘technological superiority’, is indicated as very important by the experts.

6.4.2 Compatibility

Together with ‘technological superiority’, ‘compatibility’ was indicated as highly important. The experts argued that the struvite installation can be seen an additional process within the MWWTP. The main focus of MWWTP is on producing clean water, thus not on the production of struvite. Such struvite installations must work together with the rest of the MWWTP. Experts said in general, that first the installation had to fit in with a specific water flow within the MWWTP. Secondly, the MWWTP could not fully depended on the functioning of the struvite installation. Meaning that if the struvite installation is turned off, the rest of the MWWTP should still be working. Therefore, ‘compatibility’ was ranked as very important by experts. One expert even indicated that the struvite installation could be seen as complementary good of another installation which was purchased simultaneously (I3, 2019). In the earlier compared articles (van de Kaa, Fens, et al., 2018; van de Kaa, Janssen, et al., 2018; van de Kaa, Kamp, et al., 2017; van de Kaa, Scholten, et al., 2017), ‘compatibility’ was determined to be relevant. However, it was never discussed as one of the most important factors as in this case. It might be because that the discussed technologies within these articles are viewed as an essential technology. In this case, as earlier discussed, the struvite installation is seen as additional technology within the MWWTP. A MWWTP must work even if a struvite installation is not present or fully functioning.

6.4.3 Agenda setting

‘Agenda setting’ is one of the factors of the newly proposed framework from Chapter 4 and it is absent in earlier frameworks around standardization. Although this factor did not come to mind to the experts during the first round of interviews (Table 13). This factor was indicated as highly important in the categories in which it was categorized during the second phase of this research. When discussing this factor during the BWM interviews, the experts indicated the “Ketenakkoord Fosfaatkringloop” was indeed of influence. Through Union of Water Board the MWWTPs have signed this accord. Herewith, they are not obligated to take a struvite installation. However, experts indicated that it did help to motivate them to look for possible solutions for the recycling of phosphorus to help closing the P-cycle. This successful ‘agenda setting’ can be seen in the best interest for the future of the life, as life without phosphorus is impossible (Buckwell & Nadeu, 2016; Butusov & Jernelöv, 2013). This cause for ‘agenda setting’ has not been seen in the studied literature for constructing the framework. Within the articles from which agenda setting was identified as a relevant factor, environmental causes arose the most times with successful agenda setting (Ho & O’Sullivan, 2018a; Markard & Erlinghagen, 2017)

6.4.4 Pricing strategy

The final factor which is being discussed is the 'pricing strategy'. As the struvite installation is bought via a contractor, the exact price of such an installation was not known according to the experts. They only know the price for the total package, thus including the price of complementary goods, installation, etc. Furthermore, when this factor was brought up, some experts had conflicting arguments and had a hard time making the pairwise comparison with this factor. This was due to the opinion of some experts that price should not be leading when choosing a struvite installation. As they indicated that, in line with the obtained results, factors such as 'technological superiority' and 'compatibility' should be leading. However, money is limited and the decision about the exact struvite installation must get approval of higher management. This can cause that the preferred option, cannot be purchased. Comparison of the results of pricing strategy with the other previously published literature is complicated. In the paper of van de Kaa et al. (2011) it is discussed that, a low price will help to win a standards battle. However, in this case the exact price was not known by the experts as they only know the total package price offered by a contractor. Thus, it cannot be said if the technology providers of struvite installations make use of low pricing strategies.

6.4 Multi-mode standardization

With the answers of the three sub-questions answered, the final step of this research, answering the main research question, could be made. The main research question was: *"Which are factors of influence in order to achieve success within multi-mode standardization process in the context of phosphorus recovery through struvite formation from municipal wastewater according to experts?".* In total eleven factors were identified, from which 'technological superiority' and 'compatibility' were identified as the high important factors. The factors 'pricing strategy', 'agenda setting', and 'current installed base' were identified as the medium important factors. The factors 'complementary goods', 'market communications', 'financial support' and 'suppliers' were classified as the low important factors. Finally, for the factors 'financial strength', 'appropriability strategy', 'market communications' and 'suppliers' a significant difference in weights were observed. Therefore, factors were not classified as high, medium or low important factors. Initially it was thought that the purchasing process of a struvite installation would show strong characteristics of a multi-mode standardization case. Yet, from the eleven factors which were identified as relevant, nine factors were stemming from the original framework based on market-mode standardization by van de Kaa et al. (2011). This indicates that this case is more a market-mode based standardization process and not the expected committee-, market, government-based standardization process. However, of the eleven factors which were identified as relevant, it was indicated by the experts that six of these factors were influenced by other actors than the technology providers (Figure 3). This shows that the technology providers are not the only stakeholders influencing the purchasing process of a struvite installations. Furthermore, the two factors from the proposed framework which were identified as relevant, namely 'agenda setting' and 'financial support', were indicated to be influenced by other stakeholders than the technology providers. The case which was analyzed within this thesis focusses only in the situation in the Netherlands. Comparing to other countries, it is known that in Germany and Switzerland regulations were made which makes phosphorus recycling from communal wastewater obligatory (Verhulst, 2017), thus, possibly showing stronger characteristics of a multi-mode standardization than within the Netherlands. Furthermore, influences from a committee-based perspective can be expected in Germany, as research has been conducted in the standardization process around municipal wastewater (Freimuth et al., 2018). However, one must keep in mind that governments of Germany and Switzerland do not specify via which method phosphorus has to be recovered (Verhulst, 2017).

7. Conclusion and recommendations

7.1 Conclusion

The main goal of this research was to assess the weights of factors of influence within multi-mode standardization for the context of phosphorus recovery through struvite formation from municipal wastewater. This goal is displayed in the following main research question: "*Which are factors of influence in order to achieve success within multi-mode standardization process in the context of phosphorus recovery through struvite formation from municipal wastewater according to experts?"*. To answer this main research question, a set of three sub-questions were proposed. The first sub-question to be answered within this research was: *"What are the factors for success in multi-mode standardization process?"*. To answer this first sub-question a literature research was conducted. Through the literature research the framework of van de Kaa et al. (2011) was altered and extended from a framework only suitable for market-based standardization with 29 factors, to a framework including 45 factors involved with success within multi-mode standardization. In total 17 new factors were identified. Furthermore, 4 factors from the old framework were redefined and/or recategorized. To answer the second sub-question: *"What are the relevant factors for phosphorus recovery in form of struvite from municipal wastewater according to literature and experts?",* content analysis of available literature and expert interviews were conducted. From this, eleven factors from the proposed framework from the first sub-question were concluded to be relevant. These factors are: 'financial strength', 'technological superiority', 'compatibility', 'complementary goods', 'pricing strategy', 'appropriability strategy', 'market communications', 'financial support', 'agenda setting', 'current installed base' and 'suppliers'. The third and final sub-question: "*What is the importance of each relevant factor for phosphorus recovery in form of struvite from municipal wastewater according to experts?"* was answered by applying the BWM method. In this research, the BWM was applied twice with the factors divided in different categories, namely 'original categories' and 'core and peripheral categories'. Additionally, it was tested if there was a significant difference between the obtained weights of a factor. In Table 9 an overview is given of the obtained global weights from both BWM and whether these weights are significantly different or not. As shown in Table 9 the obtained weights for the factors 'financial strength', 'appropriability strategy', 'market communications', and 'suppliers' are significantly different. Furthermore, the factors 'technological superiority' and 'compatibility' were ranked as the most important factors in both 'original categories' and 'core and peripheral categories'.

*Table 9: The obtained global weights of the BWM applied with the 'original categories' and the 'core and peripheral categories'. The obtained global weights of a factor are marked with a * when they are significantly different.*

Factor	Global weight of BWM applied with 'original categories'	Global weight of BWM applied with 'core and peripheral categories'
Financial strength	0,1659*	0,0487*
Technological superiority	0,1964	0,2422
Compatibility	0,2006	0,2026
Complementary goods	0,0519	0,0508
Pricing strategy	0,0767	0,0806
Appropriability strategy	0,0402*	0,0906*
Market communications	0,0165*	0,0281*
Financial support	0,0220	0,0256
Agenda setting	0,0796	0,0892
Current installed base	0,0998	0,1112
Suppliers	0,0503*	0,0305*

With help of the sub- questions, the main research question: *"Which are factors of influence in order to achieve success within multi-mode standardization process in the context of phosphorus recovery through struvite formation from municipal wastewater according to experts?"* could be answered. By constructing the framework following from the first sub-question, factors for success in multi-mode

standardization could be analyzed. From sub-question two and three the relevant factors and their influence were obtained according to the experts, as is shown in Table 9. From the eleven factors which were deemed to be relevant, the factors 'technological superiority' and 'compatibility' were ranked as most important factors by experts.

7.2 Theoretical and practical contributions

7.2.1 Theoretical contributions

This research contributes to previous conducted research on multi-mode standardization and phosphorus recovery from wastewater in different ways. First, this research contributes to the multi-mode standardization literature as broad explanations are given when it can be said that multi-mode standardization is successful. Furthermore, it agrees with Wiegmann et al. (2017) that many different explanations can be found in standardization. It also remarks the lack of explanation about these standards and when standardization is successful within studied literature. Therefore, it should always be discussed by an author what their definition of the standard and their understanding of successful standardization within their presented research is. Secondly, in this research the first steps were made in designing a framework which can be used to identify and evaluate the relevant factors for success in a multi-mode standards battle. Furthermore, this framework builds on earlier literature about multi-mode standardization and proposed frameworks which include factors which are relevant within standards battles (van de Kaa et al., 2011; Wiegmann et al., 2017). Third, the proposed case which was studied, the purchasing process of a struvite installation within MWWTP, showed directly that the newly proposed framework is relevant and more complete as earlier proposed frameworks. This is the case, because two out of the eleven identified relevant factors (i.e. 'agenda setting' and 'financial support') were deemed to be relevant by experts. In addition, 'agenda setting' was also identified as medium important within the standardization process by experts. This shows the importance of the proposed framework for further research. Additionally, as this framework proves its relevance, this research also agrees that phosphorus recovery from wastewater is indeed a multi-mode standardization process. Furthermore, the multiple actors involved, which caused for the recategorization in 'core and peripheral categories', showed the broad influence from other actors besides the technology providers. Especially, the factors 'financial support' and 'agenda setting' showed for instance influences from government and European Union (Table 13). That phosphorus recovery was already a multi-mode standardization problem was previously suggested in a study about wastewater treatment in Germany (Freimuth et al., 2018). Fourth, this research contributes to earlier literature within different technology fields which uses the BWM to determine the importance of relevant factors involved within successful standardization. Here it is the first time that the BWM was used in the phosphorus recovery from wastewater field. Moreover, possible standardization literature about phosphorus recovery lacks theoretical insight about all specific factors involved. Earlier studied literature involves life cycle assessment which compares all types of different phosphorus recovery techniques (Amann et al., 2018; Remy & Jossa, 2015). Furthermore, the found global weights can be used to compare results from similar future studies, like was done with the top rank factors. Further comparison will give more insight in the importance of the factors in the different technology fields and the general importance in standardization. Finally, this research also contributes to the BWM literature which makes use of local and global weights. Previous comparable studies which uses the framework of van de Kaa et al. (2011) have no record of applying the BWM twice with factors divided in different categories. Consequently, the statistical analyses which has been performed has also not been done so far. The applied statistical method in this research could be used in further research if is chosen to apply the BWM method multiple times. This can be the case when there is an unequal number of factors in the categories, which could lead to biased results.

7.2.2 Practical contributions

Additional to the theoretical contribution, some practical contributions were made in this research as well. The most important practical contribution which has been made is the possible use of this

framework for decision-making when purchasing a new technology. A MWWTP chooses a struvite installation based on the best scoring option which was offered. They could compare the current test with the obtained results and, if needed, align such a test accordingly. For example, in such a test the scores obtained for the factors 'technological superiority' and 'compatibility' should play a bigger role in the decision-making process than the 'financial strength' or 'financial support'. Secondly, this proposed framework and BWM could be applied to other technologies which have similar purchasing strategies. Additionally, this not only applies to MWWTP, but to all types of firms which use similar testing methods to decide which new technology they should invest in. By using the framework and the BWM, such a test could be constructed or adapted accordingly. A third and final practical contribution are the identified factors within the proposed framework. Firms can use this knowledge to make new strategies which is involved around multi-mode standardization.

7.3 Limitations and recommendations

7.3.1 Proposed framework

As mentioned earlier in Chapter 6.4, it was expected that this case would show more characteristics relevant to a multi-mode case. However, most identified factors (i.e. nine out of eleven) were factors from a previous published framework about market-mode based standardization. Although this new framework has proven its relevance, as new identified factors were considered relevant, further testing should be performed with multi-mode standards battles. This will show the possible application of the proposed framework within multi-mode standards battles. In the meantime, this framework should be used when analyzing standards battle via the BWM instead of the now used framework of van de Kaa et al. (2011). Because it is a more comprehensive framework and only relevant factors are used for the BWM. This gives a higher chance that all relevant factors are identified within the first step of the BWM.

The proposed framework in this research still cannot be considered complete. First, during the literature research it was difficult to identify factors due to limited knowledge of discussed cases and the naming of indirect factors. This can have the effect that some factors might not have been identified during the literature research. Secondly, at the end of the identification of relevant factors the experts were asked if they thought a factor was missing. Here, one expert pointed out that he missed a factor taking the opinion of a future client of the produced struvite into account (I2, 2019). According to this expert, the experience from purchasing a struvite installation has taught them first to investigate what a possible client seeks in a produced product. Based on these wishes, the companies seek out a technology. Therefore, it is recommended that the studied literature is evaluated again by another person to verify the framework. Furthermore, the framework should be extended with a factor 'fit to client needs' in the category 'other stakeholders'. This factor can be described as: "When a proposed standard produces a product which has to be sold again. How well does the product fits the client needs?". Finally, when conducting interviews with experts about the relevant factors there should always be asked at the end if they think all relevant factors were identified or if factors are missing.

7.3.2 Identification of a possible winner within the standards battle

Within this study it was not possible to predict a type of struvite installation which could possibly win the standards battle. To identify the possible standard technology, the BWM with relevant factors should be tested on the possible technologies. Here a pairwise comparison between the technologies would be made on each factor. Then the average weight would be multiplied by the global weight. The obtained scores could then be compared with each other to see which type of struvite installation would score the best. However, within the first round of interviews, the experts indicated that there is a knowledge gap about the different types of struvite installations. This knowledge gap is caused a by the fact that the experts do not directly choose from the different technologies which are available. They choose a main contractor who has made a deal with one of the technology providers. Hereby,

the experts do not encounter all different technologies resulting in the lack of knowledge. Furthermore, the experts indicated that they do not really believe that there would be a winner within the standards battle. As each MWWTP has different requirements for the struvite installation and the struvite installation scores different on these set requirements. The requirements can be linked to 'technological superiority' and 'compatibility' which are seen as the two most important factors by experts. As each installation would score differently on these two factors based on the requirements of the MWWTP, predicting a winner of this standards battle would be impossible. Furthermore, it was indicated by the experts that the need for the same quality of struvite is no longer present. This is because the company Aquaminerals at this present moment buys al the produced struvite which cannot be sold directly as fertilizer from the MWWTPS. Aquaminerals is then responsible for further trading of the produce. Thus, experts indicated that at this moment there is no need to aim for the same quality, as they already can sell their produced struvite. To prevent selecting a case where there is a possibility that there is no winner in a standards battle the following is recommended. First, when there is limited literature about the possible case this should be seen as a warning that there might not be a standards battle. Second, an early interview with at least one expert in the field should be conducted to verify if the proposed case is suitable.

7.3.3 Use of local and global weights

During the application of the BWM in this research local and category weights were used to calculate the global weights. As shown Chapter 5.3, recategorizing and applying the BWM twice gives for some factors significantly different global weights. In chapter 6.2 two possibilities were explained which could explain these significant differences. Namely, non-comparable number of factors in the categories and advantages of a high scoring category. Therefore, it is recommended that the number of factors should be similar, when using local and category weights. Furthermore, recategorizing can be applied when it is thought there will be one high scoring category which can cause biased results. When it is decided to do a recategorization, it is still applicable to conduct the BWM with the original categories. The interviews with the experts did not take much more time when applying the BWM twice, as they were already familiar with the method and factors. Additionally, the method to test for significance has already been constructed within this research. Researcher can use this method to compare their own obtained results.

7.4 Reflection

One of the challenges of being a double degree student in Life Science & Technology (LST) and Management of Technology (MoT) was finding a suitable project. Although the research was done to fulfill the requirement of the MoT degree, a link with LST was preferred. Furthermore, because of the double degree the specialization of the second year of the MoT program was not done. These two points made me initially scared that it would be hard to find a suitable thesis project. However, with a project about a standards battle I directly found a connection. This was because I felt the basic knowledge was present through the course Technology Strategy and Entrepreneurship. Furthermore, it was possible to analyze a battle within the field of my other master degree. During this thesis, unexpectedly, knowledge obtained about statistics via Research Methods came to use.

During this research it was decided to compare the BWM with factors divided within different categories. This decision was made because possible analyzes about a winner of the standard was no longer possible. Furthermore, the insights from the interviews arouse interest to see if recategorization based on different characteristics gave different results. As these insights were noticed at a later stage within the thesis, it was decided not to change the questions and the story of the thesis. However, due to interesting results, the significant difference of weights for a factor were included within the thesis.

This project gave me the challenge to dive deeper within this standards field. As a possible manager in the technological field it is important to understand why to choose for a certain technology. This

project in the standardization field gave a deeper insight about the considerations made by managers. The acquired knowledge via this project will help me in later stages to evaluate decisions when it comes choosing between different technologies. Furthermore, better understanding of standardization and the involved factors in this process will help with presenting argumentation to others who are not familiar with the technologies. This would be done by explaining the factors, showing importance of these factors, and finally display which technology scores best on those factors.

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8.2 Interviews

I1 2019: Employee at waterboard. 20 February 2019, at location about the identification of relevant factors.
I2 2019: Employee at waterboard. 21 February 2019, at location about the identification of relevant factors.
I3 2019: Employee at waterboard. 11 March 2019, by phone about the identification of relevant factors.
I4 2019: Employee at waterboard. 1 April 2019, at location about the BWM.
I5 2019: Employee at waterboard. 1 April 2019, at location about the BWM.
I6 2019: Employee at waterboard. 3 April 2019, at location about the BWM.
I7 2019: Employee at waterboard. 4 April 2019, by phone about the BWM.
I8 2019: Employee at waterboard. 4 April 2019, by phone about the BWM.
I9 2019: Employee at waterboard. 4 April 2019, by phone about the BWM.
I10 2019: Employee at waterboard. 10 April 2019, by phone about the BWM.

Appendix A: Case background

The P-recovery discussed in this report focuses on P-recovery from municipal wastewater in the Netherlands. In the Netherlands municipal wastewater is generally a mixture of household sewage, wastewater from industry, and run-off rain water (STOWA, 2017b). The removal and recovery of phosphorus are done at different points within a MWWTP. The part first of this appendix explains how phosphorus is removed from wastewater. The second part elaborates more on the recovery possibilities. Finally, some more explanation about regulation on recovered phosphorus will be given.

A.1 P-removal from wastewater

A.1.1 MWWTPs within the Netherlands

Phosphorus is removed from the wastewater by capturing it in the sludge of a MWWTP through chemical treatment, biological treatment or by a combination of both. This combination of both treatments is done when the wanted effluent concentrations of the water cannot be reached by biological treatment alone (STOWA, 2017b). In 2016, there were a total of 327 MWWTPs in the Netherlands. A large majority of these MWWTPs, i.e. 298, had an incorporated system for phosphorus removal (P-removal). Of these 298 P-removal system a total of 46 applied a chemical treatment, 120 applied biological treatment, and 133 applied a combination of both treatments (CBS, 2016). Two trends around P-removal can be clearly observed in the last years. More MWWTPs are recovering phosphorus, i.e. 53% in 2000 compared to the 91% in 2016. Furthermore, there is a decrease in P-recovery via the chemical treatment (Figure 5). In addition, it can be said that the Netherlands is one of the front runners with biological P-removal. In 2015 it was estimated that within Europe around 10% of the MWWTPs removed phosphorus biological, while in the Netherlands this number was already at 36% (CBS, 2016; Ryan, Walsh, & Boyce, 2016).

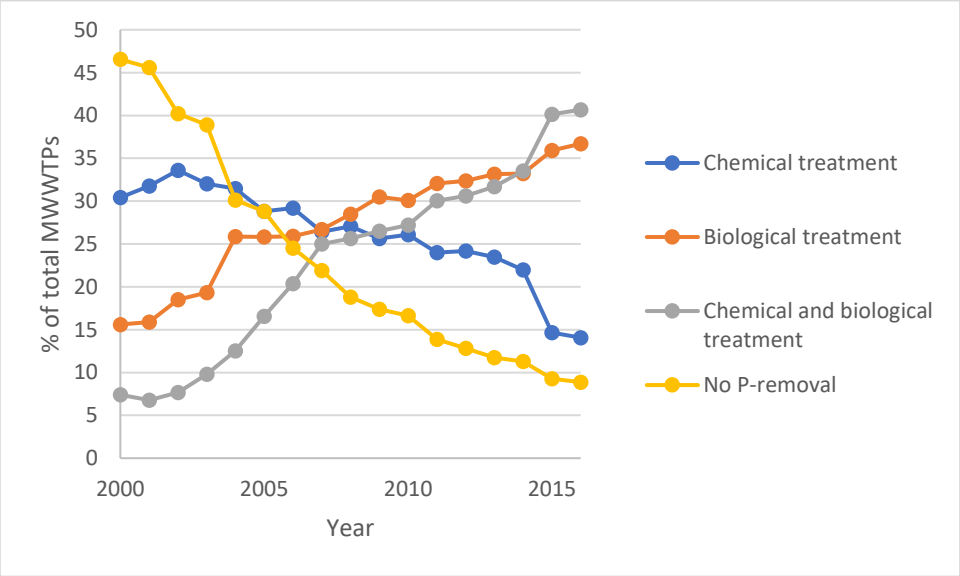

Figure 5: Graphic presentation of the percentages of chemical, biological, combination or no P-removal treatment in MWWTPs in the Netherlands over the years 2000-2016. Numbers were retrieved from (CBS, 2016)

A.1.2 Chemical and biological treatment for P-removal

Chemical treatment for P-removal can take place at three different points within a MWWTP: during the primary sedimentation, in the aerobic chamber or before the secondary sedimentation (Figure 6). The removal of phosphorus by chemical treatment is normally done by adding a dose of iron and aluminum salts. This results in a non-solvable compound in water (STOWA, 2017b). The biological treatment in which phosphorus is removed depends on micro-organism which can uptake large amount of phosphorus, i.e. polyphosphate-accumulating organisms (PAOs). Through uptake and

excretion of phosphorus compounds during the presence or lack of oxygen, aerobic and anaerobic conditions, by the POAs it is possible to recover phosphorus at a targeted point in a MWWTP (point 1a, 1b or 1c Figure 6) (Korving, 2018; STOWA, 2017b).

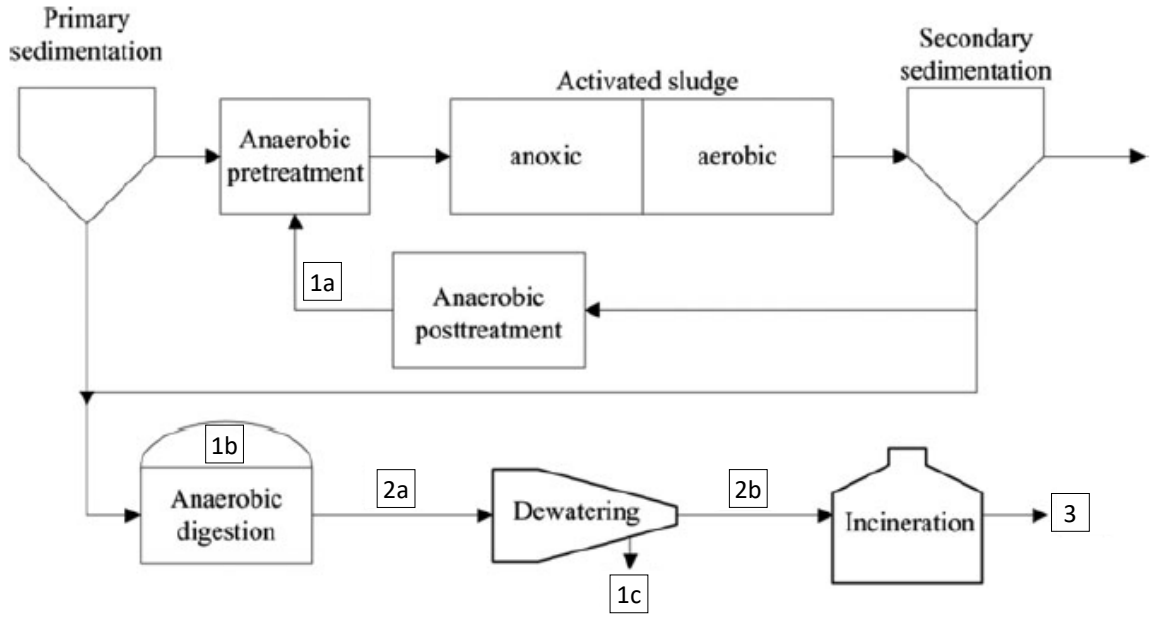

Figure 6: Simple overview of a MWWTP including possible routes for P-recovery. The possible locations where P-recovery can find place (depending on the design of the MWWTP) are from the liquid phase (1a,1b, and 1c), sludge phase (2a and 2b) and from the sludge ash (3).Adapted from rom Desmidt et al. (2015).

A.2 P-recovery from wastewater

Once phosphorus is captured in the sludge within a MWWTP it can be recovered at a targeted place. The first option to recover phosphorus is from the liquid phase through formation of struvite, however this is only applicable when P-removal is done biologically (point 1a, 1b, or 1c in Figure 6). The second option is from the sludge phase (point 2a and 2b in Figure 6), of which no method is present currently within the Netherlands. Finally, recovery can be done from the sludge ash (point 3 in Figure 6), the incineration of sludge and possible recovery of phosphorus is not carried out by MWWTPS themselves but elsewhere (Arcadis Nederland B.V., 2017; Desmidt et al., 2015; STOWA, 2017b). Within the Netherlands the incineration of sludge is carried out by SNB and HVC. These two companies can process around 50-55% of the total produced sludge by MWWTPS. Until 2012, SNB and HVC worked together with Thermphos for recovery of phosphorus from the sludge ashes. However, after Thermphos went bankrupt in 2012, a new deal was made with Ecophos for the P-recovery from sludge ash. In June 2018 Ecophos opened its first factory in Duinkerken in France. (Arcadis Nederland B.V., 2017; Nord France Invest, 2018). Through this process around 82% of the phosphorus relative to the MWWTP influent can be recovered (L Egle et al., 2016).

As mentioned, this report focusses on P-recovery through controlled formation of struvite from the liquid phase. Struvite formation at MWWTP is a process which occurs naturally, causing higher operational costs, e.g. through narrowing of the pipes within a MWWTP which must be cleaned. Controlled formation of struvite has its operational and financial advantages for a MWWTP (Arcadis Nederland B.V., 2017; Desmidt et al., 2015). The formation of struvite depends on multiple factors, amongst others the pH, magnesium concentration, and retention time (Le Corre, Valsami-Jones, Hobbs, & Parsons, 2009). Within literature multiple techniques can be found for struvite formation, in this report the focus is on the current techniques found in the Netherlands. In 2017 there was a total of 7 installations originating from four different techniques (Table 10) (Arcadis Nederland B.V., 2017;

Ryan et al., 2016). The struvite produced by the Airprex, NuReSys and Phospaq installations can be used as basic raw material for fertilizers while the Pearl installation delivers a market ready product (Arcadis Nederland B.V., 2017; Verhulst, 2017). The amount of phosphorus recovered is lower compared to recovery via sludge ash, i.e. between 10-40% of the MWWTP influent (Verhulst, 2017).

Table 10: Overview of current struvite installations within the Netherlands (Arcadis Nederland B.V., 2017)

Type of installation	Location of recovery in MWWTP	Location of MWWTP
Airprex	1b	Echten and Amsterdam-West
NuReSys	1a or 1c	Land van Cuijk and Apeldoorn
Phospaq	1a or 1c	Olburgen and Tilburg-Noord
Pearl	1a or 1c	Amersfoort

A.3 Regulation around recovered phosphorus.

The possible usage of phosphorus recovered from the liquid phase and sludge ash differs as well. Within the Netherlands at this moment there is a surplus of phosphorus use in fertilizers , while this is not the case in other European countries. Thus, the potential market of recovered struvite as fertilizer is elsewhere than the Netherlands (Verhulst, 2017; I2, 2019). However, the regulation around the produced struvite is complicated. Within the Netherlands, the produced struvite from municipal waste water is defined as waste product. The struvite with a waste status can only be sold as fertilizer and falls under in that case under the fertilizer regulations within the Netherlands. When it is wanted that struvite can be traded as basic raw material for other products. Therefore, an End-of-Waste (EoW) must be obtained. To gain an End-of-Waste (EoW) status four criteria must be met. At this present time, there is no generalized way to gain the EoW status. This means that each EoW request is assessed as each individual case, per location, and per application. Simultaneously, if a product wants the EoW status, it also needs to fulfil the European regulation about chemical compounds, also known as the REACH. Companies can apply for a REACH certificate, but this is a costly process. However, as struvite is a recovered produce it can make use of the exception of the REACH certificate obligation. Namely, it can register under the already gained REACH certificate of the Berliner Wasserwerke. Therefore, at least 80% of the struvite must be equal to the product on the certificate. Additionally, no dangerous contaminations can be present. As struvite as no official European status yet, export of the struvite is complicated as well. The export of struvite is possible, however, the regulation of both countries has to be met (de Jong & de Weerd, 2017; Verhulst, 2017).

A.4 Manner of purchasing struvite installation

During the interviews, additional to identification of relevant factors, the manner of how a struvite is purchased was discussed as well. Originally it was thought that a MWWTP chooses for a specific installation based on their requirements. However, during the interviews it arose that the process is more complicated and can be described as followed: The MWWTP publishes after a research the wanted requirements. Based on these requirements, one or multiple main contractors put forward a possible solution. These main contractors have made different agreements with possible technology providers and other contractors, for example a civil contractor who will be responsible for the concrete work needed to be done in the project. The main contractor also puts forward a struvite installation of which they think is best suited for the presented situation. When there are multiple solutions offered, the MWWTP is obligated to choose the best fitted solution based. On simplified overview of the involved actors of this purchasing process is given in Figure 7.

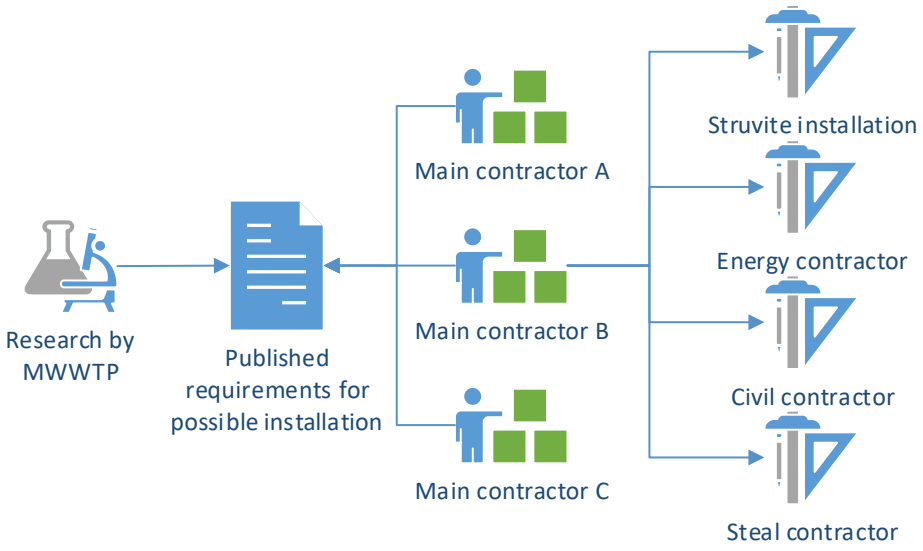

Figure 7: Simplified overview of actors involved when purchasing a struvite installation.

Appendix B: An overview of identified factors which influence success within multi-mode standardization.

Within this appendix a full overview including the broad explanations is given of the identified factors influencing success within multi-mode standardization. The results of the literature study which was conduction to gain these results are given in Table 11.

Table 11: Overview of identified factors and their broad explanation which are relevant with success in multi-mode standardization.

Factor	Explanation
Characteristics of the standard supporter	
1 Financial strength	The financial strength of a firm can be seen as perquisite for active participation in committee-based standardization when high costs are involved (Mattli & Büthe, 2003; Wakke, Blind, & De Vries, 2015). Furthermore, it can influence negation power within a committee as a firm have something to bring to the table. In all, impacting the outcome of standard settings (Borraz, 2007; Pelkmans, 2001). Within the government financial strength helps with enforcement of standards (Trienekens & Zuurbier, 2008). Finally, for firms it can help for example with the marketing or help surviving the period were earnings from standard are low (van de Kaa et al., 2011).
2 Brand reputation and credibility	A positive reputation of committee or SDO will create better credibility and legitimacy about the developed standard which helps with further implementation. It also helps attracting other firms to join negations settings, which influences the size and diversity and thus impacting the possible standard (Bakker et al., 2015; T. Egyedi & Spirco, 2011; van den Ende et al., 2012). Firms with good reputation obtained by previously standard setting receive positive attitude towards new proposed standards (van de Kaa et al., 2011).
3 Operational supremacy	When the standard supporters made better use of their resources than its competitors which positively influences their chances of reaching dominance within a standard (van de Kaa et al., 2011).
4 Learning orientation	Firms can learn from previous experiences within cooperation standard setting, this will help preventing them from making mistakes crossing similar situations (Funk & Methe, 2001; Meyer, 2012). Moreover, previous successful or failure within cooperation sets a pattern for future cooperation (Rosen et al., 1988). For example, stakeholder which previously hindered the standardization process are excluded from a new committee. Ranganathan, Ghosh, and Rosenkopf (2018) showed further committees consisting out of stakeholders which have greater heterogeneity experiences in committee-based standardization are better in achieving consensus. Experiences in previous participations can also help create legitimacy of a stakeholder and put in a valuable position such as chair with creation of new committees (van de Kaa & de Bruijn, 2015). For the government previous experience of setting a standard by enforcement can help facilitating enforcement of improved or new standard (Delmas & Montiel, 2008). The firms learning capability on the core capabilities and new knowledge absorptive capacity,

	learning from previous experiences can help with reaching dominance in new standard setting process (van de Kaa et al., 2011).
5 Coordination through market leadership	The coordination of a standard can be steered by a market leader within a commission or just by the market leader himself. For example, a market leader possesses the IPR of an essential part of the standard which can be used to its advantages to steer a standard outcome (Axelrod et al., 1995; Vercoulen & van Wegberg, 1998). Furthermore, market leaders can choose to not accept a proposed standard by a committee, but through lobbying push the government to intervene within the standard setting process resulting an enforced standard by the government (T. Egyedi & Spirco, 2011; T. M. Egyedi, 2000). The lack of support of market leader hinders implementation of a standard (X. Gao, 2014; Meyer, 2012). Governments can also take initiative to steer coordination, by example mandate SDO to work together towards harmonized standards in order to prevent multiple standards and lower uncertainty (Erlinghagen, Lichtensteiger, & Markard, 2015).
6 Foresight	The ability of stakeholders to estimate the future. A lack of foresight by stakeholders can be seen as cause of failure, as multiple standards and high switching costs might arise due to this (Abbate, 2001; Puffert, 2000, 2002)
Characteristics influencing the committee composition	
7 Size of committee	In general, the larger a committee is the higher the chance for acceptance of a standard. As for example, the chances of firms offering compatible products increases. However, the more participants a committee the larger the costs are for coordination and chances are to become unworkably large making it harder to reach consensus (Axelrod et al., 1995; Markus et al., 2006; van den Ende et al., 2012; Vercoulen & van Wegberg, 1998)
8 Diversity within a committee	Diversity of a committee is needed in order to successfully design and diffuse a standard; thus, active participation of heterogeneous actors is essential. By diversity a committee also ensures that all needed technology profiles are present while designing the standard, increasing its chances to success. Furthermore, as standardization can be used in order to prevent regulations which are conflicting with stakeholders' interest, all stakeholders need to represented to prevent those "regulatory capture". However, it can be harder to reach consensus when more diverse actors participating within a voting process. However, a lack of diversity within a committee can lead to incompatible standards (Bakker et al., 2015; Blind & Mangelsdorf, 2016; P. Gao et al., 2014; Markus et al., 2006; van den Ende et al., 2012)
9 Committee formation capabilities by stakeholder	The successfulness of a stakeholder in forming a committee is important as this can be used in order gain an advantage over the competition, gain broad support from the industry, broaden its installed base, or even achieve technological superiority through collaboration which are factors directly impacting the possible success of the standard (Dan, 2018; X. Gao, 2014).
10 Winners effect	Firms are more likely to join a committee if they see they can gain something from the committee-based standardization. Which can bring

	essential information, increase size, increase diversity, and so on. Stakeholders will keep participating within a committee when they can see the benefits and prospects of future gain from such outcome (van de Kaa & de Bruijn, 2015; Vercoulen & van Wegberg, 1998). However, it might bring forward the prisoner's dilemma where the outcome for firm A is not the same as for firm B. In which good coordination is needed in order to reach consensus(Farrell & Saloner, 1988; Mattli & Büthe, 2003)
11 Exclusivity of a committee	Exclusivity of a committee, by paying participation fee for example, can help controlling a size and diversity in order to prevent it becoming unmanageable. However, such participation fee cannot be to high to discourage players, to have all interested firms involved. Exclusivity can also lock out players that they can no longer participate. Although, the lock out of firms can cause counteraction taken by excluded firms, hindering the standardization proposal brought by the committee (Axelrod et al., 1995; Markus et al., 2006; Mattli & Büthe, 2003; Pelkmans, 2001).
12 Distribution of employees of firm within standardization committees	Firms can one or multiple employees within (different) committees. These employees can simply attend meeting where voting takes place and influences the outcome of a standard. When there are multiple employees within a committee from one company, they can use it to gain power and steer standard design in certain direction (Leiponen, 2008; van de Kaa & de Bruijn, 2015).
Consensus reaching committee characteristics	
13 Coordination within a committee	A standardization process within a committee involves not only technical but also strategic and political battles. Firms have their own private interest within a committee. Thus, good coordination within committee is important in order to be able to reach consensus about a standard as well as to recognize problems on time (Borraz, 2007; Fukami & Shimizu, 2018; Garud et al., 2002).
14 Rule of voting	There are multiple ways how a standard is determined within a committee, e.g. majority voting, everybody as to agree, weighted voting. Stakeholders know how in which way consensus is reached use this in their advantage to ensure success or failure within a standardization process. Strategic voting by stakeholders might cause that not the technologically superior standard is chosen (Borraz, 2007; Gandal et al., 2003; Spulber, 2016). For example, during development of the WiFi standard, a stakeholder brought along supporters for his proposal to meetings in order to win the majority vote (van de Kaa & de Bruijn, 2015). However, the voting process within studied literature was mostly appointed when it led to standardization delay or failure.
15 Veto points	Veto point within a committee can influences the standardization development, it even can lead to standardization delay or failure (Hail et al., 2010; Meyer, 2012)
16 Timing of participation	Early timing with formal SDO with proposing standards may help to gain important positions such as chair or secretariats within a commission (Blind & Gauch, 2009).

Characteristics of the standard	
17 Technological superiority	A standard contains features which will make it better compared to other standards, making it more likely to achieve dominance (van de Kaa et al., 2011).
18 Compatibility	If two interrelated entities are able to fit and function together, we speak of compatibility. Standard which are backwards compatible it means that the new standard is designed that it works with previous generations of a standard which are already are implemented (e.g. a new version of Word). When standards are horizontal compatibility it concerns the fit between functionally equivalent object (e.g. two Lego bricks) (van de Kaa et al., 2011). Compatibility can also be created by gateway technologies; gateway technologies create compatibility between non-compatibility. The availability of gateway technologies can hinder standardization of one specific standard, as different standard are now able to function together (De Vries, de Ruijter, & Argam, 2011).
19 Complementary goods	Complementary goods are needed in order to be able to successfully commercialize a certain standard (van de Kaa et al., 2011).
20 Flexibility of adaptation	When the incremental costs and time that is needed to adapt a standard to the changes in the customer needs are low, the standard is more likely to become successful (van de Kaa et al., 2011).
21 Flexibility during standard design	Within a committee a standard is designed to the stakeholders needs. Low flexibility within standard design phase, thus none or a few stakeholders are allowed to make changes to the proposed standard, can lead to standardization failure as the standard does not meet requirements of stakeholders. Furthermore, lower incremental costs and time that is needed to adapt a standard to the changes with technological improvements increases the chances of success for a (T. Egyedi & Spirco, 2011; van de Kaa et al., 2011; van den Ende et al., 2012).
22 Openness of standard during standard design	The level of openness about essential information of a standard. The more open a standard is, the larger is has chances of reaching success. Openness of standard design influences amongst others future growth expectations, exclusivity and size, as a committee may require that no royalties can be earned on IPR and essential information is shared within committee. As costs such as licensing fees decrease or even disappear will attract firms to participate and thus influences it size (Blind, 2011; Erlinghagen et al., 2015; Funk & Methe, 2001; X. Gao, 2014; Markus et al., 2006). Another advantage of open standards is that they encourage compatibility between different systems (Abbate, 2001).
Standard support strategy	
23 Pricing strategy	Throughs strategic pricing of a standards, firms try to create a market share. Temporarily low pricing helps for example by creating an installed base making further implementation of the standard more attractive. Low pricing strategies are in general positively related with chances of reaches success of standard (van de Kaa et al., 2011). Government may also choose to set prices of certain products and by giving price

	premiums to producer steer towards usage of certain standards (Farina et al., 2005) .
24 Appropriability strategy	Strategies that firm or committee undertake after the standard is developed to possibly protect the standard from imitation. A more open strategy, which can result in a higher installed base for example, increases the chances of a standard being successful (van de Kaa et al., 2011). An open strategy off committees can be for example that designed standards are made freely available to firms after request (Mattli & Büthe, 2003).
25 Timing of entry	The time the standard is introduced within the market, in general early introduction of standard is positively related to success of product (van de Kaa et al., 2011). Furthermore, the timing of entry to which a standard might be proposed to international SDO influences the chances of success as well. When a standard is already is used on the (national) market, this increases it chances of becoming the chosen international standard by a SDO (T. M. Egyedi, 2000).
26 Market communications	Communications with the possible customers influences the chance of reaching big market share. Early announcement can lead that customers delay buying (and possible non-compatible) products, waiting for introduction of possible standard. In later stage, market communications can be used to form expectations about which standard may become successful, these expectations might turn into self-fulling prophecies (van de Kaa et al., 2011).
27 Possession of scare assets	Government which possess scare assets can control availability of these scare assets. Regulation of which standards may or may not use these scare assets and determine which standard can be successful (Funk & Methe, 2001; Gandal et al., 2003; P. Gao et al., 2014; X. Gao, 2014; Pelkmans, 2001). Furthermore, firms which possesses scare assets can create an advantage by not sharing these scare assets with other firms (van de Kaa et al., 2011).
28 Distribution strategy	Strategies used by a firm in order to increase their distribution system strengths (van de Kaa et al., 2011).
29 Commitment	Commitment within a committee is of high importance for success of standard, as stakeholders have to accept and adopted such standard outcome in order to be successful (Vercoulen & van Wegberg, 1998). A lack of broad firm support towards a standard, thus commitment, may lead to negative idea's towards with customers (Dan, 2018; Meyer, 2012). Commitment of stakeholders can be created through already made investments within committee, knowing that there is something to gain from the outcome, openness and flexibility standard designing phase or by previous made agreements (Pelkmans, 2001; Trienekens & Zuurbier, 2008; van de Kaa & de Bruijn, 2015; van den Ende et al., 2012). Furthermore, as the return on investment are usually low within the early stages, commitment of stakeholders is important to survive these stages (van de Kaa et al., 2011). When there is a fractioned government, for example in China, lack of commitment can also lead to standardization failure. As local authorities choose to support local standards instead off proposed national standard (van de Kaa, Greeven, & van Puijenbroek, 2013).
30 Regulation by government	Governments can choose to enforce standards, including standards designed by an SDO, through regulation increasing adoption a standard

	(Cabral & Kretschmer, 2006; Gandal et al., 2003; Ho & O'Sullivan, 2018a). The regulation of standard, can cause the blockage of comparable standards (Puffert, 2000). Governments might also set performance standards, resulting in a market battle between possible standards who meet these performance standards (de Vries & Verhagen, 2016; Markard & Erlinghagen, 2017). Furthermore, regional standards may compete with national standards, hindering the standardization process through regulation (Thompson Clarke Shipping Pty. Ltd, TI Consultants Pty. Ltd, & Lewis, 2017). Finally regulations of countries can influence standard setting with international SDOs, as the standard applicable with the most stringent rules will be chosen (T. M. Egyedi, 2000). Governments can also choose to apply deregulation, meaning that previous set standards now need to compete with market or committee based standards (Farina et al., 2005). Comparable to deregulation governments might also offer regulatory relief towards firms if certain standards are met, thus making more favourable of certain standards above others for firms (Wätzold, Bültmann, Eames, Lulofs, & Schucht, 2001).
31 Control of the market by government	Besides enforcement of standards via regulation, the government can use its market control to influence a standardization process. Governments can for example influence market demand, create market protection for national proposed standards, act as lead adopter, or uses immense purchasing power (Cabral & Kretschmer, 2006; Funk & Methe, 2001; Meyer, 2012; Rosen et al., 1988; van de Kaa et al., 2013).
32 Financial support	A committee or firm can offer financial support in order that their proposed standard is implemented (Meyer, 2012). Furthermore, government can offer financial support towards a specific standard development or deployment of a standard with the of help funding (de Vries & Verhagen, 2016; Farina et al., 2005; Meyer, 2012; Puffert, 2002; van de Kaa et al., 2013)
33 Lobbying	Lobbying can take up many forms. For example, firms or stakeholder of committee might lobby at the government to intervene in the standardization process by enforcing one standard (T. Egyedi & Spirco, 2011; T. M. Egyedi, 2000; Thompson Clarke Shipping Pty. Ltd et al., 2017). A stakeholder also might lobby at the government when they feel being excluded from a standardization process, with successful lobbying, the stakeholder will be no longer excluded from the standardization process (Mattli & Büthe, 2003). Furthermore, lobbying can also be done at stakeholders who hold a veto point within a committee, pushing them to use their veto point in order delay or fail the standardization process (Meyer, 2012).
34 Agenda setting	Successful agenda-setting, alignment of interests of stakeholders, raises the importance of about the possibility of a certain standard leading to the involvement of more stakeholders. This involvement can be that they join a committee, increasing the size, diversity and so on of the committee, thus increasing the chances of successful standardization (Garud et al., 2002; Markard & Erlinghagen, 2017). The performance standard set by regulation explained above can also be seen as agenda setting, as it steers firms towards use and innovation of technical standards (de Vries & Verhagen, 2016; Ho & O'Sullivan, 2018a).

Other stakeholders	
35 Current installed base	The current installed base refers to the number of units in which the standard is already implemented and in use. A higher installed base increases the chances of success to reach dominance with a standard (van de Kaa et al., 2011). Furthermore, the current installed based within other countries influence choices made by government about standards. Government tends to enforce the same standards are their neighbouring countries or countries which they want to trade with (Puffert, 2000, 2002; Trienekens & Zuurbier, 2008).
36 Previous installed base	Some standard can be seen as an upgrade from an already established standard. As that standard has already an installed base, consumer might choose to simply upgrade to new standard, thus positively influences the chances of reaching dominance. (van de Kaa et al., 2011). Furthermore committee tends to support a current or known standard instead of a new or emergent standard (Funk & Methe, 2001).
37 Big fish	A big fish can be seen as someone who as a buyer or as someone influence availability of complementary but is not seen as developer during the standardization process. A big fish can exercise a lot of influencing power however, by promotion, financial support, buying power, or exclusive support towards a standard (Markus et al., 2006; Townes, 2012; van de Kaa et al., 2011; van den Ende et al., 2012). A lack of big support increases uncertainty about a standard, which can lead to delaying of the process or even failure (P. Gao et al., 2014; Meyer, 2012).
38 Suppliers	Gaining support of broad range of suppliers who deliver complementary or services related with the standard helps achieving dominance for the standard (van de Kaa et al., 2011).
Environmental factors	
39 Bandwagon effect	Sometimes users choose to implement a certain solution to their problem which has been proven useful for other users with a similar problem as more information hereof is available (van de Kaa et al., 2011). This can also be done through enforcement of laws by regulation by applying the same standards as their neighbouring countries have (Puffert, 2000).
40 Network externalities	Through cooperation of firms, within a committee for example, a basis can be created for achieving positive network externalities (Van Wegberg, 2004). Network externalities can be described as the value of a product, which have standards implemented, increases with every new user. A high installed based leads to high network externalities effects, increasing the chance of reaching dominance (van de Kaa et al., 2011).
41 Multiple standards	When there are multiple competing standards, the potential market share of a standard can decrease, negatively influencing the chance of reaching dominance (van de Kaa et al., 2011). Within a committee multiple competing standard can arise when a committee fails to reach consensus about one standard or when multiple SDO are working on the same type of standards (Blind, 2011; Ho & O'Sullivan, 2018a). Furthermore, within De Vries et al. (2011) research has been conducted in which a total of eight factors are identified which are involved leading up to multiple standards.

42 Uncertainty in the market	When uncertainty about a standard is high within a market, firms and consumers delay implementing a standard as they do not want to take on the risks attached by choosing a standard (van de Kaa et al., 2011).
43 Rate of change	The speed of with a standard and market changes within a specific industry (van de Kaa et al., 2011). For example, when the rate of change is high, a negotiated started through a committee might take too long and cannot keep up with the changing paste of the technology. This can then lead to multiple standards and thus can be seen as standardization failure (Lu, Morris, & Frechette, 2016; Meyer, 2012; Vercoulen & van Wegberg, 1998).
44 Switching costs	The costs involved when a switch between standards have to be made (van de Kaa et al., 2011).
45 Scandal or accident	Through the occurrence of a scandal or accident the rise for a type of standard occurs. These new standard are put in place in order to prevent more stringent standards from the government or on top of already regulated standards (Delmas & Montiel, 2008; Trienekens & Zuurbier, 2008).

Appendix C: Reviewed literature and categorization of its type of mode

Within this appendix an overview is given of the studied literature to build the framework including factors for success within multi-mode standardization. Furthermore, the type of multi-mode standardization, e.g. committee- and market-based or committee- and government-based standardization, is given. The type multi-mode standardization was assigned according to Wiegmann et al. (2017) and for the additional studied literature is was assigned after reading.

*Table 12: An overview of studied literature to build the framework including factors for success within multi-mode standardization. Furthermore, it is given from the in which type of multi-mode standardization they can be classified. When articles were only from a market-, committee-, or government-based perspective they are marked with an M, C or G. Articles which were reclassified after studying are marked with an *.*

Article	Committee- and market- based standardization	Committee- and government- based standardization	Government- and market- based standardization	Committee-, market- and government-based standardization
Abbate (2001)				X
Axelrod et al. (1995)	X			
Bakker et al. (2015)				X
Blind (2011)	X			
Blind and Gauch (2008)		X		
Blind and Mangelsdorf (2016)		X		
Borraz (2007)		X		
Cabral and Kretschmer (2006)		X^G		
Dan (2018)	X			
de Vries and Verhagen (2016)		X		
De Vries et al. (2011)	X			
Delmas and Montiel (2008)				X
den Uijl and de Vries (2013)	X			
Erlinghagen et al. (2015)				
Farina et al. (2005)				X*
Farrell and Saloner (1988)	X			
Fukami and Shimizu (2018)	X			
Funk and Methe (2001)				X
Gandal et al. (2003)	X			
Garud et al. (2002)	X			
Hail et al. (2010)				X

Ho and O'Sullivan (2018b)				X
Leiponen (2008)	X[C]			
Lu et al. (2016)				X
Markard and Erlinghagen (2017)				X
Markus et al. (2006)	X			
Mattli and Büthe (2003)				X*
Meyer (2012)		X		
P. Gao et al. (2014)		X		
Pelkmans (2001)	X			
Puffert (2000)			X	
Puffert (2002)			X	
Ranganathan et al. (2018)	X			
Rosen et al. (1988)			X	
Spulber (2016)	X			
T. Egyedi and Spirco (2011)		X		
T. M. Egyedi (2000)		X		
Thompson Clarke Shipping Pty. Ltd et al. (2017)				X
Townes (2012)		X		
Trienekens and Zuurbier (2008)				X
van de Kaa and de Bruijn (2015)				X
van de Kaa and Greeven (2017)				X
van de Kaa et al. (2013)				
van de Kaa et al. (2011)	X[M]			
van de Kaa, Papachristos, and de Bruijn (2019)	X			
van den Ende et al. (2012)	X			
Van Wegberg (2004) V	X			
Vercoulen and van Wegberg (1998)	X			
Voorberg, Bekkers, and Tummers (2015)	X			

Wakke et al. (2015)	X			
Wätzold et al. (2001)				X
X. Gao (2014)		X		

Appendix D: Relevant factors

Within this appendix the identified relevant factors will be discussed. In the first part of this appendix the identified relevant factors and the explanation why they are indicated as relevant is given. In the second part of this appendix, further elaboration is given of why factors are classified as core or peripheral influence factors.

D.1 Identified relevant factors

In Table 13 an overview is given the identified relevant factors and there explanation according to the performed content analysis of available literature and interviews with interviewee I1, I2, and I3.

Table 13: Identified relevant factors and their explanation

Factor	Explanation
1 Financial strength	"A struvite installation is a large investment a financial guarantee of the contractor is wanted as certain agreements have to be met." (I1, 2019; I2, 2019; I3, 2019)
2 Technological superiority	"The relief on manual labour and maintenance of the proposal influences which contractor will be chosen" (I1, 2019) "Test were conducted with the NuReSys and Airprex installation, these resulted influenced which contracted was chosen" (I2, 2019) "The installation needs to remove specific amount of phosphorus to relieve pressure on the waterline, the importance was the protection of the main waterline and not the possible product formation" (I3, 2019) "There are two main options when looking at installing phosphorus recovery technologies: before and after sludge dewatering. The first has the advantage that it improves the sludge dewaterability and thereby decreases the sludge transport and treatment costs, while the other technology provides more phosphate as a separate grain and therefore more recovered material" (Verhulst, 2017) "Not every technology leads to a product with direct applicability in agriculture which means an extra treatment step is needed to make the struvite directly usable" (Verhulst, 2017) "The total size of installation is also relevant, as sometimes there is limited space, so it is questionable if some techniques could fit in the appointed space" (Verhulst, 2017)

3 Compatibility	"The struvite installation has to be able to work together with the rest of the MWWTP as there is a specific point herein where it is wanted to place such installation" (I1, 2019) "The struvite installation needs to work together with the MWWTP and when problems might occur it needs to be easily decoupled from the MWWTP. As it is important the MWWTP keeps on running with or without the struvite installation." (I2, 2019) "The struvite installation that was installed was part of larger change at the MWWTP, amongst other an anammox installation was installed as well. These two installations can be seen as combination which are responsible for phosphorus and ammonium removal, thus compatibility is of high importance. This alongside the importance of the installations needs to work together with rest of MWWTP" (I3, 2019)
4 Complementary goods	"A struvite installation comes with complementary goods such as software or pumps. There is a preference towards these goods, which influences which contractor is being chosen." (I1, 2019) "The struvite installation was part of the total energy factory which was being installed, the struvite installation can be seen as small part of the total factory." (I2, 2019)
5 Pricing strategy	"The total price influences the final choose" (I1, 2019; I2, 2019) "The total price is of influences; the price of struvite installation is not known as it was part of a the energy factory which was being build." (I3, 2019)
6 Appropriability strategy	"With the Pearl installation there is no freedom how to run it or trading of the struvite as this is determined by Ostara. While by NuReSys there is freedom how to run and trade the made struvite" (I1, 2019) "When choosing for the Pearl, you have an obligatory contract in which you have to sell the produced struvite to Ostara. This played a role in the decision to build an Airprex system in Echten" (Verhulst, 2017)

7 Market communications	"During the contract proposal, different struvite installations are welcome to come by. As taking a struvite installation is a high investment earlier contact can help establish certain trust which can influence the final choose" (I1, 2019) "There was no focus on market communications, however by chance information about the Airprex was found in Germany. If this information was not found it could have taken a couple more years before a struvite installation was installed" (I2, 2019)
8 Financial support	"When choosing a struvite installation for the MWWTP in Amersfoort a LIFE+ subsidy of the European Union available. This subsidy was for a struvite installation, not for a specific type of installation" (I1, 2019)
9 Agenda setting	"We as water board did sign as well the 'Ketenakkoord Fosfaatkringloop', it did not implement a certain solution but you sign it with means of working towards something' (I3, 2019) "The 'Ketenakkoord Fosfaatkringloop' which have as goal to create a sustainable market where phosphate is reused as much as possible"(Ketenakkoord Fosfaatkringloop, 2011) "The beliefs and priorities of a water board contribute to the decision whether nutrient recycling has priority" (Verhulst, 2017)
10 Current installed base	"Because the Airpex installation in Berlin there was proof on concept to imply a struvite installation on large scale" (I2, 2019) "It gives a proof of concept, you known that something works." (I3, 2019) "One of the supporting reasons to choose the Airprex installation at the time, was the fact that the Airprex technology was already installed in Germany" (Verhulst, 2017)
11 Suppliers	"There are multiple suppliers involved when purchasing a struvite installation. Besides the technology provider there are for example the main contractor, steal, energy contractor and concrete contractor" (I1, 2019) "There are multiple technology providers involved with such a project. The main contractor makes a plan of approach and hereby

	uses these different technology providers to carry out the project" (I3, 2019)

D.2 Division of relevant factors in core and peripheral influences categories

During the interviews it was indicated by the interviewees that some factors were relevant, however they were not related to the technology provider but to different actors. Therefore, the factors were reclassified within core and peripheral influence factors according to the argumentations in the expert interviews with experts I1, I2, and I3. Some of these argumentations already captured in Table 13.

Core influence related factors

The factors which are in the core influence category, are the factors which are related directly to the technology provider, there are: 'technological superiority', 'compatibility', 'appropriability strategy', 'market communications', and 'current installed base'. 'Technological superiority' was considered as core influence as the technology which is being chosen is the one considered the best suited for the given requirements. Therefore, it depends on the specific installation and thus on its technology provider. Similar, the 'compatibility factor', how well installation fits in the MWWTP, also depends on the specific installation, thus on the technology provider. Furthermore, some installations come with a contract which determine the trading of the produced struvite. Moreover, some market communications were experienced which are provided by the technology provider. This lead to the classification of the factors 'appropriability strategy' and 'market communications' in the core influence category. Finally, the 'current installed base', which gives proof of concepts and this should be provided by the technology provider, was also classified within the core influence category (I1, 2019; I2, 2019; I3, 2019).

Peripheral influence related factors

The other six of the mentioned relevant factors where categorized as peripheral influence factors, these factors did have an influence on the type of struvite installation that was installed. However, they were not influenced by the technology provides of the struvite installation but by other actors, these peripheral influence factors are: 'financial strength', 'complementary goods', 'pricing strategy', 'financial support', 'agenda setting', and 'suppliers'. First the 'financial strength' is categorized as a peripheral influence factor as the MWWTP pays attention to the financial strength of the main contractor and not the financial strength of the specific struvite installation. Furthermore, the factors 'complementary goods', 'pricing strategy' and 'suppliers' are also related to the main contractor. As these factors were provided by the main contractor and not by the technology provider. For instance, the main contractor has a contract with other suppliers who help the installation of a struvite installation. Furthermore, the main contractor is also involved in choosing complementary goods which are needed to have a struvite installation running. Lastly, the total price which the MWWTP must be payed is also related to these other suppliers and complementary goods and thus not only depended on the struvite installation. During the interviews, one MWWTP brought forward that financial support was obtained. However, this support was towards a struvite installation and not to a specific struvite installation. Thus, the factor financial support is also categorized in the peripheral influence category. Finally, 'agenda-setting' was done amongst others via the 'Ketenakkoord Fosfaatkringloop'. Similar like with the factor 'financial support', it does not prescribe a specific struvite installation. However, this agenda-setting does help raising awareness of P-recovery (I1, 2019; I2, 2019; I3, 2019).

Appendix E: SPSS Results

Within this appendix the SPSS results are discussed according to the steps taken to be able to say if the weight of the same factor obtained by the BMW applied to the original category or core and peripheral categories differs significantly.

Appendix E.1: Kolmogorov-Smirnov test

Before significance between the weights could be determined the type of test which is needed to be used, paired samples T-Test or Wilcoxon signed-rank test, had to be chosen. A paired samples T-Test was applied if the data was normally distributed, otherwise the alternative was used (Sekaran & Bougie, 2016). The normality of the data was determined with help of the Kolmogorov-Smirnov test. Where it was assumed that the data is normally distributed with a p-value is higher as 0.05 (UvA Wiki Methodologiewinkel, 2014b). From the Kolmogorov-Smirnov test it was concluded that the factor 'financial strength' from the 'original categories' and the factors 'financial strength', 'complementary goods', and 'agenda setting' from the 'core and peripheral categories' were non-normally distributed. The outcome of SPSS of this test is given in Figure 8.

Appendix E.2: Paired samples T-Test

For the samples which were normally distributed, the paired samples T-Test was applied to test for significance of weights of a factor. Here it was assumed that when the p-value is below 0.05, the difference in weights of the factor is significant (Sekaran & Bougie, 2016; Uva Wiki Methodologiewinkel, 2014a). For the factors 'appropriability strategy', 'market communication' and 'suppliers' the difference in weights was concluded to be significant as the results show in Figure 9.

Appendix E.3: Wilcoxon signed-rank test

The samples were the data from was non-normally distributed, the Wilcoxon signed-rank test was applied to test for significance of weights of a factor. Here, like the paired sample T-test, the difference was assumed to be significant when the p-value falls below 0.05 (Sekaran & Bougie, 2016; UvA Wiki Methodologiewinkel, 2014c). From this test is was concluded that the weights obtained for 'financial strength' are significantly different as the results shown in Figure 10.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Financial_strength_OC	,364	7	,005	,736	7	,009
Financial_strength_CPC	,348	7	,011	,729	7	,008
Technological_superiority_OC	,230	7	,200*	,881	7	,232
Technological_superiority_CPC	,236	7	,200*	,851	7	,126
Compatibility_OC	,205	7	,200*	,935	7	,590
Compatibility_CPC	,272	7	,127	,894	7	,297
Complementary_goods_OC	,184	7	,200*	,923	7	,489
Complementary_goods_CPC	,337	7	,016	,855	7	,136
Pricing_strategy_OC	,260	7	,169	,903	7	,352
Pricing_strategy_CPC	,258	7	,176	,949	7	,722
Appropriability_strategy_OC	,223	7	,200*	,918	7	,456
Appropriability_strategy_CPC	,246	7	,200*	,873	7	,198
Market_communications_OC	,290	7	,077	,841	7	,102
Market_communications_CPC	,275	7	,118	,863	7	,160
Financial_Support_OC	,238	7	,200*	,860	7	,151
Financial_Support_CPC	,168	7	,200*	,920	7	,466
Agenda_setting_OC	,283	7	,094	,842	7	,104
Agenda_setting_CPC	,431	7	,000	,541	7	,000
Current_installed_base_OC	,220	7	,200*	,900	7	,333
Current_installed_base_CPC	,257	7	,181	,879	7	,224
Suppliers_OC	,206	7	,200*	,896	7	,309
Suppliers_CPC	,254	7	,191	,761	7	,017

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 8: Test of normality outcome of SPSS. Data was assumed to be normally divided when p (seen as Sig. in this figure) is larger as 0.05. Factors stemming from the 'original categories' can be recognized by OC behind the factor, while factors from the 'core and peripheral categories' can be identified with CPC behind the factor.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Technological_superiority_OC - Technological_superiority_CPC	-,04581	,07775	,02939	-,11773	,02610	-1,559	6	,170
Pair 2	Compatibility_OC - Compatibility_CPC	-,00201	,05060	,01912	-,04881	,04478	-,105	6	,920
Pair 3	Pricing_strategy_OC - Pricing_strategy_CPC	-,00377	,03336	,01261	-,03463	,02708	-,299	6	,775
Pair 4	Appropriability_strategy_OC - Appropriability_strategy_CPC	-,05034	,02853	,01078	-,07673	-,02396	-4,669	6	,003
Pair 5	Market_communications_OC - Market_communications_CPC	-,01160	,01245	,00470	-,02311	-,00009	-2,466	6	,049
Pair 6	Financial_Support_OC - Financial_Support_CPC	-,00413	,01484	,00561	-,01785	,00959	-,736	6	,489
Pair 7	Current_installed_base_OC - Current_installed_base_CPC	-,01139	,06500	,02457	-,07150	,04873	-,463	6	,659
Pair 8	Suppliers_OC - Suppliers_CPC	,01980	,01571	,00594	,00527	,03433	3,334	6	,016

Figure 9: Paired samples T-Test outcome of SPSS. Data was assumed to be significantly different when p (seen as Sig. in this figure) is smaller as 0.05. Factors stemming from the 'original categories' can be recognized by OC behind the factor, while factors from the 'core and peripheral categories' can be identified with CPC behind the factor.

Test Statistics[a]

	Financial_strength_CPC - Financial_strength_OC	Complementary_goods_CPC - Complementary_goods_OC	Agenda_setting_CPC - Agenda_setting_OC
Z	-2,366[b]	-,338[b]	-,845[c]
Asymp. Sig. (2-tailed)	,018	,735	,398

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Figure 10: Wilcoxon signed-rank test outcome of SPSS. Data was assumed to be significantly different when p (seen as Sig. in this figure) is smaller as 0.05. Factors stemming from the 'original categories' can be recognized by OC behind the factor, while factors from the 'core and peripheral categories' can be identified with CPC behind the factor.