How to structure my building-related data portfolio?

In order to optimize facility maintenance management

Research on structured facility maintenance management service provision aimed at flat roofs of existing buildings by using a Building Information Modeling approach

Master Thesis

Definitive

Maurice Breedijk

November, 2017

"No man is an Island,
entire of itself;
every man is a piece of the Continent,
a part of the main…"

John Donne (dean of St. Paul's Cathedral in the 17th century)

"No one can whistle a symphony; it takes a whole orchestra to play it"

Halford Edward Luccock (a prominent American Methodist minister and professor of Homiletics at Yale's Divinity School; 1885-1961)

"The world's most valuable resource is no longer oil, but data!"

Economics, 2017

Colophon

MASTER THESIS

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Preface

This MSc thesis report presents the result of my graduation project for the Master track 'Construction Management and Engineering' at the University of Twente. This research is conducted in collaboration with Van Reisen Bouwmanagement and shows how we can manage and exchange building-related data in a structured manner within the context of facility maintenance management.

At time of writing, I already work at Arcadis for almost 3 years. During this start of my professional working career, I have benefited greatly from the knowledge I have gained during my study but most of all during my MSc thesis project. Optimizing business processes from an information management point of view, is nowadays one of the biggest challenges in AEC-Industry. I have applied my learnings in defining 'generic' business processes and related information needs, and accordingly managing projects supported by a set of products (IT & data). Next challenge is to implement this 'new way of working' within other project teams, both internally (colleagues) as externally (clients, third parties).

Although I have to take the next step in my working career, I still have to close a previous chapter, my study carrier. By combining technical- and process oriented studies in different inspiring environments, I have laid a fine foundation for my professional carrier. And on the way, the learning environment and fellow students have taken care of a lot of fun and new friendships. The final bit of my study carrier, my MSc thesis, was a very long and bumpy ride. Luckily, I now have the opportunity to close this chapter in a decent manner.

I would like to use this opportunity to express my gratitude to all the people who have contributed to my graduation project. I would like to thank Van Reisen Bouwmanagement for their interesting cases to study, sharing and connecting me with their network/relations, and providing me a graduation spot in which I was able to expand my enthusiasm of BIM into an interesting research study. I also want to thank my graduation supervisors at University of Twente, Dr. T. Hartmann and Prof.dr.ir.ing G. Doréé for their contribution. In particular I would like to thank my graduation coach Dr. Irina Stipanovic for her support and guidance, especially during the last phase completing the final steps.

During my whole educational career, I have had great support from my closet friends, my family and in particular my parents, sister and my girlfriend Marloes. I would like to thank them for all their support, their patience in times of stress, their acceptance of my decisions and their permanent confidence. Without them, I wouldn't have the opportunities or being able to accomplish all my goals. I'm very grateful to have you all in my life!

Maurice Breedijk
November 2017

Summary

One of today's major challenges in FMM is to structure day-to-day operational needs and effectively manage required information. With the right information at hand, a management board is able to make well-founded decisions regarding effective FMM services. Next, in our current competitive business environment it is essential that all available resources (manhours, material, etc.) will be used optimally. Optimizing the deployment of available resources, also depends upon the supply of accurate, relevant, and speedy information. When we are able to design a management information system that captures and exchange the wealth of information at hand, it is possible to optimize the FMM service provision and contribute to reducing the total life cycle costs (LCC) of an asset.

One way of doing this is Building Information Modeling (BIM). BIM offers a platform for enhanced interdisciplinary collaboration, the capability to manage change, and the ability to extend information support throughout the building life-cycle. In this regard, the 'buildingSMART' organization has provided the IDM and MVD protocols to describe required business needs and processes, as well as to provide in a formalized method to capture these business needs and processes within an information model.

This qualitative research contributes to the design of IDM's and MVD's within the field of FMM service provision and with regard to the developments of BIM and IFC in the AEC-FM industry. It is decided to concentrate on yearly recurring FMM processes aimed at flat roofs of existing buildings, since these are responsible for one of the most important and yearly returning cost items in building maintenance (Reisen et al., 2014). Besides, IDM and MVD developments to support 'workflows' in FMM of existing buildings are still missing. The research took place in the field of FMM services, as provided by the company 'Van Reisen Bouwmanagement' and their clients. Subsequently, the main research objective is stated as follows: *The development of an object-oriented information model and implementation of an associated prototype information system that improves the efficiency of facility maintenance management services - aimed at flat roofs of existing buildings - by 'van Reisen Bouwmanagement'.*

The major contribution of this research is a prototype information model and ontology framework (class model) that takes into account both FMM process related data and object-oriented building information (related to flat-roofs) and structures it for efficient use. The information model and class model provides a solution for the identified challenges to support 'daily' workflows in FMM, regarding the fragmented information provision / requirements throughout the FMM phases and standardizing the quality of information involved actors have at their disposal. The prototype information model is built by using MS Excel, and is validated by using source triangulation. Scientifically and practically, the developed information model proves relevance in optimizing FMM decision making and deployment of available resources.

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Definitions and abbreviations

Definitions

Attribute (IFC)	An attribute is a (allocated) property of an object that describes a specific 'value' for the object (for example; an ID number, fire safety class, etc.)
Big data	The ever-increasing amount of data that organizations are storing, processing and analyzing. Owing to the growing number of data sources in use (Tankard et al., 2012 in Jiao et al., 2013).
Building Information Model	Building information Model (BIM) is the management of information and the complex relationships between the social and technical resources that represent the complexity, collaboration, and interrelationships of today's organizations and its building environment (Jernigan, 2007). As a result, BIM generates and leverage (building) data during a buildings lifecycle and allows stakeholders to have access to required information through interoperability between technology platforms (buildingSMART, 2012).
Class Model	A class model is used in software engineering and is based on a static structure diagram that describes the structure of a system by showing the system's classes. A class is a description of a set of objects that share the same attributes, operations, methods, relationships and semantics (Muller, 2009).
Existing Buildings	In this report I refer to existing buildings as already but not recently developed buildings.
Facility Management	Profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology (IFMA, 2004 in Lavy & Shohet, 2010).
Facility Maintenance Management	Also known as building maintenance and could be seen as an activity in the larger context of FM (Barret & Baldry, 2003; Tompkins, White, Bozer, & Tanchoco, 2010). It could be defined as "the keeping, holding, sustaining or preserving of a building and its services at an acceptable standard to enable its function" (Brett, 1997 in Fong & Wong, 2009).

Industry Foundation Classes Open, neutral and standardized specification for Building Information Modelling (BIM) developed by buildingSMART. It is designed to be able to store and exchange all building information over the whole lifecycle.

Information Delivery Manual Integrated reference for process and data required by BIM, by identifying the discrete processes undertaken within building construction, the information required for their execution and the results of that activity (Wix & Karlshoj, 2010).

Interoperability The ability of diverse systems and organizations to work together (interoperate).

Model View Definition Set of information from an information model that can be supported by a type of software application (Wix & Karlshoj, 2010). It specifies what information should be exchanged, and in what form and structure the IFC entities are to be used (Venugopal, Eastman, Sacks, & Teizer, 2012).

Abbreviations

AEC(-industry)	Architecture, Engineering, and Construction- industry
BM	Building Maintenance
BIM	Building Information Model
ER	Exchange Requirement
ERM	Entity-Relations Model
FM	Facility Management
FMM	Facility Maintenance Management
FP	Functional Parts
IAI (now buildingSMART)	International Alliance for Interoperability
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
IT	Information Technology
LCC	Life Cycle Costs
MVD	Model View Definition
PED	Project Engineering Data
PMD	Project Management Data
RSN	Roofing Service Nederland
UML	Unified Modeling Language

1. Introduction

Architecture, engineering, construction (AEC) and facilities management (FM) are information intensive industries, facing many challenges in organizing and managing their specific processes. Considering facility management processes, involved managers are continually faced with the challenge of improving and standardizing the quality of information they have at their disposal. This is initiated by the fragmented and dissociated nature of the AEC-FM industries (Vanlande, Nicolle, & Cruz, 2008), as well as the vast amount of information produced within different processes and used for a wide variety of purposes throughout a buildings life-cycle (Becerik-Gerber, Jazizadeh, Li, & Calis, 2012; Golabchi & Kamat, 2013; Vanlande et al., 2008). These issues are particularly expressed within facility maintenance processes of existing buildings, were facility managers are still losing money and waste a lot of time due to poor information- management and exchange. Especially information from earlier lifecycle phases and information generated by third parties is often scattered in multiple formats/systems or it is inconsistent. At worst scenarios there isn't enough time available to process or gather all required information and facility maintenance and management (FMM) activities put in motion on the basis of incomplete or inaccurate information.

Consequently, one of today's major challenges in FMM is to structure day-to-day operational needs and effectively manage required information. In which the efficiency of F(M)M processes depends on the integrity and effectiveness of the information flowing between all those involved in the process (Scott, Cheong, & Li, 2012). It's important for operational managers and their upper management to have a solid data collection, which allows them to form a complete picture of their property portfolio, and to effectively manage (upcoming) maintenance activities. To accomplish this, incorporating a proper information system is vital. One way of doing this is Building Information Modeling (BIM). BIM offers a platform for enhanced interdisciplinary collaboration, the capability to manage change, and the ability to extend information support throughout the building life-cycle.

This research focused on objected oriented information model to support facility maintenance management service provision at existing (already built) buildings. The research took place in the field of FMM services, as provided by the company 'Van Reisen Bouwmanagement'. The scope includes general building objects related to flat roofs, since these are responsible for one of the most important and yearly returning cost items in building maintenance (Reisen, Kraan, & Bosch, 2014). The results of this research are useful for industry professionals, building owners, BIM developers and researchers involved in the implementation of BIM and are interested in streamlining building-related data with information technologies to support FMM services.

Why should you be interested!? Because, it can ***save money!*** Reliable, relevant, and timely exchange of information is the key to optimizing FMM services and subsequently optimizing value for money in the ownership of physical assets. With the right information at hand, a management board is able to make well-founded decisions. This approach to decision making encourages a long-term outlook to the FMM decision-making process rather than attempting to save money by (only) responding to faults (unplanned maintenance). Next, in our current competitive business environment it is essential that all available resources (manhours, material, etc.) will be used optimally. Optimizing the deployment of available resources, also depends upon the supply of accurate, relevant, and speedy information. When we are able to design a management information system that captures and exchange this wealth of information, it is possible to optimize the FMM service provision and contribute to reducing the total life cycle costs (LCC) of an asset.

1.1 Motivation

Improved technology, the recognition of benefits arising from cooperation between supply chains and the inevitability of modernization, motivates companies to accept and experience the capabilities of BIM (ABN AMRO & Bouwend Nederland, 2012). In current practice, most BIM developments takes place within the design and construction phase, mainly focusing on improvement of project collaboration and reducing failure costs and project delays. However, the completion of a building construction is just the beginning of the total life cycle costs. Most of these costs are borne by owners and facility managers, who incur them predominantly during ongoing facility operation and maintenance (Cobouw, 2013). In view of the long lifespan (25,30, 50 or even 100 years) of buildings and the notion of existing buildings being accompanied by inadequate or insufficient information, facility managers could also take advantage from using BIM regarding cost- and process optimizations.

Although companies are aware of the benefits of using BIM during the project lifecycle, they still struggle to incorporate BIM initiatives in their daily business operations. Besides, FMM departments encounter difficulties in defining *what* needs to be maintained, according to *what* requirements, *who* is responsible, and subsequently *how* to manage associated maintenance processes effectively. Ultimately, this allows for a fairly unstructured service provision from maintenance procurement to administrative procedures and evaluations (as illustrated in Figure 1). To surmount current information management, communication and process deficiencies, more emphasis should be given to IT concepts into FMM for providing digitized maintenance and management information (Chassiakos & Sakellaropoulos, 2008; Chen, Hou, & Wang, 2013).

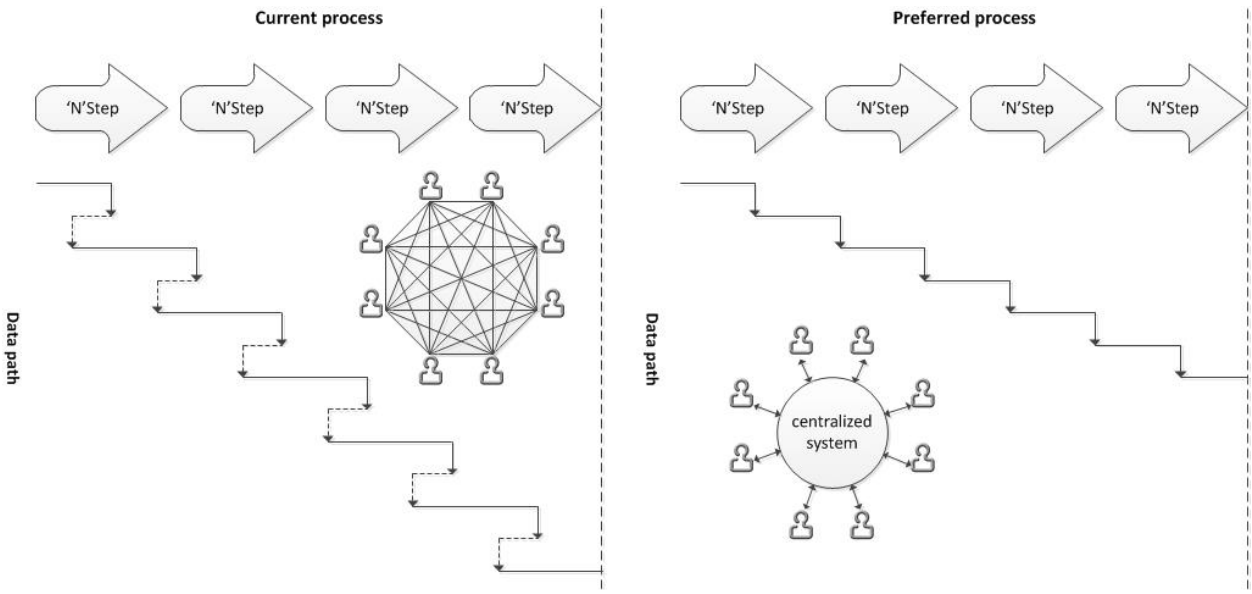

Figure 1: Data path of collecting, sharing and communicating relevant data between agencies
(Compiled on the basis of Chassiakos & Sakellaropoulos, 2008)

1.1.1 Business needs

To create and deliver value through BIM in FMM, the key resource is not the technologies themselves but the processes used to create information and knowledge that will be distributed throughout the asset owner's business. This requires i) a thorough understanding of FMM processes and ii) a specification of accompanied 'data and information needs' by the different agencies (ARCADIS, 2012; Love, Matthews, Simpson, Hill, & Olatunji, 2014). However, these requirements aren't clearly defined yet (Cobouw, 2013). Especially for proper flat roof maintenance activities there are multiple aspects and processes to be taken into account, as well as many different building-related objects and their interfaces. This is also reflected in the following quote by a consultant of Van Reisen Bouwmanagement:

"In a tender process for any kind of roof maintenance, each invitee will access the roof to make notes and drawings of the as-built situation. Consequently, we receive offers based on diverse observations with differing information content (e.g. divergent data regarding square meters, needed safety requirements, observed calamities, etc.), making it difficult to provide for an unambiguous comparison."

Another problem companies are faced with in BIM implementation is the aspect of interoperability between different IT systems, in order to exchange data via a common set of exchange and file formats. For software developers, there is a challenge to develop software that connects to the business needs and FM systems. Therefore, they need protocols describing required business needs and processes, as well as a formalized method to capture these business needs and processes within an information model.

The Information Delivery Manual (IDM) and Model View Definitions (MVD) approach offered by 'buildingSMART' are a response to the protocol issues. Translating these protocols into so called Industry Foundations Classes (IFC), standardized object representations for AEC-projects, could solve the interoperability deficiencies between different IT systems. Yet, a comprehensive reference of these concepts to individual business processes, such as flat roof maintenance services, is still missing. Therefore the goal of this research is to optimize the FMM service provision for flat roofs by defining a well-structured FMM service provision protocol and incorporating object-oriented information modeling principles translated into an information (class) model.

1.2 Research outline

The owners, technical operators, projects and consultants in this research are limited to the ones within the network of 'Van Reisen Bouwmanagement' and selected on the basis of availability and willingness to cooperate.

This case study oriented and qualitative research is divided into two parts: a process analysis and an information model design. The process analysis defines specific FMM processes and involved actors for maintaining flat roofs at existing buildings and identifies the information to be created as well as to be exchanged. Based on this analysis, an information (class) model is designed which describes how the information should be structured by BIM oriented information technologies. This information model is tested by consultants and service providers in the field of FMM, by means of a developed prototype information tool in MS Excel, it incorporates the identified FMM processes and manages involved information needs.

This research contributes to the design of a structured FMM service provision, based on the concept of object-oriented information modeling and with regard to the developments of BIM and IFC in the AEC-FM industry. The proposed information model provide insights in how to store information needs to support FMM processes of flat roofs, so it becomes exploitable, organized and to enrich the knowledge throughout the lifecycle of a building. Furthermore, this research is positioned within the end user of an IT application and the software solution provider. The process analysis is established in accordance with the IDM approach and the proposed information (class) model provides a sound basis towards a full MVD for IFC implementation, which could be supplemented by an expert in IFC software development.

1.2.1 Reading guide

The research starts with a description of the theoretical point of departure CH2. It includes an overview of relevant findings in literature regarding the AEC-industry and related to facility maintenance management. The research methods used are described in CH3, including the research framework and the steps taken. A case study is used to collect relevant data and analyze FMM services by van Reisen, the results of this analysis is captured in CH4. The translation and relations of the analyzed FMM services into an information model is explained in CH5, including the development of a prototype information model. These are the output (end products) of this research. This report finishes with a discussion of the findings from this research project and recommendations for future research (CH6), followed by some overall conclusions (CH7). The appendixes provide the documents created during the case study, data analysis and development of the (prototype) information model.

2. Points of departure (POD)

Although BIM is spreading in AEC-FM industries worldwide, both researchers as professionals in practice are still searching for effective ways to introduce and implement BIM related IT tools to support specific processes. As stated in Volk (2014), research turns to F(M)M requirements just recently, but still it's mainly focusing on new or recently completed buildings with a building information model at hand, rather than on existing buildings without BIM. Besides owners, facility managers and related consultants are hardly involved in the BIM functionality development yet.

In literature is suggested that the first step of information modeling is all about identifying business needs and processes, to identify the specific business characteristics an IDM and MVD approach is suggested by buildingSMART (Wix & Karlshoj, 2010). These approaches provide a suitable basis for modeling BIM technologies, in which interoperability issues are the hardest challenge to cope with.

Blending the above with benefits of interdisciplinary collaboration, also facility managers are left with evolving technology and the need to align their business processes, like FMM. This section describes current findings in literature (literature review) and highlights an area of attention (gap analysis), to which this report contributes.

2.1 Literature review

Following literature review captures the rationality behind facility (maintenance) management processes, describes the main principles of BIM, IDM and MVD approaches and indicates current interoperability and IFC issues. It positions the research context and serves as a structured framework throughout this report.

The concepts of data, information and knowledge are inextricably linked together and form an essential part in IT. For the purpose of clarity, the following rationality of these concepts is been taken from the research by Alavi and Leidner (1999) and will be used in this report:

The lowest level of known facts is data and has no intrinsic meaning. It must be sorted, grouped, analyzed, and interpreted. When data is processed in this manner, it becomes information and has a substance and a purpose. Information becomes knowledge once it is processed in the mind of an individual. Yet, this knowledge then becomes information again once it is articulated or communicated to others in the form of text, computer output, spoken, written words or other means. The recipient can then cognitively process and internalize the information so that it is converted back to knowledge.

2.1.1 Facility Maintenance Management (FMM)

As stated by the International Facility Management Association (IFMA, 2004 in Lavy & Shohet, 2010), facility management (FM) is taken to be: "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology." Subsequently, building maintenance (BM) is seen as an activity in the larger context of FM (Barret & Baldry, 2003; Tompkins et al., 2010), and could be defined as "the keeping, holding, sustaining or preserving of a building and its services at an acceptable standard to enable its function" (Brett, 1997 in Fong & Wong, 2009).

Generally, maintenance can be either preventive or corrective. Corrective maintenance, similar to repair work, is undertaken after a break down or when obvious failure has been located. Preventive maintenance is carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or degradation of functioning of an item (Motawa & Almarshad, 2013; Niu, Yang, & Pecht, 2010).

Information collection is basic to a FMM system, and the capability to collect detailed information allows effective FMM (Vanier, 2001; Woodward, 1997 in X. Zhang, Arayici, Wu, Abbott, & Aouad, 2009). Effective FMM of buildings must integrate and manage information, such as records on environmental monitoring, inspection, and maintenance, as well as drawings, manuals, contracts, specifications, previous maintenance work, etc. (Chen et al., 2013; Motawa & Almarshad, 2013). Ultimately, this should provide facility managers a complete picture of the extent of their existing facility portfolio (Kyle, 2001 in X. Zhang et al., 2009).

Information in AEC-FM industry is typical of the category ‘big data’. The term ‘big data’ refers to the ‘‘ever-increasing amount of data that organizations are storing, processing and analyzing, owing to the growing number of data sources in use’’ (Tankard et al., 2012 in Jiao et al., 2013). Challenges in managing ‘big data’ mainly result from three issues: volume (the increasing amount of data), variety (the wide range of data types and sources), and velocity (the high speed of data input/output) (Pettey 2011 in Jiao et al., 2013). The main goal of information management is to enable data interoperability so that data generated by one party can be smoothly shared among all participants.

Another type of FMM information refers to the ability to reuse and capture knowledge and experience, as obtained in former maintenance operations. Experience could be defined as “knowledge or practical wisdom gained from what one has observed, encountered, or undergone” (Anon, 2001 in Fong & Wong, 2009). In addition, Bergmann, 2002 in Fong and Wong (2009) defines experience as “valuable, stored, specific knowledge that was acquired by an agent in a previous problem-solving situation” and is useful for future re-use by the agent. Without the reuse of existing knowledge and experience, organizations has to create their own solutions to every problem they face, as a result they are continuously reinventing the wheel.

2.1.2 Building Information Modeling (BIM)

Building Information Modeling (BIM) is beginning to change the way we build, the way the buildings look, the way they function and the way buildings are maintained and managed (Godager, 2011). Regarding F(M)M, it could offer facility managers the ability to become more efficient and effective by linking their business processes with their facilities data. Here, it’s important to realize that BIM is not a thing or type of software but a human activity that ultimately involves (broad) process changes (Jernigan, 2007).

Within the AEC-FM industry there isn’t a common understanding regarding the term BIM. Some software developers use the term BIM as a buzzword to describe the capabilities of their products, frequently referred to as little bim (Jernigan, 2007). Most practitioners in the AEC industry regard BIM as the joint development of a 3D model for the benefit of the design and building process. However, the development of an appropriate (object-oriented) database model containing relevant data (according to an information template/framework) is also an important aspect of a BIM to be used throughout a facilities life cycle (Jiao et al., 2013). Proceeding on these two distinct characteristics, Jiao et al. (2013) distinguishes two kinds of data categories. Namely; i) project engineering data (PED) which are geometric presentations, parametric descriptions and legal regulations associated with the construction of a building, and ii) project management data (PMD) which refers to control and communication information that are generated in and closely related to management activities throughout the construction lifecycle.

This report starts from the following concept definition of BIM: *Building Information Modeling is the management of information and the complex relationships between the social and technical resources that represent the complexity, collaboration, and interrelationships of today's organizations and its building environment (Jernigan, 2007). As a result, BIM generates and leverage (building) data during a buildings lifecycle and allows stakeholders to have access to required information through interoperability between technology platforms (buildingSMART, 2012)*.

There are several BIM-focused studies aimed at improving F(M)M. For example; BIM based package for the FM Exemplar project of Sydney Opera House which is developed to manage digital data generated by procurement and benchmark sections of the project (Akhurst & Gillespie, 2006). The research by Motawa and Almarshad (2013) aims to develop an integrated system to capture information and knowledge of building maintenance operations when/after maintenance is carried out to understand how a building is deteriorating and to support preventive/corrective maintenance decisions.

An important learning aspect from these (and other) studies, is that in creating and delivering value through BIM, the key resource is not the technologies themselves but the processes used to create information and knowledge that will be distributed throughout the asset owner's business (Love et al., 2014). So to increase the operational efficiency in F(M)M, an organization must first develop an understanding of their operating systems (Kasprzak & Dubler, 2012), and specify their 'data and information needs' for the operation and maintenance of their facilities (Love et al., 2014).

2.1.3 Current IFC and Interoperability issues in AEC-FM industry

Information modelling is the procedure of developing an information model, which is an abstract yet formal representation of entities in data, including their properties, relationships and the operations that can be performed on them. The main driving force behind the development of an information model is to provide formalism to the description of a problem domain without constraining how the description is mapped to an actual implementation in particular software (Chassiakos & Sakellaropoulos, 2008).

In this line of thought, the Industrial Alliance for Interoperability (IAI) was created, with the purpose of enabling software interoperability, providing an universal basis for process improvement and information sharing in the AEC-FM industry. With respect to software, the term interoperability is used to describe the capability of different programs to exchange data via a common set of exchange formats, to read and write the same file formats, and to use the same protocols (Golabchi & Kamat, 2013). Consequently, IAI developed the International Foundation Classes (IFC) as an open standard model to allow software vendors to create interoperable applications via the IFC file format (Grilo & Jardim-Goncalves, 2010; Yu, Froese, & Grobler, 2000).

IFC is a set of definitions describing the consistent data representation of all building components and it is designed to be able to store and exchange building information over the whole building life-cycle. The class object specifications in IFC, which includes not only geometric information but also physical properties and behaviors, endows the IFC objects with intelligence (L. Zhang & Issa, 2014).

Although IFC is a rich product-modeling schema, it is highly redundant, offering multiple ways to define objects, relations, and attributes (Delfosse, Schrayen, Juchmes, & Leclercq, 2012; Steel, Drogemuller, & Toth, 2012; Venugopal et al., 2012; L. Zhang & Issa, 2014). As stated by Venugopal et al. (2012), a major drawback of the hierarchical structure of IFC is that due to its size and deep inheritance structure, it is difficult to see what a single object's definition really is. Hence, software developers need to be well versed in the IFC object hierarchy. In addition, it might be noted that human cognition is flexible and agile. This means that a person could model a BIM or a software application in different ways with respect to the IFC structure.

As a result of these semantic issues, data exchanges are often unreliable due to inconsistencies in the assumptions different implementers of exchange functions make about how information should be expressed (Sacks et al., 2010 in Venugopal et al., 2012). There are often unpredictable differences in the ways in which export and import functions treat the same data, posing a barrier to the advance of BIM (Eastman et al., 2011; Olofsson et al., 2008 in Venugopal et al., 2012). Specifying IDM and MVD protocols, targeted at specific business processes, are therefore required for IFC implementations. These protocols should reduce the scope of the full IFC model to particular scenarios to extract sub-models in order to fulfil the requirements of both end users and application developers (C. Zhang, Beetz, & De Vries, 2013).

2.1.4 IDM & MVD developments

Implementation of IFC is based on a particular view or a combination of views of IFC that define data set requirements in support of specific industry processes, a given organization's work practice, or typical business cases (Grilo & Jardim-Goncalves, 2010). This is substantially enhanced through the Model View Definition (MVD) effort which improves the way in which views are specified. However, model views are targeted specifically at software developers and certification of their software and not at the way in which industry practitioners use the software (Wix & Karlshoj, 2010).

As a response, the Information Delivery Manual (IDM) aims to provide the integrated reference for process and data required by BIM by identifying the discrete processes undertaken within AEC-FM processes, the information required for their execution and the results of that activity. For this to happen, there should be a common understanding of the business processes and of the information that is needed for, and results from, their execution.

Wix and Karlshoj (2010) sets out an IDM methodology for the provision of an integrated reference for the processes and data required by a BIM. It will specify i) where a process fits and why it is relevant, ii) who are the actors creating, consuming and benefitting from the information, iii) what is the information created and consumed, and iv) how the information should be supported by software solutions. Ultimately, this should provide a basis for reliable information exchange and sharing for users in order to be confident that the information they are receiving is accurate and sufficient for the activities they need to perform.

A Model View Definition could be designed to deal with the semantic issues in IFC implementation. MVDs narrow down the complete IFC model specification, documenting how data exchanges are applied between different application types; as such it mostly directly benefits the implementers of IFC software. One software application can implement one or several MVDs depending on the scope of its domain (Laakso & Kiviniemi, 2012).

MVDs are structured such, that different audiences can focus on the information relevant to them. The main division is between technical and non-technical. The non-technical definitions, called

Exchange Requirements (ER) are aimed at software users, the technical definitions, called Functional Parts (FP) are aimed at software developers (also known as solution providers) ("IFC Solutions Factory," n.d.; Laakso & Kiviniemi, 2012). Both parties need to know which IFC components are important for their purpose, see also Figure 2 (Wix & Karlshoj, 2010);

- software users, to be sure that IFC meets their needs;
- software developers / solution providers, to be sure they implement the right components in order to meet all user needs.

An exchange requirement describes in non-technical terms, the information that must be exchanged in order to support a particular business requirement at a particular stage of a project, with the principal audience being the end-users, but is something software developers must also be aware of in order to provide them support. Functional parts are individual units of information which software developers use to support exchange requirements, describing the information by taking into account the requirements of the IFC data model (Laakso & Kiviniemi, 2012; Wix & Karlshoj, 2010).

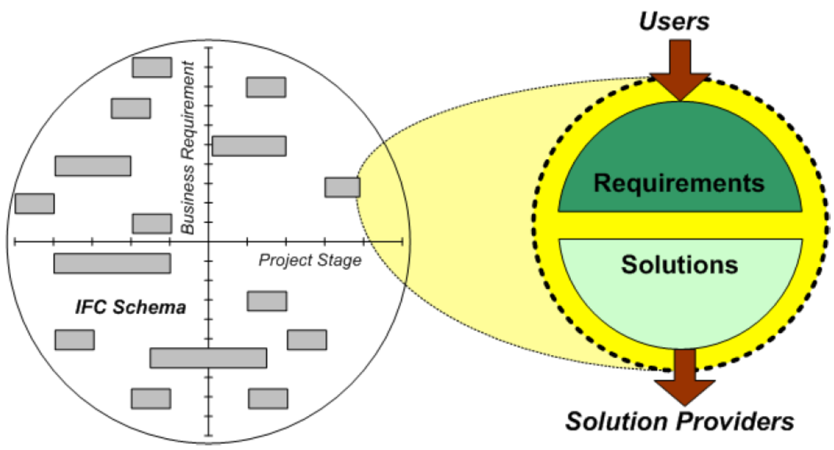

Figure 2: Business process requirements and solutions
(Wix & Karlshoj, 2010)

2.2 Gap-analysis

Studies have shown that there is no single factor causing interoperability issues among BIM related software applications. Main identified factors causing interoperability issues are i) the continually advancing and complex nature of AEC-FM projects and processes, ii) the volume of specialist disciplines involved, and iii) the software solutions employed. Although these factors have only been partially examined (e.g. still in the early stages of BIM and IFC implementation), acquired insights could be used as a practical guide on how to remove the obstacles in an attempt to increase the chance of achieving interoperable BIM implementation and collaboration in the AEC-FM industry.

In this regard, the 'buildingSMART' organization has provided the IDM and MVD approaches, since successful implementation of BIM and IFC related approaches depends on (see also Figure 3):

i) a thorough understanding of business processes and associated business needs. This is addressed by the IDM approach and is in line with current FMM challenges as formulated in section 1
ii) a reliable (IFC based) information exchange, management and sharing format for users so they can be confident that the information they are receiving is accurate and sufficient for the activities they need to perform. This asks for a comprehensive reference to the totality of information within the

lifecycle of a constructed facility. The MVD approach provides a structure to develop IFC references per specific model view (e.g. a business process).

To date, various groups and consortia have developed IDMs and MVDs for their target domain model exchanges. On-going projects are listed on the webpages of buildingSMART-tech.org and IFC Solution Factories in the Blis-Project. Among these projects are; architectural design to building energy analysis, circulation/security analysis, quantity takeoff for cost estimating, spatial program validation, or mechanical, electrical, plumbing exchange in design and construction.

As concluded by Volk et al. (2014), current IDM and MVD developments mainly focus on new rather than existing buildings and their requirements. Besides, most are aimed at analysis purposes, while there is a need for structured information provision in benefit of the daily tasks in preventive- and corrective maintenance activities. Furthermore, developed IDMs and MVDs are only partly relevant and adequate in F(M)M, since maintenance requires a high level of detail (Reisen et al., 2014; Volk et al., 2014), and due to differing requirements and information structures.

In conclusion, IDM and MVD developments to support 'workflows' in FMM of existing buildings are still missing. Additional research is needed to address current FMM challenges in formulating their business processes and related information needs through IDM. Subsequently this could be the baseline for developing structured IFC references by means of MVDs. This will make IFC more closely reflect specific FMM process needs and accelerate the use of BIM in F(M)M.

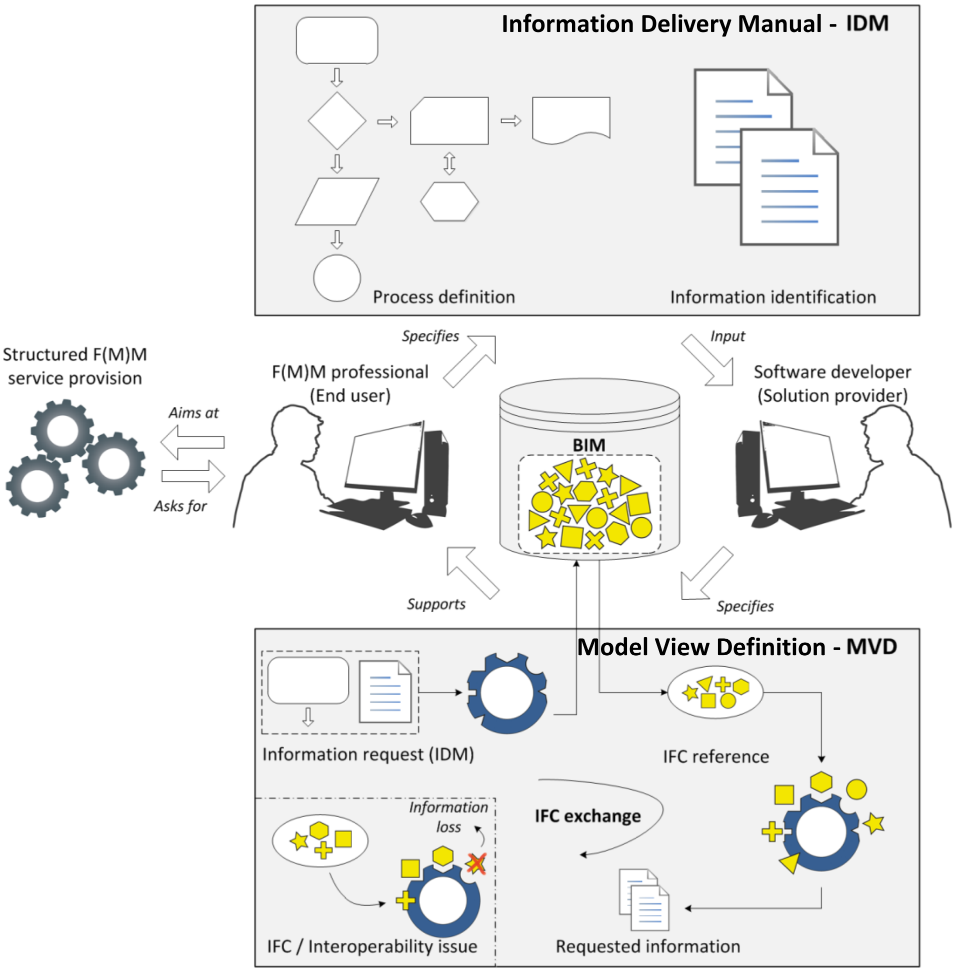

Figure 3: Gap analysis – IDM and MVD developments to support F(M)M service provision

2.3 Research context

As mentioned in the previous section, this research focuses on IDM and MVD developments to support 'workflows' in FMM of existing buildings. Identifying and developing such integrated references for all building objects and FMM processes in the domain of AEC/FM is out of the scope of this research. It is decided to concentrate on yearly recurring FMM processes aimed at flat roofs of existing buildings, since these are responsible for one of the most important and yearly returning cost items in building maintenance (Reisen et al., 2014).

Most existing buildings are built according to the traditional way of developing building projects. Meaning, after or before construction, there is no (building) information model available, other than traditional documents as (2D) drawings, building specifications, material excerpts, etc. Therefore, this research doesn't relate to-, or elaborates on any pre-developed information model.

This provides the opportunity to use a bottom-up approach, as meaningful (organizational) change begins at the 'work-floor' (Hicks, 2013). To successfully implement an organizational change, one should align its organizational processes, involved people (Stertefeld, 2013) and related information needs. These principles of managing (organizational) change is in line with the concept of IDM and MVD development, aligning business- processes and needs with (IT) information model concepts.

2.3.1 Scope

The research by Yu et al. (2000) refers to a hierarchy (developed by the IAI North American FM Domain Committee) regarding the scope of facility management functions. The identified facility management functions are classified into three basic categories: maintenance and operation management, property management, and services. Furthermore, these functions are carried out with respect to specific elements within the facility, which classifies the items into building systems and non-building systems. Both schemes are included in Appendix A, and allows me to place this research into the overall context of facility management.

As can be seen from the schemes, a building portfolio related to facility management functions and elements requires a large amount of information. Concerning FM functions, this research concentrates at the yearly recurring processes of maintenance-, alteration- and repair functions. These functions are subdivided into;

- maintenance procurement;
- preventive maintenance functions;
- project (maintenance) execution;
- and problem (defects) identification / allocation.

The FM elements are limited to the building object;

- 'flat roof';

and following related non-building system elements;

- site/ground elements;
- maintenance data;
- documents;
- maintenance records.

A flat roof could be subdivided into several other building objects as will be shown in the research results. As a general rule can be stated that a flat roof includes all mounted objects and materials on the structural roof layer, within the limits of the roof edge finishing (Bosch, 2014). This is visualized in some examples, included in Appendix B.

This research is positioned within the end user of an IT application and the software solution provider. Principles of IDM and MVD development are used as a guideline to analyze the yearly recurring FMM processes. Data results are modelled into an information (class) model (Muller, 2009), which describes and structures named FM Functions and FM Elements.

A prototype model is developed to test and demonstrate the potential value of the information model, aspects as 'user-friendliness' of the prototype model are of secondary importance and out of scope for this research. MS Excel is chosen to develop the prototype model, due to its widespread availability, lower cost, and ease of learning.

2.3.2 Research objective

The research objective of this report is as follows:

Research objective
The development of an object-oriented information model and implementation of an associated prototype information system that improves the efficiency of facility maintenance management services - aimed at flat roofs of existing buildings - by 'van Reisen Bouwmanagement'.

The provision of 'efficient FMM services' is related to- and measured by the common control factors of (integrated) project management; Money, Organization, Time, Information and Quality. Improvements should be found in dealing with the challenges of managing 'big data', in which it is important to manage data by controlling the big data characteristics; Volume, Variety and Velocity. In addition should be dealt with the capability of reusing and capturing knowledge and experience as obtained in former maintenance operations. Improving these aspects through the facilitation of an object-oriented information model, should enable data interoperability whereby data generated by one party can be smoothly stored and shared among all participants. Ultimately, this should be reflected in the control factors of integrated project management.

To accomplish the research objective, there are three sub-studies required. At first, it is necessary to identify the specific FMM processes, roles and 'information flows' by conducting a case study. Secondly, the results need to be translated to a theoretical framework, an information model that structures the information. Thirdly, the prototype information system could be developed based on the identified FMM processes and by implementing the information model. Figure 4 provides a schematic representation of this research, supported by the following sub-objectives:

Case study
Analyze and specify facility maintenance management- tasks, activities and information needs of a maintenance team aimed at flat roofs.

Theoretical framework
Compose an information model to support identified facility maintenance management processes by 'van Reisen Bouwmanagement.

Implementation
Develop a prototype information system (a demonstration model) to validate the functionality- and indicate the potential value of the composed information model.

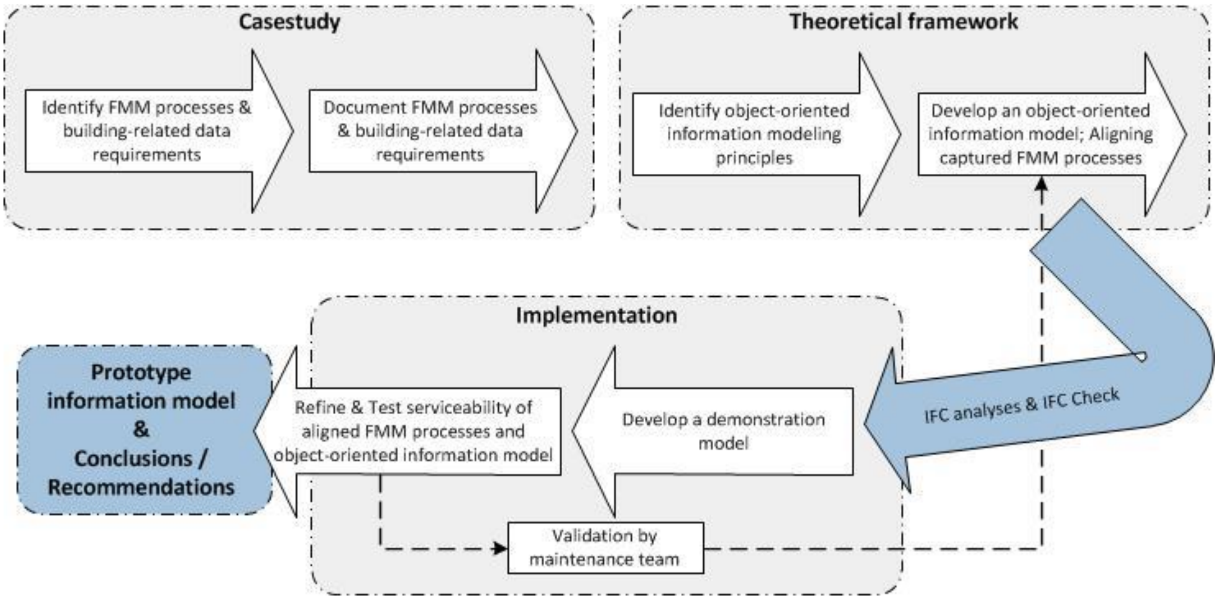

Figure 4: Research model

2.3.3 Research questions

Regarding the evolving AEC-industry and the need for additional research to address current FMM challenges, concerning the alignment of business- processes and needs with (IT) information model concepts, the following research questions have been formulated:

> ***Main research question***
> How should an object-oriented information model be structured, to optimize facility maintenance management service provision aimed at flat roofs of existing buildings? *[Par 5.2]*

The following sub-questions have been formulated within the context of - *facility maintenance management service provision aimed at flat roofs of existing buildings by 'van Reisen Bouwmanagement'*.

Sub- questions

- How is the 'traditional' process of facility maintenance management service provision designed at 'van Reisen Bouwmanagement'? *[Par 4.1]*
- Which building related object data does one require to successfully fulfill identified processes, and where/how is it stored? *[Par 4.2.1]*
- What kind of information is generated during these processes and how is it used? *[Par 4.2.2]*
- How could the identified facility maintenance management processes and information needs be captured in an object-oriented information model? *[Par 5.1]*
- To which extend does current IFC object data formats fulfill the information needs of facility maintenance managers? *[Par 5.1.1]*
- How could the developed object-oriented information model be used to support facility maintenance management services by 'van Reisen Bouwmanagement'? *[Par 5.2.1]*

3. Research method

In this study various research methods and types of data have been used in order to meet the stated objectives and to provide an answer to the research questions. The applied methodologies are divided into two parts: a process analysis and an information system design. Table 1 summarizes the types of research methods used. The research is placed within the theoretical context as defined in chapter 2 (paragraph 2.1) and concentrates on IDM and MVD development methods, defining the business process and related information needs for flat roof maintenance services as appointed in paragraphs 2.2 and 2.3.2. The IDM and MVD development methods will help to structure the process analysis results in a way that supports the objected-oriented information model (system) design.

Research method	*Sub-question 1*	*Sub-question 2*	*Sub-question 3*	*Sub-question 4*	*Sub-question 5*	*Sub-question 6*
Case study analysis	X	X	X			
IDM development (process maps, exchange requirements)		X	X			
Use cases (and information modules)				X		
Information model development (class model)				X	X	
Test case analysis and prototype development					X	X
(Final) Test case analysis						X

Table 1: Research methods used

3.1 Research structure

Figure 5 provides a visualization of the research structure, aligned with the IDM/MVD concept.

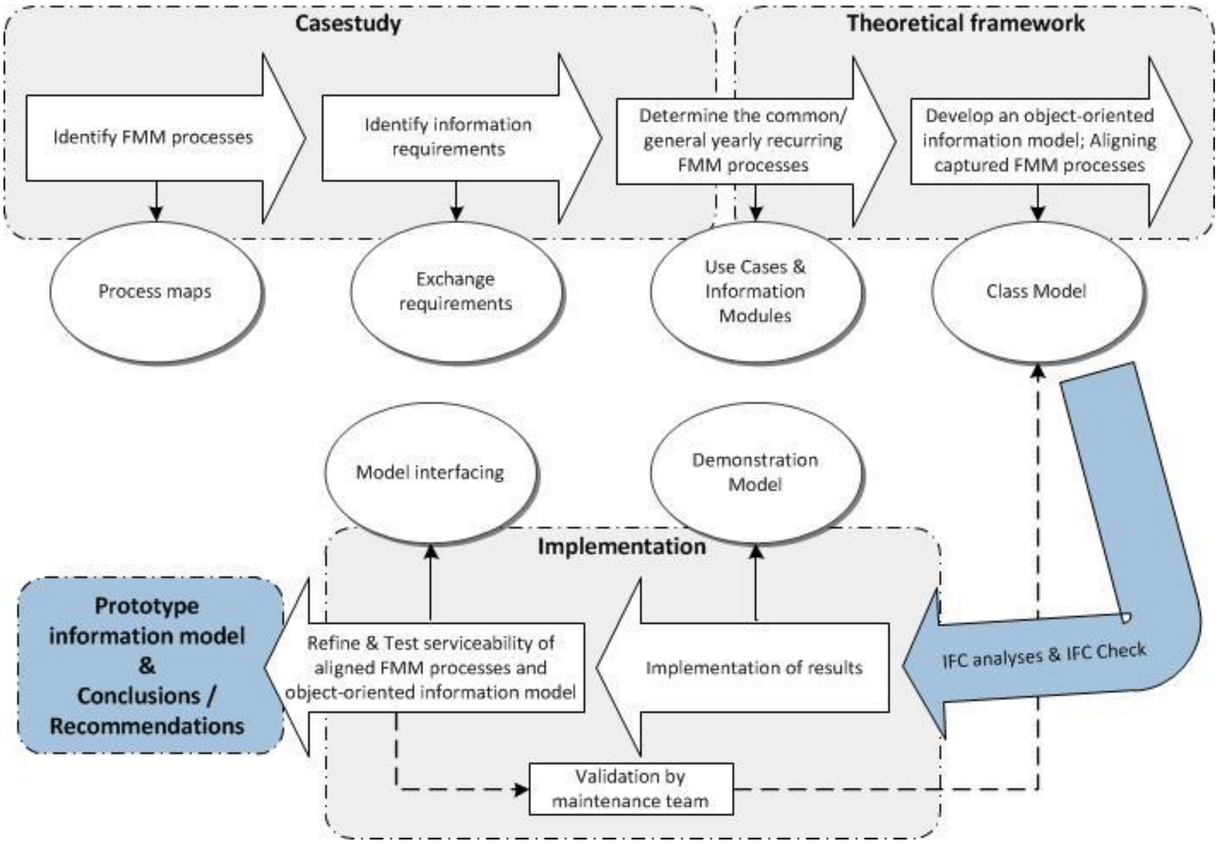

Figure 5: Research structure aligned with IDM/MVD concept

3.2 Process analysis

A case study is used to analyze specific business processes, actor activities and information flows to frame and understand FMM work practices and to give insight into how the introduction of an information model (technology) could augment the FMM service provision. The results of the case study are documented in the form of process information models by using the principles of the IDM concept. The IDM specifies;

Process maps

1) where a particular process fits and why it is relevant;

2) which actors are creating, consuming and benefitting from the information;

Exchange requirements

3) what information is created and consumed;

4) how the information should be supported by software solutions.

The process maps and exchange requirements are the result of multiple (iterative) interviews, which are held with the main stakeholders within the case study. The first interview rounds concerned the analysis of the process maps. During individual sessions the processes have been schematically drawn and subsequently compared with each other. Contradictions have been discussed with the stakeholders in a new interview round. In case of remaining contradictions (disagreement among stakeholders), van Reisen made the final decision since they are the ‘process owner’ of this research.

After the process maps were established, a new interview round has started to discover the exchange requirements of each individual activity in the process. The main interview questions during this round were; 1) What information is currently tracked?; 2) How is this information typically used?; 3) What additional information can be beneficial?, and 4) Who are the key players? For each activity, the outcomes of the interview have been documented in a table, for an example see Table 2. Similarly, as the process maps, in case of any remaining contradictions van Reisen made the final decision.

<table>
<tr><td>Activiteit nummer</td><td colspan="4">9</td></tr>
<tr><td>Omschrijving activiteit</td><td colspan="4">Uitvoeren (gezamenlijk) locatiebezoek.</td></tr>
<tr><td>Uitvoerende actor(en)</td><td colspan="4">TD’er & Onderhoudspartijen</td></tr>
<tr><td>Communicatie naar volgende actor?</td><td colspan="4">Onderhoudspartijen</td></tr>
<tr><td>Hoe verloopt deze communicatie?</td><td colspan="4">Mondeling op locatie</td></tr>
<tr><td>Consultatie tussen</td><td colspan="4">TD’er & Onderhoudspartijen</td></tr>
<tr><td>Output na afronding activiteit</td><td colspan="4">Volledig inzicht in opdracht en benodigde gebouw gebonden data t.b.v. opstellen offerte + eventuele openstaande vragen</td></tr>
<tr><td>Output opslaan t.b.v. toekomstige projecten en/of administratieve doeleinden? Ja/Nee</td><td>Ja, indien nieuwe ‘as-built’ informatie</td><td>Indien Ja, hoe en waar opgeslagen?</td><td colspan="2">Onderdeel revisie?</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Informatie behoefte</td><td>Standaard informatie ja/nee?</td><td>Waar opgeslagen?</td><td>Type informatie (tekst, document, getal, ….)</td><td>Document bevat informatie betreffende</td></tr>
<tr><td>Gebouw gebonden data. Zie tabel RSN</td><td>Ja</td><td>Nu overal en nergens opgeslagen, tekeningen, inspectie rapporten, etc.</td><td>Documenten, tekeningen</td><td>Gebouw gebonden data (as-built)</td></tr>
<tr><td>TD’er overzicht partijen + contactgegevens</td><td>Ja</td><td>Topdesk</td><td>Tekstueel</td><td></td></tr>
</table>

Table 2: Example of documented exchange requirements per activity during interviews

3.2.1 Case study

In consultation with ‘van Reisen Bouwmanagement’ it was decided to focus the case study on the yearly recurring processes of flat roof maintenance services. This allows for a solid project scope and excludes unexpected and incidental events, which require a different approach te be captured. The consulted experts and projects are limited to the ones within the network of ‘van Reisen Bouwmanagement’ and selected on the basis of availability and willingness to cooperate. In order to fully cover the yearly recurring processes, the consulted experts must conform to the profiles of;
- a building owner who outsourced technical management/maintenance (building portfolio should include building(s) with a significant flat roof area);
- technical (systems) managers (Van Reisen);
- technical operators.

For the case study four projects are selected from the building portfolio of Lindenhout, see paragraph 3.2.1.1. These projects include different buildings (in general, different in location, geometry, age, materials used, building function). The annual (flat roof) maintenance processes of last 3 years are analyzed by studying project related documents (like technical reports, tender offers, inspection forms, certified guidelines, etc.) and conducting interviews with different experts.

The strategy of the case study was to work from a 'helicopter-view perspective' towards a more 'detailed perspective' in iterative steps of interviews and project documents analysis. The results of each step are presented to the relevant experts during an interview, in order to verify that the correct interpretation is given to the results. At first the overall business processes are identified, secondly the individual FMM process steps have been appointed, thirdly the information requirements to complete each specific FMM process step were set, and finally the common/general yearly recurring FMM processes were defined and set after a final and integral check with the main actor and 'van Reisen Bouwmanagement'. Each individual step of the case study provides input for the IDM development.

The observations were finished at the moment a desired annual maintenance process was recognized, which was in line with the thoughts and needs of the different experts. This also included the required data/information needs per activity within the process. The results clarifies how building related object data should be used, received and which (new) data/information is produced during the annual maintenance processes.

The organizations 'Lindenhout' (owner of multiple facilities), 'Roofing Service Nederland' (Experts in roof-maintenance), and 'van Reisen Bouwmanagement' (Building Management & Consultancy) were the main sources during this research.

3.2.1.1 Lindenhout

Lindenhout is a member of 'Jeugdzorg Nederland' (a coordinating authority for youth care services), and offers assistance in raising and upbringing children in large parts of Gelderland and in a small area of Overijssel. Every year, more than three thousand children, young people and child educators make use of the support offered by Lindenhout. They set itself the objective to establish, maintain, and provide services in the field of youth care services, by carrying out activities aimed at the prevention of problems or impairment due to physical, mental, social or educational nature that may negatively affect youth in their development to adulthood.

To meet these objectives, Lindenhout has around 630 employees spread over more than 60 locations. These locations offer a large variety of building functions; day care, housing, offices, sport halls, etc. They have owned properties as well as leased properties at their disposal, and for both they must manage related facility maintenance processes. Their building stock changes continuously, each year they invest in several new properties, but also discard some. This fluctuation in building portfolio makes it even more challenging and interesting to provide structured and efficient FMM services. Within Lindenhout's organization, there is only one facilities manager, who is responsible for all kinds of facility management functions. With regard to FMM service provision, 'van Reisen Bouwmanagement' is their primarily adviser, and is involved during the entire FMM service provision.

3.2.1.2 Roofing Service Nederland

Roofing Service Nederland is a nationally operating roofing company, specialized in synthetic and bituminous roofing systems. Besides new construction projects, they are actively involved in planned maintenance, renewal or replacement of various roofing systems from small to large buildings. Furthermore, they are part of a joint service provider in total building maintenance and property management. This service provider, called 'Onderhoud Support', consists of a contractor, Roofing Service, an installation-, and a painting company. Together they strive to work together efficiently and sustainably. Their clients include; housing corporations, real estate agencies, industrial companies, government agencies, healthcare institutions and hospitals.

Roofing Service Nederland is an important actor in the case study, considering the maintenance services to roofs at Lindenhout's properties. Over the years they have become the primarily partner in roof maintenance at Lindenhout.

3.2.2 IDM

The IDM development process has the objective of understanding identified case study results as well as to document the results in so called process maps and exchange requirements. Process analysis (process discovery and data mining) is the conventional process used in IDM development and also in IFC development and extension. It assumes that there is no initial presence of software or other exchange requirements. The IDM development is applied as described by buildingSMART (2012), 'process discovery and data mining'. The individual stages of the IDM development (interpreting and documenting case study results) are linked to the iterative stages of the case study, including a feedback loop after each stage to validate the results.

The process maps have been prepared on the basis of steps 1 & 2 of the case study, describing the flow and configuration of activities and involved actors within the defined scope of FMM services for this research.

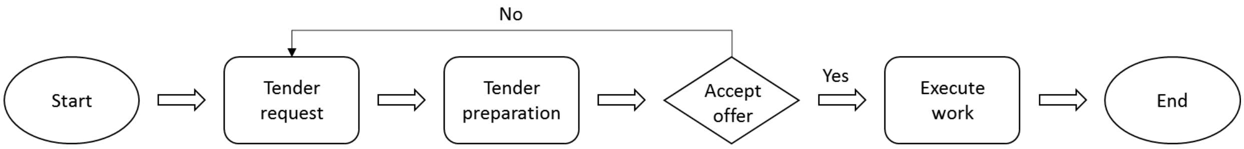

Figure 6: Schematic example of a process map

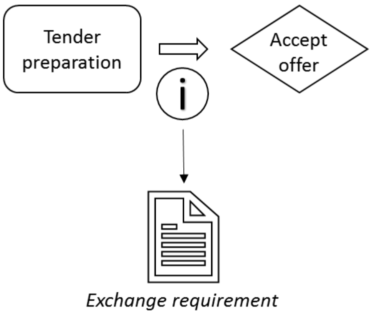

Figure 7: Exchange requirement

The actual information that is within the process boundary is determined by the contents of the exchange requirements that support the activities within the process. The exchange requirements represent the connection between process and data. It represents (a bundling of) the relevant information defined within the information model, to successfully complete the information exchange between two (business) processes at a particular stage. The exchange requirement also incorporates relevant information to successfully complete a decision-making process. These exchange requirements are derived from steps 3 & 4 of the case study. For example, as illustrated in Figure 7,Figure 3 the exchange requirement describes the required information needed by the managing board to unambiguously compare different offers in their decision making process. This can be used in the previous step to get the right information to the managing board.

The information is provided in a set of information units, which are required to fulfill the process activities at that moment. An information unit typically deals with one type of information or concept of interest (bundled by subject) such as the project location, roof deck type, roof deck element, etc.

The end result of the process analysis provides use cases and information modules that describes and supports the common/general FMM service provision by 'van Reisen Bouwmanagement'. It describes the process and information in non-technical terms and contains the input for the information model development phase.

3.3 Information model design

The results from the process analysis phase forms the starting point of the information model design. The literature by Muller (2009) is used to translate the detailed steps (IDM development) into UML use cases and a class model. The use cases shows the mechanism for capturing, retrieving, and querying the information for each individual step of the process and the interactions between the systems and service groups. The class model is the structure for storing the information and is the end product of the IDM development. A class model is, in turn, the starting point for a software developer to develop a software application that can exchange information according to the protocols established by the exchange requirements and presented in the use cases.

The class model is built from scratch, since current literature doesn't provide a sound basis of the specific FMM services as studied in this research. The design of the class model complies with the notion standard of the Unified Modeling Language (UML).

The content of the class model is compared with the current substances of the IFC development. This included the check whether identified data set requirements are defined in IFC and how a building model designer (for example an architect) could model those data set requirements according the IFC format. Resulted findings will make IFC more closely reflect real project-, process- and modeling needs and accelerate the use of BIM in practice.

On the basis of the use cases and the class model a demonstration model has been developed. The demonstration model was used as a prototype to test the completeness of the information model (class model) and how it could be used (according to the use cases) in practice to optimize the FMM service provision by 'van Reisen Bouwmanagement'.

3.4 Validation

The individual stages of the IDM development are linked to the iterative stages of the case study, including a feedback loop after each stage to validate the results. This resulted in a (check)list with requirements and process- / information needs which is used to validate the class model and demonstration model. The feedback loops were conducted as 'cognitive walkthroughs' and task analysis with industry professionals (Van Reisen, RSN). Walkthroughs consisted of going through each step of the documented processes to ensure they were consistent with the actual (or typical) response to the situation. Any differences or variances and edits to the process model were made before developing a conceptual model (a prototype information model).

The (prototype) information model was developed to help validate the functionality of the framework through a prototype system. This involved developing a basic user-interface which guides the user through multiple process steps to interact with the designed framework (class model) and to demonstrate the potential functionality.

An overall validation is performed by means of a pilot project, a test case analysis is used to ensure that all process- and information needs are included in the information model. This helped to validate the information model to ensure that it is flexible to include cases beyond the initial case studies used for development. In addition, the test case is used to help validate the usability of the prototype information model by a consultant of 'van Reisen Bouwmanagement'.

4. Data analysis – IDM development

The building- assets and portfolios of Lindenhout are used as research context to develop an IDM and associated information model, related to FMM service provision of flat roofs. To maintain their flat roof assets a - in AEC-industry - commonly used maintenance workflow is applied, which is managed and monitored by van Reisen Bouwmanagement. This chapter describes the involved FMM processes and actors, the information required for their execution and the results of associated activities. Ultimately, a general - yearly recurring - FMM service provision process is described, which fits the (daily) tasks and processes of the three main actors studied during this research.

4.1 Process maps

The research results are described as a linear sequence. However, presented results originate from a cyclic development process with multiple interviews, work sessions, document analysis and feedback rounds with industry specialists. The case study started with documenting current workflows which served as baseline for the FMM service provision, next steps included some optimization proposals initiated by field experts. These optimizations arise from the idea of information modeling capabilities, *"if we had an information that support us, how could we adapt the process to work more efficiently?"*. This report presents the final (concluding) results of respective analyzes.

4.1.1 Process analysis

As is common in most large organizations, Lindenhout applies a fixed hierarchical management structure to organize their core businesses and responsibilities (see Appendix C). Within Lindenhouts organization, there is one facilities manager who is responsible for all kinds of facility management functions, including maintenance activities concerning all buildings within the different regions. With regard to FMM, van Reisen bouwmanagement is their primary consultant. To develop an efficient and structured yearly recurring FMM process, it is not only important to understand where a process or activity fits and why it is relevant. One should also gain insight into the main actors involved, who are creating, consuming and benefitting from the activities and information within the process.

4.1.1.1 Involved actors

It's important to have clear communication between the different organizational layers, to ensure everyone can carry out their (daily) tasks and all different interests within the organization are represented. In general, the upper management (board members) is interested in; contracts signed, budgeting, work progression, deviations (of scope), etc. At lower level, the executing (maintenance) parties are dependent on accurate information regarding; dimensions, material features, situation/site characteristics, safety issues, etc. Each individual actor has his own place and function in the organization, and thus has his own interests. Actors also have their own particular view, ideas or risk allocation on certain issues or activities, like the execution of maintenance aspects. To gain insight into all these interests, the following actors (table 1) have been identified and linked to individual activities within the yearly recurring maintenance activities of flat roofs at Lindenhout:

Internal organisation			
General Management actors			
Board of Supervisors	Board of Directors	Board of Employees	Regional Managers
Indirectly involved	*Indirectly involved*	*Indirectly involved*	*Directly involved*
Facility Management actors			
Facilities Services Department	Financial Department	Technical Services Department	
Directly involved	*Directly involved*	*Directly involved*	
Building users			
Employees	Clients		
Indirectly involved	*Indirectly involved*		

External organisation	
Advisors	
Building Management & Consulting firm (Van Reisen)	Advisors specific disciplines
Directly involved	*Indirectly involved*
BM Servicies parties	
Building Maintenance Services parties (RSN)	Third parties (sub-contracting)
Directly involved	*Indirectly involved*

Table 1: Involved actors in case study

The actors involved in the case study have been selected on the basis of their contribution to specific tasks to be executed. A subdivision is made between directly- and indirectly involved actors. Directly involved actors perform and are responsible for one or more specific tasks in the process, without these actors the process will be on hold / stopped. Indirectly involved actors are the ones who should be informed about certain activities, or should be consulted for additional input. The case study involves three main (directly involved) actors;

- Lindenhout (subdivided over different hierarchical layers) as client;
- van Reisen Bouwmanagement as technical consultant and general management;
- Roofing Service Nederland (RSN) as main executive party.

Together, they are responsible for the continuity and execution of the annual flat roof maintenance services.

Board members at Lindenhout needs to be informed about maintenance progress and possible deviations to the maintenance budget, therefore they are indirectly involved actors. The involvement of secondary advisors or third parties depends on the project or subject at stake. Normally, their expertise is not required for annual maintenance. If so, it involves specific knowledge which is difficult to define in advance. Therefore they are defined as indirectly involved actors. Nevertheless, they have been given a place in the process and to a certain extent their interests / information needs have been defined. Yet, the overall focus of the case study is aimed at the directly involved actors.

4.1.1.2 Main FMM process

The general and yearly recurring workflow of FMM services is based on; the specification of required maintenance activities and accompanied quotation requests, selection and contracting of parties, and monitoring / evaluation of maintenance work and technical conditions (Figure 8).

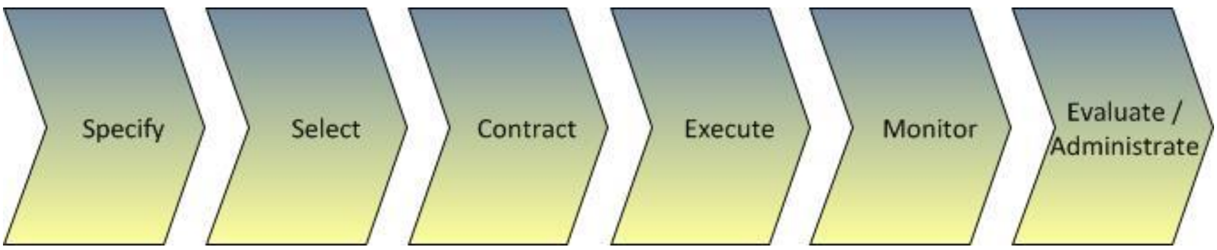

Figure 8: Main process phases in FMM service provision

As is common in AEC-industry, Lindenhout subdivides their maintenance activities in preventive and corrective maintenance. They formulate a further subdivision of preventive maintenance as 'regular maintenance (annually)' and 'extensive maintenance' (end of building elements lifespan). The starting point of preventive maintenance activities are based on an annually established maintenance plan. For the upcoming year, this plan describes their planned preventive maintenance activities (regular and extensive), per building element and per specific building. This forms the input for the FMM process steps as shown in figure 6. Since Lindenhout has no long-term maintenance contracts for roof maintenance, each of these process steps annually return for both preventive as corrective roof maintenance activities. Then, these steps are completed in a fairly fixed pattern, initiated by Lindenhout and van Reisen.

Appendix D provides an overview of the identified processes in FMM service provision at flat roofs by Lindenhout and van Reisen. In general, the most important activities are:

1) Roof inspection (technical conditions) -> specifying maintenance plans
2) Requesting and preparation of tenders for annual maintenance
3) Annual maintenance work (roof top cleaning and second technical inspection)
4) Handover; providing handover document including list of defects (calamities).

After completion of this annual process of preventive maintenance, follows a fairly similar process to specify and execute corrective maintenance work based on identified defects during the regular maintenance work.

4.1.2 Capturing activities

The core of the annual FMM process is the specification of maintenance work resulting in a tender request by the client and subsequently the preparation and final tender offer by the executive party. In this case study this specific process forms the starting point to define a structured annual FMM service provision. Other processes are defined as sub-processes since; the roof inspection (technical conditions) forms the main input for the specification phase; and maintenance work and defects identification forms the output of the specification phase. In turn, the list with defects forms the input for another specification phase / tender request (contract). Appendix E includes a detailed activity-, process- and information flow of the specification- and contracting phase. Per activity the information input and output is specified. It clearly reflects the large amount of information that comes together in this part of the maintenance process.

The diagram also shows that there a two types of information categories, namely; object-related information and process-related information. Object-related information involves all data concerning specific building-elements, mostly displayed in drawings. Process-related information refers to ensuring the continuity of the process flow or informing / consulting involved stakeholders. Furthermore, it can be seen that there are several 'alternative routes' incorporated. These alternative routes follows after a decision point. Most decision points refer to the consideration whether the information available at that moment is sufficient to continue to the next activity. If not, an alternative route should be followed, which is represented by getting back to a previous activity. These alternative routes could be seen as kind of feedback loops.

4.2 Exchange requirements

Continuing on the findings of the previous section, this part starts by introducing an optimized annual maintenance process. This optimized plan has emerged from a critical assessment - with the main responsible project managers at van Reisen - on the mapped and currently applied maintenance processes by Lindenhout and van Reisen bouwmanagement. These optimizations arise from the idea of information modeling capabilities, *"if we had an information that support us, how could we adapt the process to work more efficiently?"*.

Subsequently, the information exchange requirements have been identified based on several use cases. These use cases represents some specific key moments in the process wherein an exchange of information takes place. The complete list of information requirements per use case is represented in a so called information module.

4.2.1 Information modules design

After the activity and information flow analysis, a structured and improved FMM workflow is formulated. Important aspect of this workflow is the integration of defects (calamities) maintenance within the yearly recurring maintenance cycle and the way it is connected to the technical inspection and the standard annual maintenance works (see Figure 9).

In the current FMM process, van Reisen bouwmanagement carries out a full technical inspection on all building elements, including flat roof related elements. However, in contrast to other building elements, the flat roof elements are often difficult to inspect. This is because van Reisen doesn't have the (safety) equipment available to enter a flat roof, and this equipment isn't always available on site. In such cases they are forced to inspect the roof top from a distance (from other buildings) or sometimes they just can't inspect the related roof top. Even when they can enter the roof top, it is often hard to conduct a thorough inspection since the roof top is very sensitive to the accumulation of all kinds of organic material. A thorough technical inspection of a flat roof is therefore rarely the case by the yearly general building inspection of van Reisen.

Each year preventive maintenance work is performed, which mainly involves the removal of the organic material and reparation of some small defects which are detected during the preventive maintenance work. After completion of the preventive maintenance work a briefly description of the work performed is formulated and sometimes some defects are noted. This annually results in a fairly poor overview of the technical state of their flat roofs related building elements.

Given these observations, the main improvement of the annual maintenance cycle is the incorporation of a technical inspection by the company who performs the preventive maintenance work. This company has the equipment to access the roof top safely, and can thoroughly observe the technical conditions of the flat roof after their preventive maintenance work. From this inspection report, an efficient plan could be drawn for required corrective maintenance work.

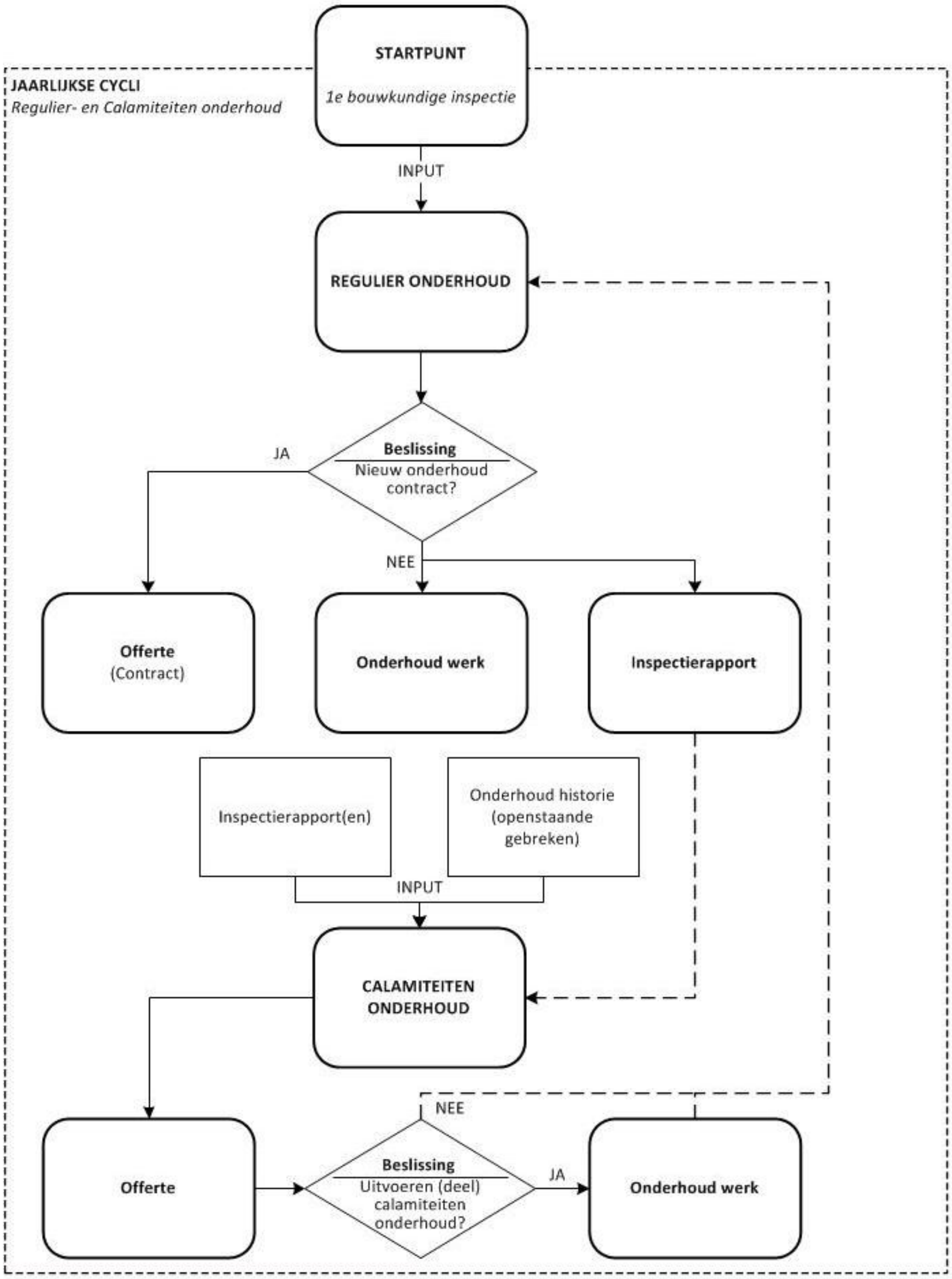

Figure 9: Improved annual maintenance cycle

To support the process steps of the improved FMM workflow, standard information modules have been formulated. These information modules should contain information specific to the needs of the respective process stage. The following information modules have been formulated:

Case 1: Inspection of technical conditions
- Information requirements for the benefit of technical report
- Information requirements for the benefit of safety aspects

Case 2: Requesting and preparing of tenders
- Annual maintenance work
- Identification of defects (calamities)

<u>Extensive maintenance aspects (not part of annual maintenance)</u>
- Adding an additional roof-top layer
- Replacing roof-top layer
- Adding an additional layer of insulation

Case 3: Execution of maintenance work
- Annual maintenance work
- Identification of defects (calamities)

<u>Extensive maintenance aspects (not part of annual maintenance)</u>
- Adding an additional roof-top layer
- Replacing roof-top layer
- Adding an additional layer of insulation

4.2.2 Information exchange requirements analysis

Based on the formulated information modules, the required information per module is specified. These results also originate from a cyclic development process with multiple interviews, work sessions, document analysis and feedback rounds with industry specialists of Roofing Service Nederland. These specialists involves employees who physically execute the work, and technical managers who prepare the tender requests. Appendix F provides the results of the information requirements analysis per specified information module, including a list of references of the analyses. Figure 10 provides a small selection of the results.

HEMELWATERAFVOEREN EN TOEBEHOREN - DAKVLAK [nummer]	**Input**	***Eenheid***	**Case 1: Inspectie rapporten**	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	**Case 2: Opstellen offertes**	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	**Case 3: Uitvoeren onderhoud**	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
HWA afvoer: Stadsuitloop	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Ja / Nee*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															

Figure 10: Selection of the results of the information requirements analysis

To structure the information requirements, we first had to consider which main flat-roof objects we should specify, secondly we decomposed those elements to lower level elements, and finally we could specify the required information needs. This object-oriented modeling approach is adopted considering the BIM and IFC methodology and to be consistent with the class model approach in the next phase of this research.

The end result of this phase is a complete list of required information per information module. An information module supports a specific activity or several process steps (use case) within the formulated annual FMM cycle. For example the information module regarding tender requests (case 2), represents the information available to prepare a tender offer. The executing party could also use this information module by preparing their site visit; unknown or incomplete information has been made visible in advance. During the site visit one could focus on these specific information points to draw a complete picture of the asset and required maintenance work. This should ultimately result in a tender offer that precisely represents the specified and required maintenance work.

The required information per building object forms the input for the next phase, the development of a class model. The class model describes the required information per object in so called 'attributes'. An attribute is a (allocated) property of an object that describes a specific 'value' for the object (for example; an ID number, fire safety class, etc.).

4.2.3 Verification of information exchange requirements

The exchange requirements have been verified by means of work sessions with field experts of RSN. In the work session we explained the FMM process we have drawn, and related use cases. Per specific use case (specific moment in time) we analyzed and discussed the exchange requirements, any remarks have been noted and processed in a definitive exchange requirement (Appendix F).

5. Information model design

The class model is developed according to the model building theory of Muller (2009). This chapter provides an overview and description of the developed model. The model is built from scratch, meaning that no existing class model regarding FMM service provision has served as basepoint. The model is entirely based on the results of the case study, as described in the previous chapters. Furthermore, the functionality of the class model has focused on four main aspects (sub-parts) of the annual maintenance process (Figure 11), formulated as the following use cases:

1) <u>Starting point: adding a new building to the database</u>; *this use case is meant to register 'general' building- and owner related information into the information model, when a new building has to be added to the building portfolio of van Reisen. This forms the starting point of the annual maintenance cycle of that particular building. [Actor: van Reisen]*
2) <u>General inspection of technical condition</u>; *consists of a general building inspection of all building related objects/assets, among others to check the specific objects and their attributes (is the available information still correct?), to identify visible defects, and to check to what extent already know defects deteriorate. With this information we ensure that the data in the information model remains updated, and van Reisen is able to make a proper / well founded maintenance plan related to the most urgent maintenance needs. [Actor: van Reisen]*
3) <u>Preventive maintenance work, technical handover document and defects identification</u>; *this use case starts with a tender request [Actor: van Reisen] for annual maintenance. Based on provided building related information, several parties prepare an offer [Actor: executive companies]. Once the job is awarded to one company [Actor: van Reisen], the company carries out the maintenance operations and capture a set of predefined data related to; the work that was performed, as well as possible new defects which become visible after / during the maintenance work. [Actor: executive company]*
4) <u>Corrective maintenance work and technical handover document</u>; *here it comes to repairing a specific defect, also starting with a tender request [Actor: van Reisen] followed by some offers [Actor: executive companies]. Once the defect is repaired, the executive party will update the 'as-built' situation by documenting their corrective maintenance work and possible new object-related information (new materials used, etc.). [Actor: executive company].*

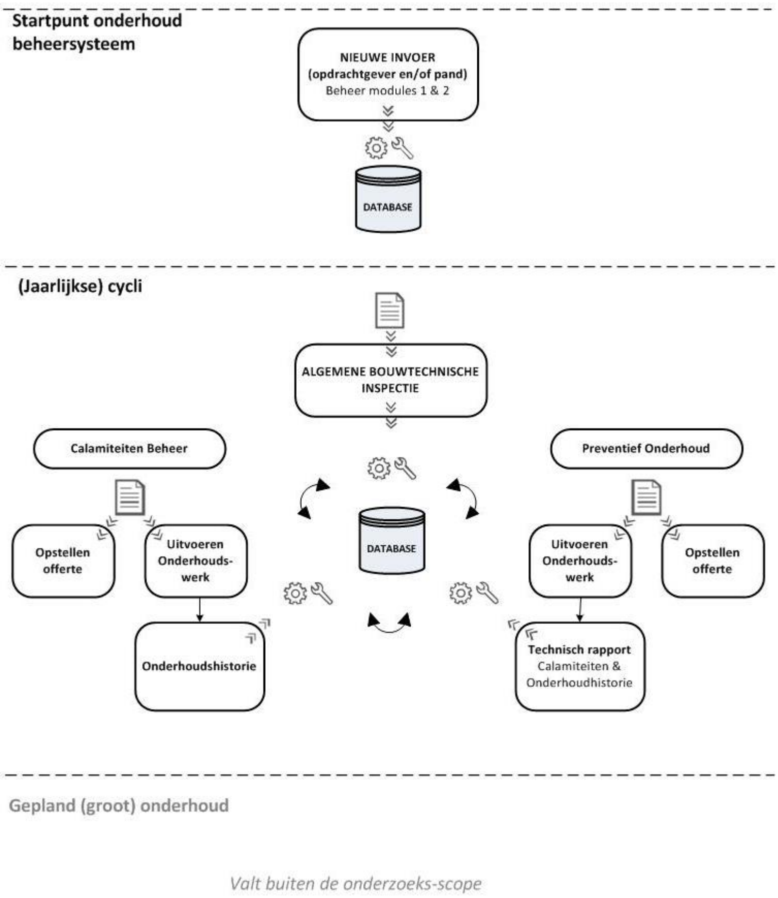

Figure 11: Use Case integration regarding desired information system in relation to the improved annual maintenance cycle and defined information modules

5.1 Class Model

Appendix G shows the developed class model. The class model makes a distinction between; building (flat-roof) object-related elements, location and general building related data, and FMM process-related elements. The building- and locations related elements are derived from the information requirements analysis. The FMM related elements are the result of the process and activity analyses, and is based on the improved annual maintenance cycle as visualized in Figure 9 & Figure 11.

The class model is designed with information that can be shared as well internally (within the clients company) as externally (with executive parties). Regardless of which organizations involved (each organization has its own internal information needs), the class model involves the minimum (required) information that needs to be shared within annual maintenance cycle, based on the experiences with different clients of the involved specialists within this research. For example, a specific selection list of executive parties to select for annual maintenance may differ between different clients and could change over time (also the process how to select parties). Therefore, this kind of 'internal' information isn't incorporated in the class model. On the other hand, once parties are selected or has executed some maintenance work, they became part of the 'maintenance/building history', and therefore related information to these parties are included in the class model.

The core (top-classes) of the class model consists of the classes; *Property* (representing location and general building related data); *Roof* (representing (flat-roof) object-related data); *FacilityManagementFunction (*representing FMM process-related data). To connect these classes, I added the class *FacilityManagementElement* which forms the center of the above-named core classes (see Figure 12). Each property consists of objects which need to be managed / maintained (*Facilicty Management Elements*), for this research we focused on the object 'flat-roof' and its underlying objects (technical data), then each object is part of maintenance process and therefore related to the class *FacilityManagementFunction*.

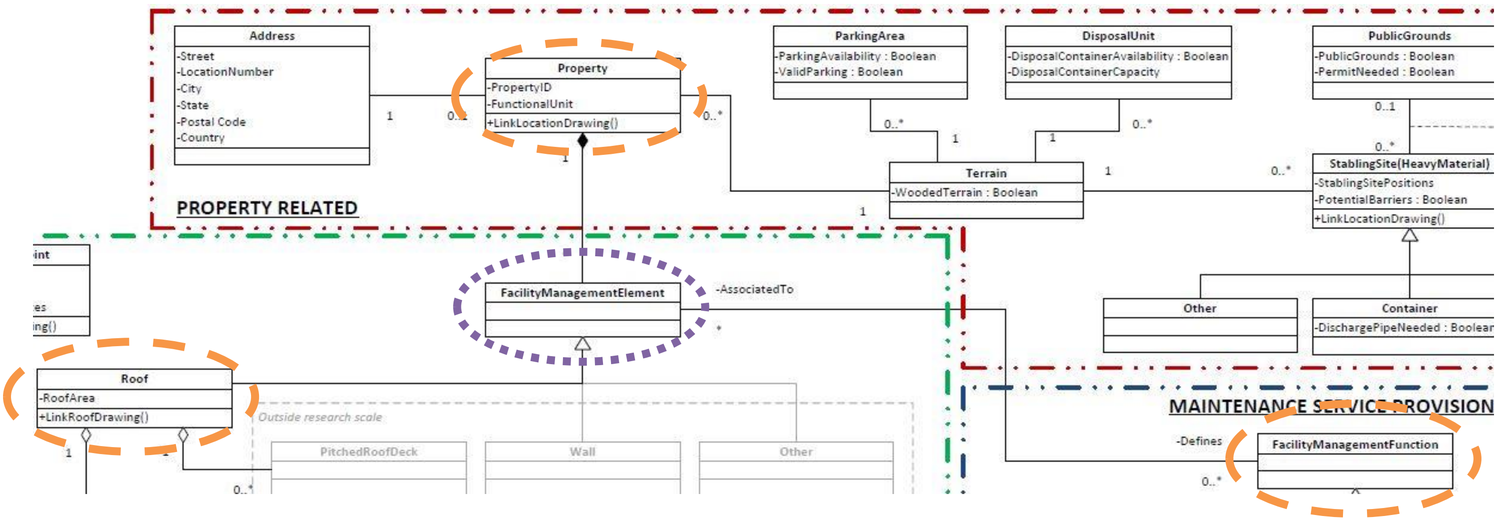

Figure 12: Core (top-classes) of the class model

The class *Roof* is decomposed in underlying building objects, for each underlying object a sub-class is drawn. For example, the class *RoofDeckLayer* consists of the sub-classes; *TopLayer (RoofCovering)*, *BallastLayer*, *InsulationLayer* and *SubstructureLayer.* Specific (technical) data per class is documented as attributes. In some cases an object is related to specific documentation or a process, in such cases a class operation is included. For example, the class *Technical Unit* relates to objects which are often bound to service contracts with their suppliers. The specific kind of data within that contract often differ and cannot be specified in general attributes, therefore the class operation 'ShowServiceContract' is used to link the contract to the class *Technical Unit*.

The sub-classes of the class *FacilityManagementFunction* are all related and unique for the annual maintenance process activities of van Reisen as presented in chapter 4.2.1. Each (sub-)class represents an activity within the annual maintenance cycle. The class operations documented per (sub-) class shows the information needed to successfully accomplish the activity. That is the information that should be derived from the information model. In order to receive or document the requested information, one should provide the information model with some specific data, this is presented as attributes.

If one makes use of another maintenance process, the sub-classes and their attributes of the class *FacilityManagementFunction* will differ in that case.

5.1.1. IFC analysis

The class model is the starting point for a software developer to develop a software application that can exchange the information as captured in the class model and according to the protocols / process steps of the use cases. To ensure interoperability between different software applications, the information should be modeled according to a generic 'language' (IFC) which can be supported by different applications.

The way in which object-oriented models (in (3D) building models) are modeled by designers/architects, wherein one assigns data to specific building objects, is related to the systematic in which the IFC-format is built. A designer or architect has to model (assign) objects and its specifications to the right 'object classes' and 'attributes' of the IFC, otherwise the different software applications doesn't 'know' where the specific object or its specification is modeled within the building information model.

A thorough analysis of the current IFC-format 4.0 has been conducted, in order to check whether the class object specifications of the developed class model are supported by the IFC-format. If the IFC-format doesn't support an object or specification (attribute) within the class model, then it means that there is no formal 'language' to capture that specific object or specification. Consequently, the information at stake will be lost or incorporated in the model at a different (wrong) place.

A full overview and analysis of the IFC-check is given in Appendix H. The analysis provided the following main insights;

- Overall can be concluded that IFC supports all kind of data types, like; textual data, numeric data, geometry, labels, documents, etc.
- IFC supports as well the object-oriented (technical) data as the process related data. To what extend process related data regarding FMM service provision should be modeled in a generic IFC model is up for debate, since this is very specific information for one process and might be only relevant to manage / monitor in one single software application.
- For multiple objects or specifications within the case study, IFC doesn't provide in a standard object class, attribute or specification/quantity entity. This complicates the modeling process by designers/architects, since there is no standard 'protocol' how to assign related objects or

specifications to the IFC. For example; for the thermal resistance of a material, the IFC provides in a standard attribute, namely *IfcThermalResistanceMeasure*. However, this isn't the case for data related to a roofdeck number. To model a roofdeck number, one could assign this data to several IFC entities (by semantic interpretation), for example; *'IfcSpatialZone -> Name of Description'*, or *'IfcRoof -> IfcIdentity -> IfcText'*. This could result in data loss by transferring data to another software application, since there is no clarity to which IFC entity the data is assigned to. Another situation where data coverage is an issue is where IFC does not provide a modelling construct. For example, if a designer whishes to place a specific technical unit (like a specific type of fanner), IFC has no construct to represent that. The designer has the choice of either representing the fanner with walls and slabs, or of using an IFC proxy object. Both of these solutions pose challenges for analysis, here is also no clarity to which IFC entity the data is assigned to. The most important challenge for this latter problem lies, like that above, in the development and adoption of modelling conventions and guidelines for these cases. Appendix H provides an overview which data are not supported yet in an object-class or attribute by the IFC-format.

- To 'know' what kind of data should be modeled into the information model, IFC could provide in so called 'property sets' *IfcPropertySet* for specific objects or process elements.
  Considering the FMM service provision, some (parts of a) property sets are still missing. For example, a property set regarding the access point of a roof. In order to efficiently execute the maintenance work, it is important to know; where the access point of the roof is located; how the roof could be reached (access method); and what kind of external material should be brought to access the roof. Appendix H provides an overview which data are not supported yet in a property set by the IFC-format.
- One major difference between the class model and the IFC-format is the use of Site elements. According to the case study and as incorporated in the class model, one should be provided with different, site related data, during their FMM service provision. For example; the availability and distance to a parking lot, the capacity and distance to a waste container, possible barriers around the building, etc.

5.2 Prototype information model

5.2.1 Information model design

The final part of the research is the development of the prototype information model, meant to validate the class model and correspondingly the improved annual maintenance cycle and information modules. The information model is built in MS Excel by using VBA coding. The results and functionality of the prototype model will be discussed in this section. Appendix I provides a visualization of the prototype functions and defined information modules (outputs), summarized in Figure 14. In general, the prototype information model is built onto the following principle;

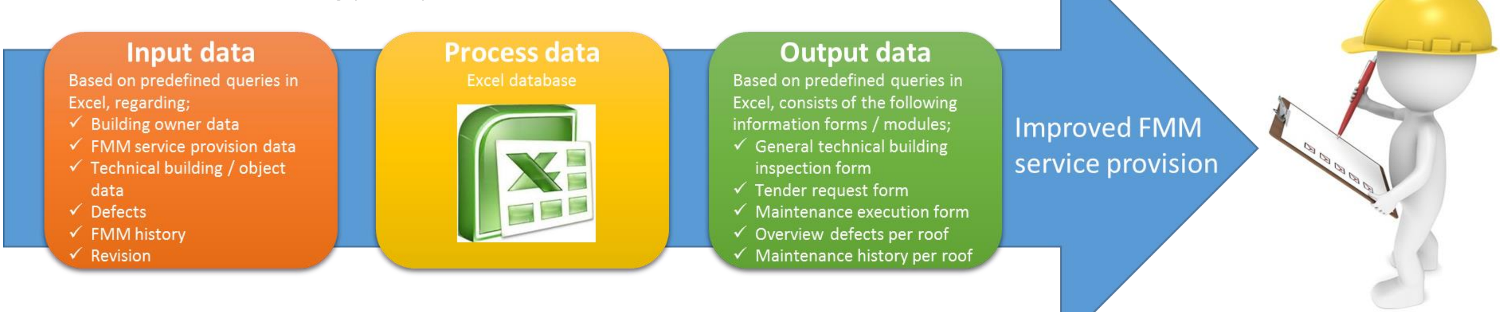

Figure 13: Prototype information model

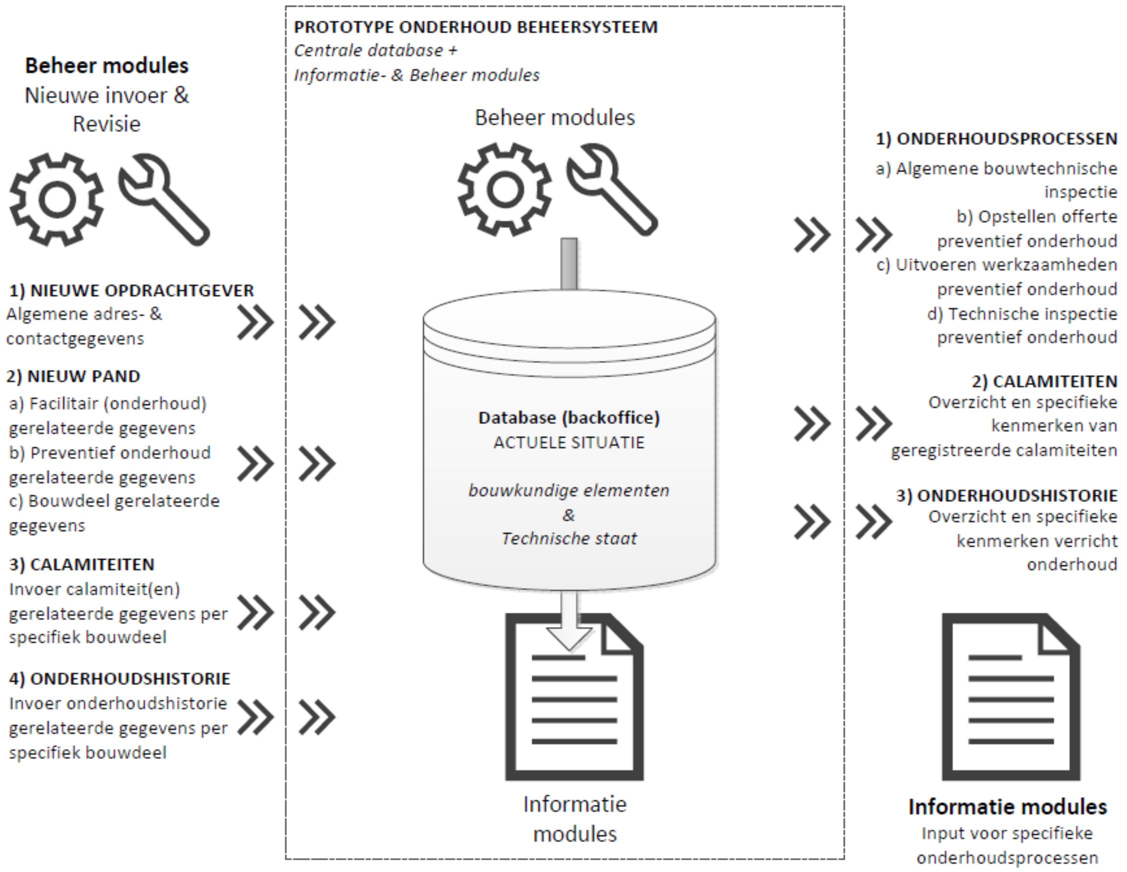

Figure 14: Functionality of prototype information system

Figure 15 provides an example of an 'automatically' generated information module (template) by the prototype information model. This example shows the required information needs for maintenance work (use case 4) regarding two identified defects (calamities). It communicates detailed information (without redundancy) to fulfill the technical maintenance services, as well as decision making- and process related information to plan needed maintenance work more efficiently.

CALAMITEITEN BEHEER

Opdrachtgever:	Reisen, Van
ID-Code Gebouw:	Lind-1.a.1
Printdatum:	7-12-2014

VAN REISEN BOUWMANAGEMENT & ADVIES
Postbus 97 - 2200 AB Noordwijk
Tel: (071) 362 3770 - Email: info@vanreisen.nl

Gegevens calamiteiten

Kenmerken — *Calamiteit:* *Lind-1.a.1_1B-27.21_L1a_C1*

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ID Gebouw element	Lind-1.a.1_1C-47.11_10
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Omvang	50 m2
Status	Openstaand
Herstelperiode	
Datum van constateren	10-8-2014
Herstelurgentie	6 maanden
Uiterlijke hersteldatum	februari-15
Onderhoudskosten	
Verwachtte kosten	€ 400,00
Bijgaande offerte	Offerte Onderhoud Vegetatie dak.pdf

Aanvullende opmerkingen

FOTO 1 Test foto - Calamiteit 1a.JPG

FOTO 2 Test foto - Calamiteit 1b.JPG

Kenmerken — *Calamiteit:* *Lind-1.a.1_1B-27.21_L2a_C1*

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ID Dakvlak	Lind-1.a.1_1B-27.21_2(a)
ID Gebouw element	Lind-1.a.1_1C-27.11_10
Specificatie	
Omschrijving	Slechte randafwerking, niet waterwerend
Omvang	Op 2 plaatsen; 10cm bij 10cm
Status	Openstaand
Herstelperiode	
Datum van constateren	10-8-2014
Herstelurgentie	1 maanden
Uiterlijke hersteldatum	september-14
Onderhoudskosten	
Verwachtte kosten	€ 200,00
Bijgaande offerte	Niet Beschikbaar

Aanvullende opmerkingen

FOTO 1 Test foto - Calamiteit 2a.jpg

FOTO 2 Test foto - Calamiteit 2b.jpg

Figure 15: Example of an information template generate by the prototype information model

5.2.1.1 Relation with IDM's functional parts

The prototype model is built up from multiple individual functional parts, describing specific units of information by taking into account: the FMM process activities, identified information requirements and the object-oriented class model structure. Figure 16 represents how the functional parts identified in the case study analysis and related data structure of the class model works, and how they are incorporated in the prototype information model. The figure provides an example of the functional part related to the activity *'Preparation of a tender bid for annual maintenance'* focused on the information requirements regarding *'Fouling types of a roof deck'*.

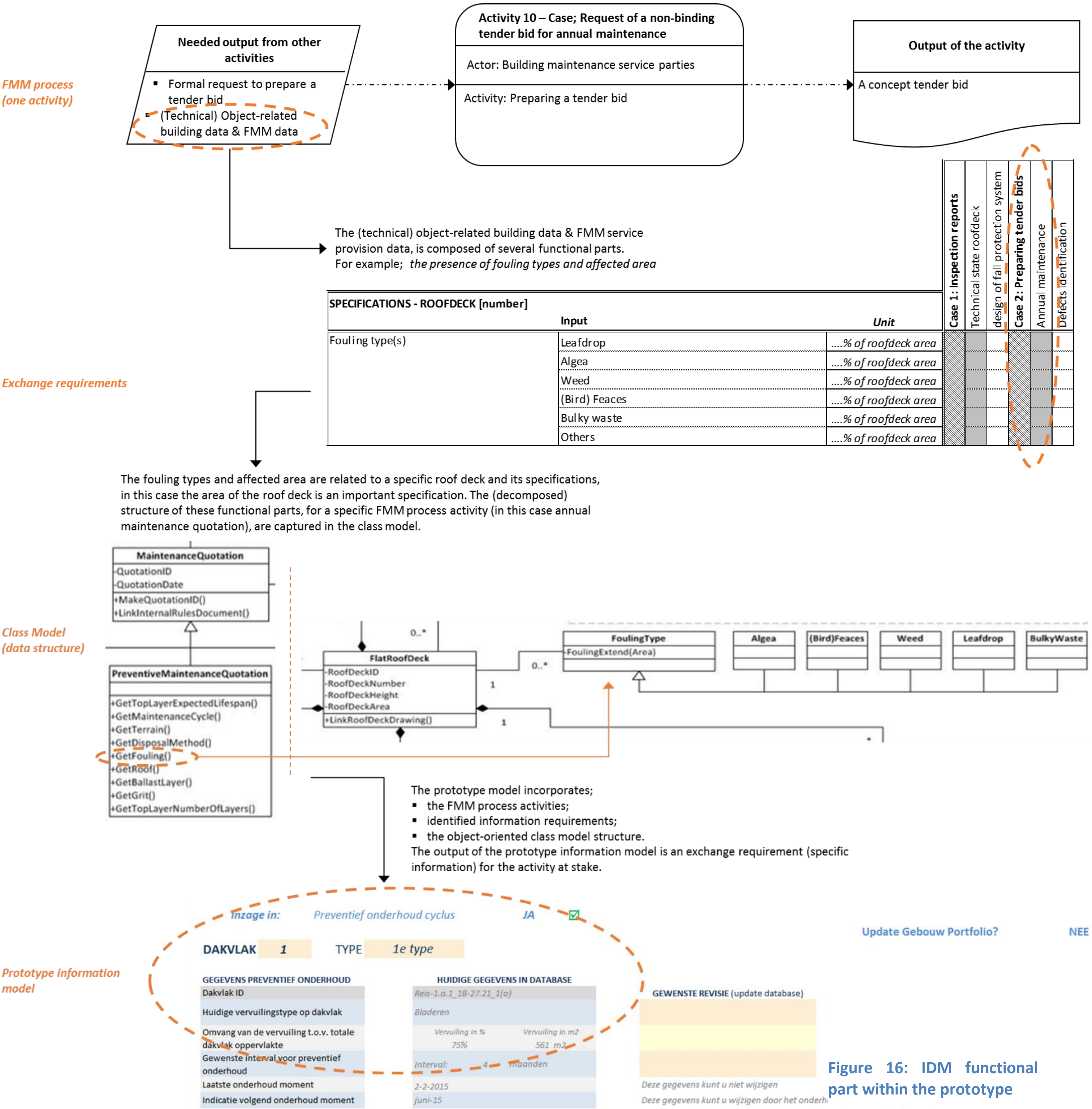

Figure 16: IDM functional part within the prototype

5.2.1.1 Relation with IDM's business rules

The (end) user of the prototype information model doesn't care about how the exchange requirements, functional parts or the class (information) model is structured, nor how the software is technically developed. However, they do need to know what information they can expect and how to use the (prototype) information model during the FMM processes. In this context, specific '*business rules*´ could be formulated by the software developer, providing guidance to the (end) user when working with the (prototype) information model.

The incorporated business rules in the developed prototype information model have emerged during the development process of the prototype. These business rules have not been separately documented, since most business rules arise from the use of the chosen software model itself and the way it is (technically) modelled. However, such kind of business rules are important to develop an information model and ask for understanding and tuning of; the process(es) at stake, different types of data and a sense of feeling how to deal with usability aspects. Business rules are therefore indispensable for a proper information model. The business rules formulated in the prototype information model could be used as guidelines in future developments.

Figure 17 provides two examples of business rules as incorporated in the prototype. The first business rule states in which numeric unit the total area must be filled in, this ensures that always the same numeric unit is used and when the data is shared the data will be interpreted correctly. The second business rule offers several options to describe the structural design of the roof-deck, this provides a kind of structure for the (end) user to describe the requested data in terms (most) field-experts will understand.

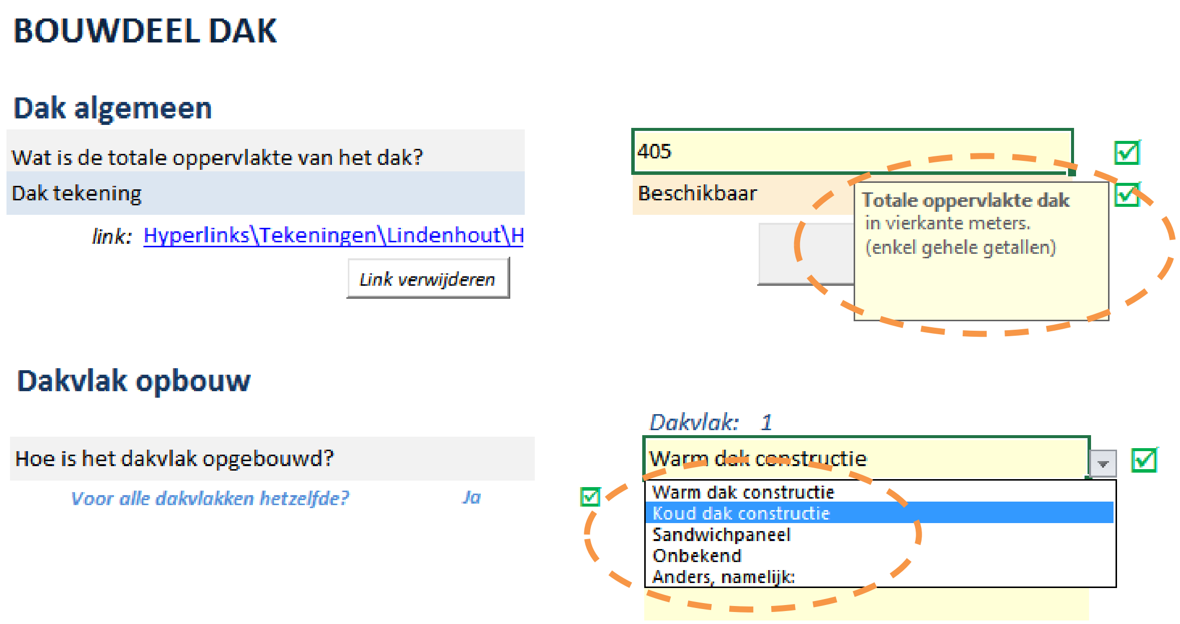

Figure 17: IDM business rules within the prototype

5.2.2 Information model validation

The prototype is validated by applying source triangulation. Firstly relevant literature has been used to set up structure of the information model (IDM development, Class Model), field experts and future users of the model have been consulted, and finally the model has been applied in a couple of test- projects. These test-projects have been used to validate the completeness of the prototype information model, according to the identified information requirements and as adopted by the class model. These validation results are provided in Appendix J.

Next to consulting field experts and future users during the development process, they have also validated the prototype during cognitive walkthroughs. This included testing on usability of the prototype, as well as providing feedback regarding the added value of the prototype in context of the common control factors of (integrated) project management; Money, Organization, Time, Information and Quality. By using the prototype model including data of the test-projects, is concluded that the model is easy to use and correctly represents the optimized annual FMM process cycle.

The prototype also shows the potential added value of an information model for (annual) FMM service provision by van Reisen. The biggest benefit is the structured availability of requirement information without redundancy. On any moment in time, van Reisen can retrieve the actual (and required) information for a specific process or object from the model. Firstly, this saves Time in searching for the right information. Secondly it provides in up-to-date information, being able to make well-founded decisions regarding their FMM plans and ultimately saving Money.

Finally, the prototype shows that using the information model asks for some dedication and structured way of working by the users (Organization). If one ‘forgets’ or doesn’t properly enters new / or revise data, the added value of the information model (Information accessibility and information Quality) will decrease.

6. Discussion

This research contributes to the design of IDM's and MVD's within the field of FMM service provision and with regard to the developments of BIM and IFC in the AEC-FM industry. Scientifically and practically, the developed information model proves relevance in optimizing FMM decision making and deployment of available resources.

This chapter summarizes the main findings provided in the previous chapters. Moreover, it describes the theoretical contribution as well as the practical implications and recommendations. Lastly, the limitations of this research are explained.

6.1 Theoretical contribution

The major contribution of this research is an information model and ontology framework (class model) that takes into account both FMM process related data and object-oriented building information (related to flat-roofs) and structures it for efficient use. The information model and class model provides a solution for the identified challenges to support 'daily' workflows in FMM, regarding the fragmented information provision / requirements throughout the FMM phases and standardizing the quality of information involved actors have at their disposal.

The first task in designing the information- and class model is the tracking and mapping of information needs to their origins and needed format to support more effectively FMM processes. This allows for information capture throughout the lifecycle of a building, specified to support FMM activities on flat-roofs. By linking FMM process related data and building information, exchange requirements were included within the information model to ensure that appropriate information is readily available when needed. This resulted in three main moments of information exchange;

1) from offer request (FMM manager) to the preparation of the tender offer (maintenance party);
2) from the accepted tender offer to the personnel that executes the maintenance work; and
3) at the completion of the maintenance work to the FMM manager to update the information model according to executed maintenance work (revision).

These findings are captured according to IDM methods, with regard to maintenance and repair work of buildings these IDM's are still missing in literature.

In addition to the designed IDM's (What and Why), this research also takes into account the first steps towards a full MVD (How) to translate the analyzed processes and information requirements towards a structured information framework that could be integrated within BIM developments. This have resulted in a class model that integrated FMM process related data, as well as building related data, and is validated by a prototype information model. The validated information framework (class model) can be used by software developers to bring the MVD to a next level and to design a professional FMM software program. In literature the class model can be used as basepoint, to analyze and incorporate additional FMM processes and to add other building related object data (next to that of flat roofs).

Next to the provision of a class model for structured FMM service provision, an analysis of the IFC structure has been conducted in order to identify gap's within the IFC structure. An IFC 'gap' doesn't necessarily mean an absence of an IFC modeling construct, entity type or property set, it could also involve a multi-interpretable way of modeling in terms of the encoding of information within the very flexible constructs provided by the IFC language. For example, for the thermal resistance of a material, the IFC provides in a standard attribute, namely *IfcThermalResistanceMeasure*. However, this isn't the case for data related to a roofdeck number. To model a roofdeck number, one could model this data to several IFC entities (by semantic interpretation), for example; *'IfcSpatialZone -> Name of Description'*, or *'IfcRoof -> IfcIdentity -> IfcText'*. One major difference (an IFC gap) between the class model and the IFC-format is the use of Site elements. According to the case study and as incorporated in the class model, one should be provided with different, site related data, during their FMM service provision. For example; the availability and distance to a parking lot, the capacity and distance to a waste container, possible barriers around the building, etc. These findings can be used to optimize the IFC language in future research, or to write specific roadmaps to guide modelers within the IFC language. Together with the structured information framework, this will make IFC more closely reflect specific FMM process needs and accelerate the use of BIM in FMM.

6.2 Practical implications and recommendations

A significant benefit of the information model is an increase in efficiency. The information model is attempting to use a BIM-based framework, enabling to capture relevant information and then manages that information based on how FMM are currently handled. The improved management of information should allow for quicker information access and reduced time spent sorting through information by FMM personnel. Improving the management of information and increasing the efficiency to which it can be retrieved and stored can help minimize failure costs and provides a sound basis for long-term decision making regarding planned maintenance. The improved management of information of the framework can allow for personnel to do more work in the same amount of time and resources by improving information access and improving the efficiency to which they are able to complete any particular activity. This is reflected by; less loss of information/knowledge during the life cycle of a building; less loss of time during preparation and execution of maintenance; less additional failures by using wrong parts or wrong installation; and less losses due to downtime of a building asset. Altogether, resulting in time and cost savings for all related FMM processes and stakeholders.

Revised workflow to more efficient processes is another potential benefit of the research. By understanding the processes that were mapped, redundancy can be removed. If the information model can be modeled to one central system (or linked systems), the information only needs to be entered once (in one system). Subsequently, the management of the information will only need to take place in one area. Removing the redundancies will improve the quality and efficiency of information management. Examples of a revised process would be a reduced number of steps needed in a FMM process, thus making it more efficient. This includes, for example, a reduction of calls to find information in plans and specifications, looking up previously completed maintenance work, etc. since the maintenance manager will have access to this information through the framework.

The developed information model could also be used as a sound basis for long-term decision making in planned maintenance, considering the remaining life cycle of a building (LCC) or specific building assets in relation to upcoming maintenance and by analyzing related failure modes (asset management). Among others, previous maintenance information can be used to evaluate current maintenance performance and costs, as well as to predict upcoming maintenance work by 'general' asset deterioration. The key factor is to find an optimal level of maintenance service in order to be consistent with the organization's objective of attaining minimum total cost. These methods, LCC analysis and asset management, are additional processes that can be analyzed and enrich the 'knowledge' within the information model. Further research is needed to incorporate these processes, this research could be used as a roadmap to take a first step in developing IDM's and MVD's for additional (FMM) processes.

Lastly, the class model and prototype information model is a first step towards a fully developed MVD, which can be used by a software developer to design a FMM software program. The prototype information model validates the structure of the designed class model, but also reflects the 'main principles' and usability of the desired software program. This helps a software developer to have a 'better' understanding of the challenges ahead, as well as to identify or exclude possible issues in an

6.2.1 Recommendations van Reisen

- IT development is booming nowadays and software capabilities, software versions, software vendors, etc. are growing/changing faster than ever before. Organizations that are not yet familiar with the IT capabilities shouldn't be discouraged with these fast developments. The best way to adopt and get familiar with it is by 'just' doing it! I recommend van Reisen to test the prototype model in more detail by adding more pilot-projects to the information model and more importantly to use the information model during the annual FMM service provision of multiple projects. By doing this van Reisen can experience to what extent this 'new way of working' fits their own and their client's organizations, besides they are able to create a benchmark and truly analyze the added value of the information model regarding the project management control aspects (Money, Time, Organization, Information, Quality) compared to their 'traditional' way of working.
- Subsequently I recommend van Reisen to complement the information model with more object-oriented exchange requirements in cooperation with executive parties like RSN. For example, for objects as technical installations, (outdoor) facades or (wooden) frames since these objects are also subject to regular maintenance and forms an important cost item within FMM of buildings.
- Implementing this new way working asks for some dedication and structure by all participants. The benefits of the information model only reveals when the documented data is relevant and up to date. This means that all participants are responsible to revise (maintenance) data or communicated revisions of data when needed. It also means that the information should be documented according to the provided structure (class model / business rules). Therefore, I recommend to provide in a guideline that describes in detail '*how one should use the information model*', '*which process steps should be followed*' and '*who are responsible for specific actions*'. Accordingly, all participants should agree on the guideline (to ensure full commitment) and stick to the agreed plan.
- Since IT technology still advances, and we are getting more and more familiar with IT applications supporting us during our day to day work, we have to make sure that the IT applications will not hold us back in widening our scope of business. Meaning, if we implement a particular software application or information model for a specific (business) process, we have to be aware to what extend this software application can support us in the future. You might want to avoid to get stuck to the boundaries of the software application you have implemented. This is also the case for the way you structure your information model, the structure highly depends on the relations you draw between object-classes and (FMM) process-classes. If you do not have a systematic approach to connect these relations to one another, you might create your own barrier to widen the scale of the information model.

6.3 Limitations

The following limitations were identified in completing the research;

- One perspective related to the point of view of van Reisen and their clients, subcontractors and its associated problems were examined in developing the information framework in order to simplify the problem set and be able to analyze the different aspects of the FMM processes. The assumption is that the information framework can be easily expanded or adapted in future research, towards a more generic information framework that suits a variety of companies.
- The identified FMM challenges are approached from the idea that required maintenance work is always being undertaken. Strategic considerations were out of scope for this research. The overall FMM process and information requirements for preventive (planned) maintenance will be more comprehensive when, for example LCC analysis or asset management methods are incorporated in the decision-making process of FMM service provision.
- The research focused on a particular set of building related data, namely that of flat roofs since these are responsible for one of the most important and yearly returning cost items in building maintenance. To provide in an integral FMM service provision of buildings, the information model should be enriched with other building related object data.
- To effectively manage the information storage during the life cycle of a building, future research should analyze when specific data is generated and accordingly at which moment it should be captured in the information model. For example, an architect chooses specific materials, related information for maintenance purposes (like expected life span of a material) could be modeled during the design stage, since it is likely that the architect could have this product information available. This research identified What kind of information should be captured, When it should be captured has to be analyzed in future research.
- It is assumed that the efficiency gains of the information model are only related to the effectiveness and usability of the model itself to support FMM processes. However, the efficiency gains of the information model highly depend on the quality and actualization of the stored information, and therefore highly depend on the discipline of its users. Accurate revision of the data by the users, is therefore an essential part that affects the potential benefits of the information model. Next to this discipline challenge, it should also be noted that this 'digitized' way of working requires a certain amount of change management. The AEC-FM industry isn't familiar with this new way of working, therefore there is also the challenge to educate involved personnel.

7. Conclusions

Based on the findings and results from this research, the following conclusion can be drawn:

- In order to develop a successful information model, that supports FMM service provision, it is important to combine / connect three 'classes' of data; 1) property related data, 2) object related data, and 3) FMM process related data. The data should be exchanged on predefined moments during the FMM cycle, according to structured (information) exchange requirements.
- The prototype information model has shown that a structured information model, combined with a (predefined) FMM process that fits within the organization of the end user, will reduce a lot of repetitive work. This relates in particular to the repeated search for; the most actual FMM data (maintenance history, outstanding defects) and building / object-related data (roof-deck area, availability of a fall protection system, etc.). Subsequently, the prototype model shows a lot of potential to save Money, since it provides in up-to-date information to efficiently deploy your resources, and FMM managers are enabled to make well-founded decisions regarding FMM plans.
- Despite the limited scope of this research, it is shown that with the support of an information model an optimized (more efficient) FMM process could be drawn. This is reflected in an annual FMM cycle as described in part 4.2.1 of this research. Further research is needed to enrich the information model with other FMM processes and building related objects, and to eliminate possible redundancies.
- By using a structured information model and linking information/data to specific exchange requirements, one could avoid a lot of redundancy. In the traditional FMM of van Reisen a lot of the same documents are (digitally) filed in several folders. For each executive party a folder is created and the same document is incorporated in each separate folder. This creates a lot of redundancy, but also a basis for possible errors. If a documented is updated during the process, one has to make sure that the updated file replaces all the former files in the separate folders per executive party. By using one single document and define some specific exchange requirements, the possibility of mistakes will be reduced.
- The structured use of an information model, as implemented by the prototype, requires strict discipline by all participants in the FMM process in terms of adherence to agreed approaches and procedures, compared to the traditional approach (current way of working). The benefits listed above can only be realized with commitment by involved personnel to operate in a disciplined and consistent manner throughout the whole (annual) FMM cycle.
- This research can act as a basepoint in research by using IDM and MVD development methods to capture, exchange and reuse data/knowledge/experience in building maintenance projects. Further research by academics and professionals is necessary to complement the information model with more object-oriented building exchange requirements and to develop the prototype information model into a mature software application and to determine what modifications are needed to adapt it for wider use. The information model could also be extended with additional FMM (related) processes, for example LCC analysis or asset management principles. By implementing these kind of analysis, the value for money during the whole life cycle of physical assets could significantly increase.
- The most significant semantic-level issues for IFC has been that of inconsistency of modelling style and possibilities, which is a significant issue for general model-based interoperability. From the perspective of modelling IFC language design, it is tempting to suggest that the IFC language should be sufficiently clear and complete in its definition that alternative modelling styles should

not be possible. This might be possible when IFC is restricted to a small domain or a single organization. However, IFC attempts to cover a wide scale of processes within the AEC-FM industry, the variation of design practice, and even more significantly the difference in regulations between different jurisdictions, make this infeasible. The reality is that certain parts of the IFC language must be left flexible in order to support unforeseeable scaling variations (Lessons learned in practice during my current work at Arcadis).

- And finally, I will end with the following quote I formulated during this research: "*Information is less unknown, when it is stated as unknown. Cause then you know, it is unknown."* With this in mind, one will take more targeted action to get the required information. When one doesn't know, whether the information is possibly available somewhere (in a document, in a person's memory, etc.) or not, one is more awaiting and keeps searching for an answer. To avoid these time-consuming (and money wasting) actions, you should give unknown information a formal status, and do not leave it in the middle.

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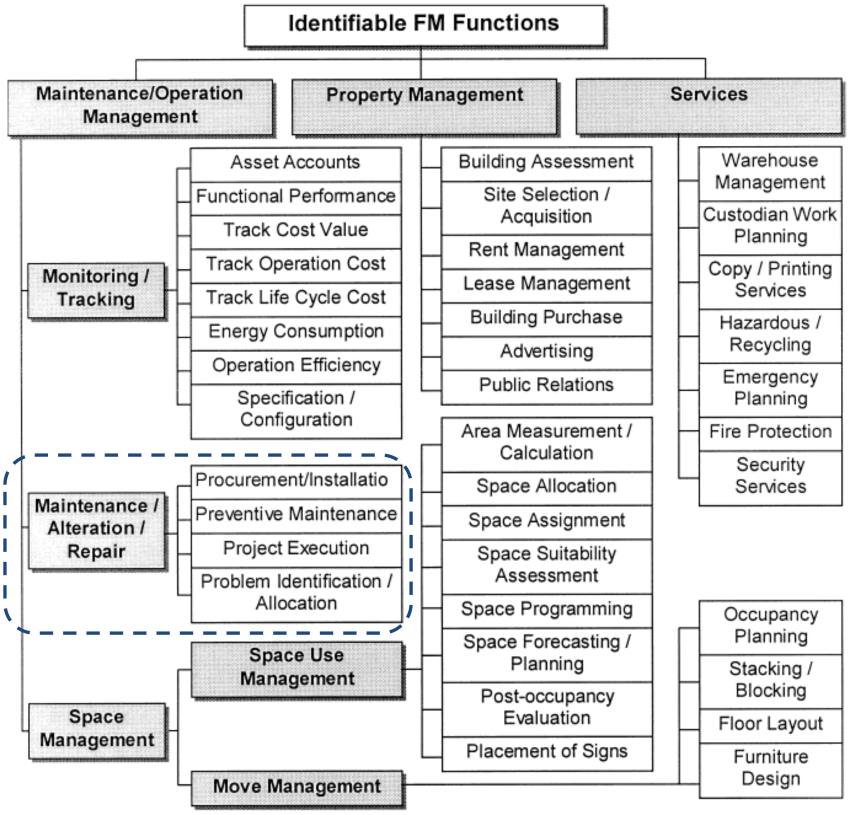
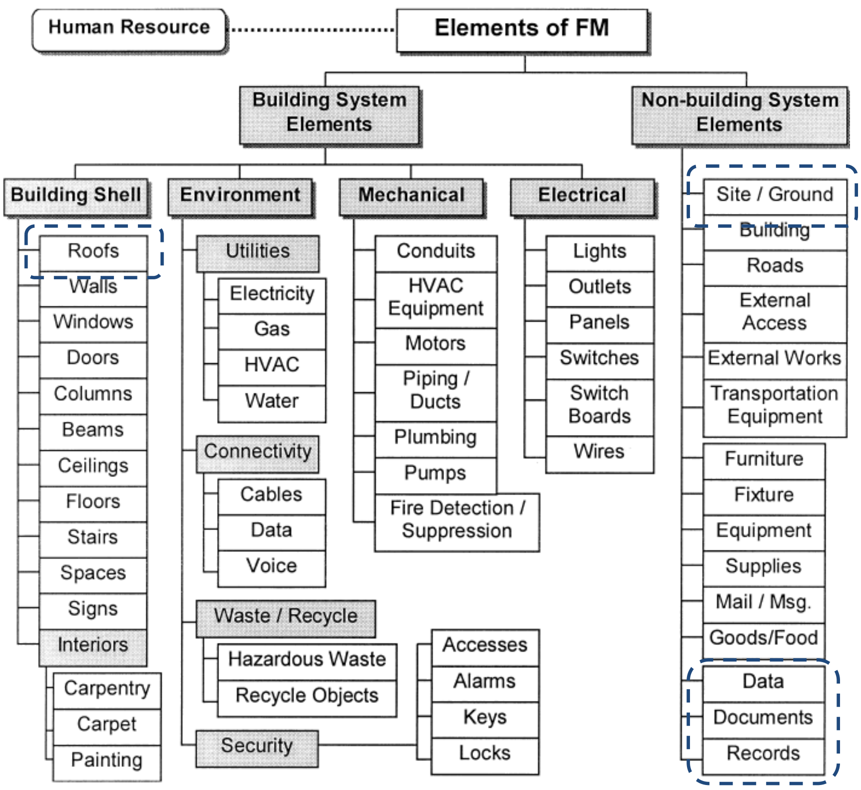
Appendix A: FM Functions and FM Elements

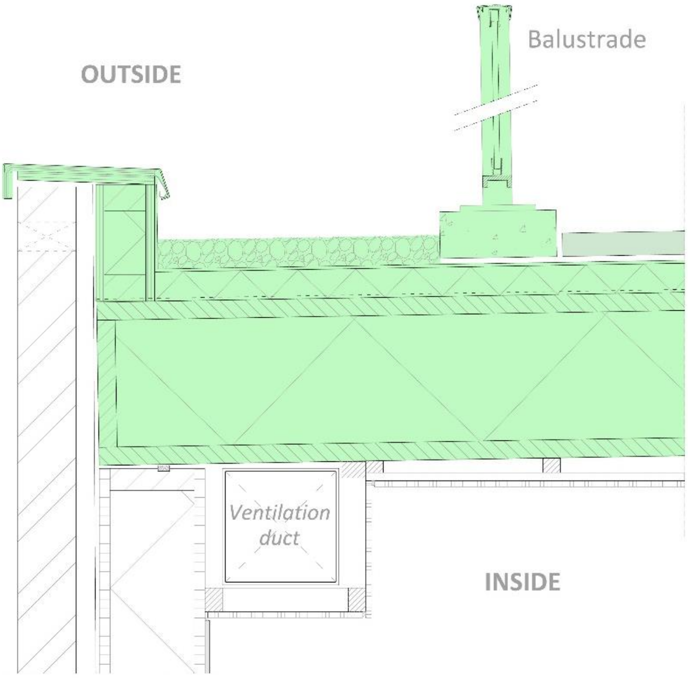
The figures illustrate the identified FM functions and FM elements by Yu et al. (2000).

Indicates the focus of this research regarding the overall facility management context.

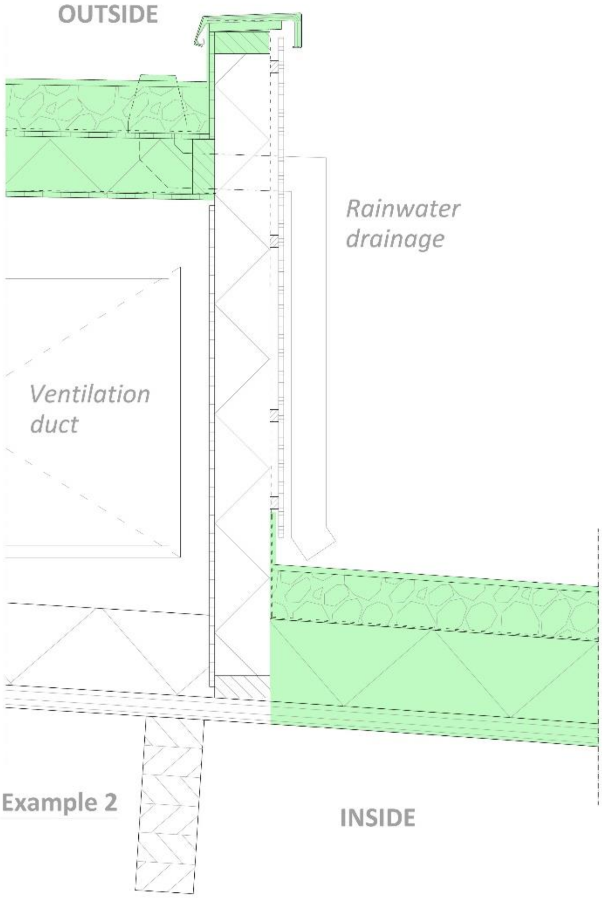




Appendix B: Flat-roof boundaries – some examples



Example 1

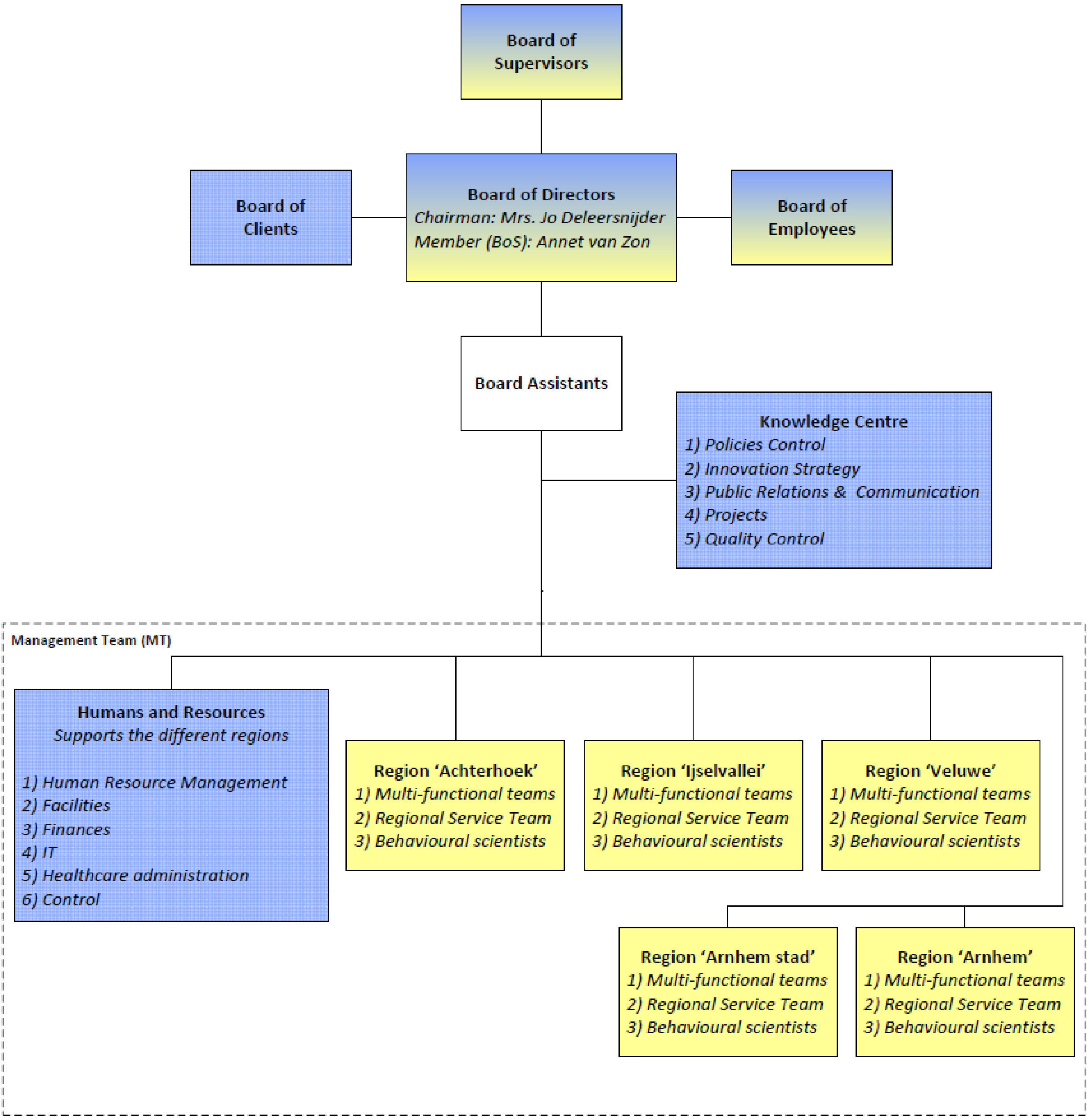


Example 2

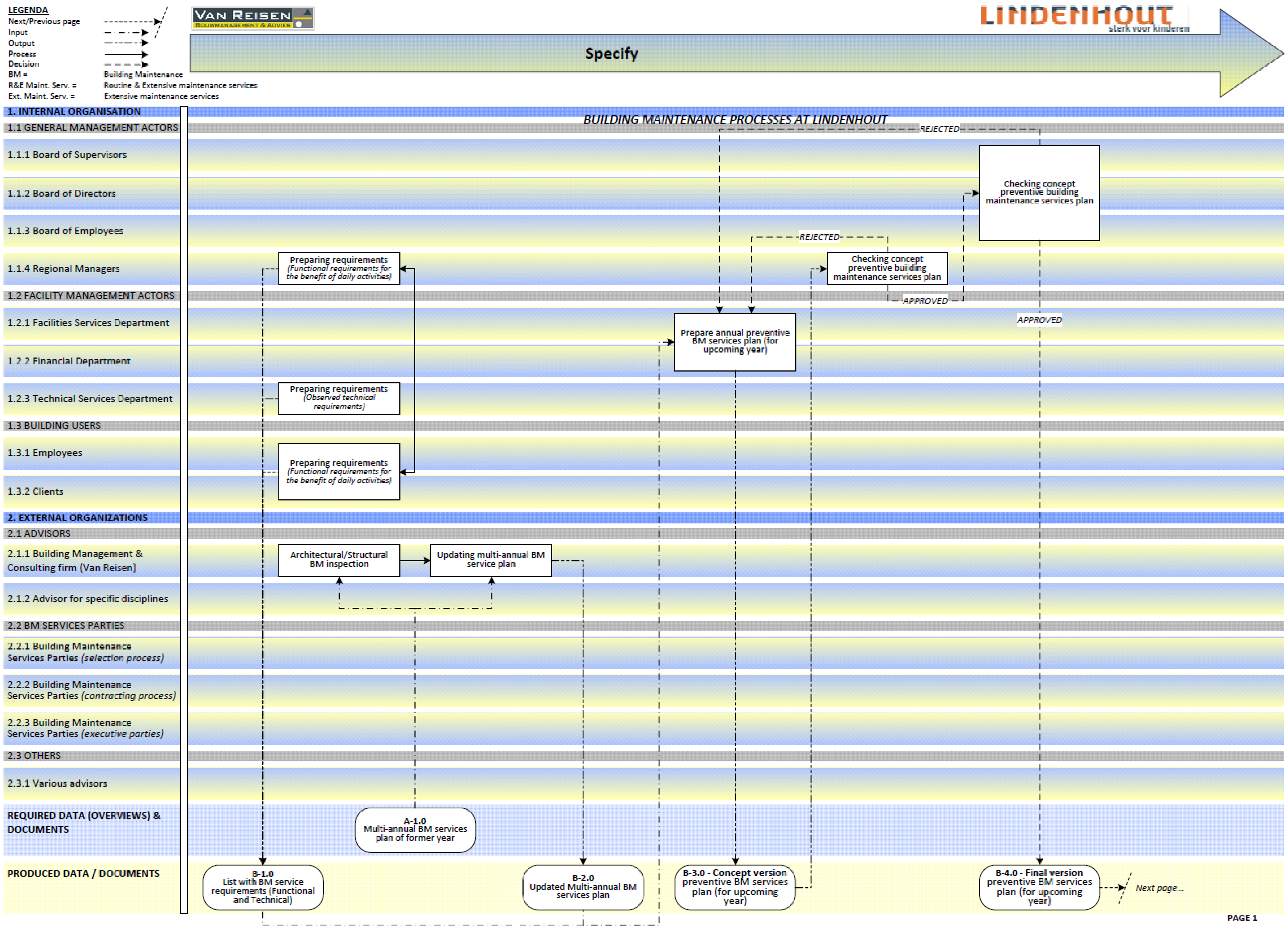
Appendix C: Organizational chart & Current BM processes Lindenhout

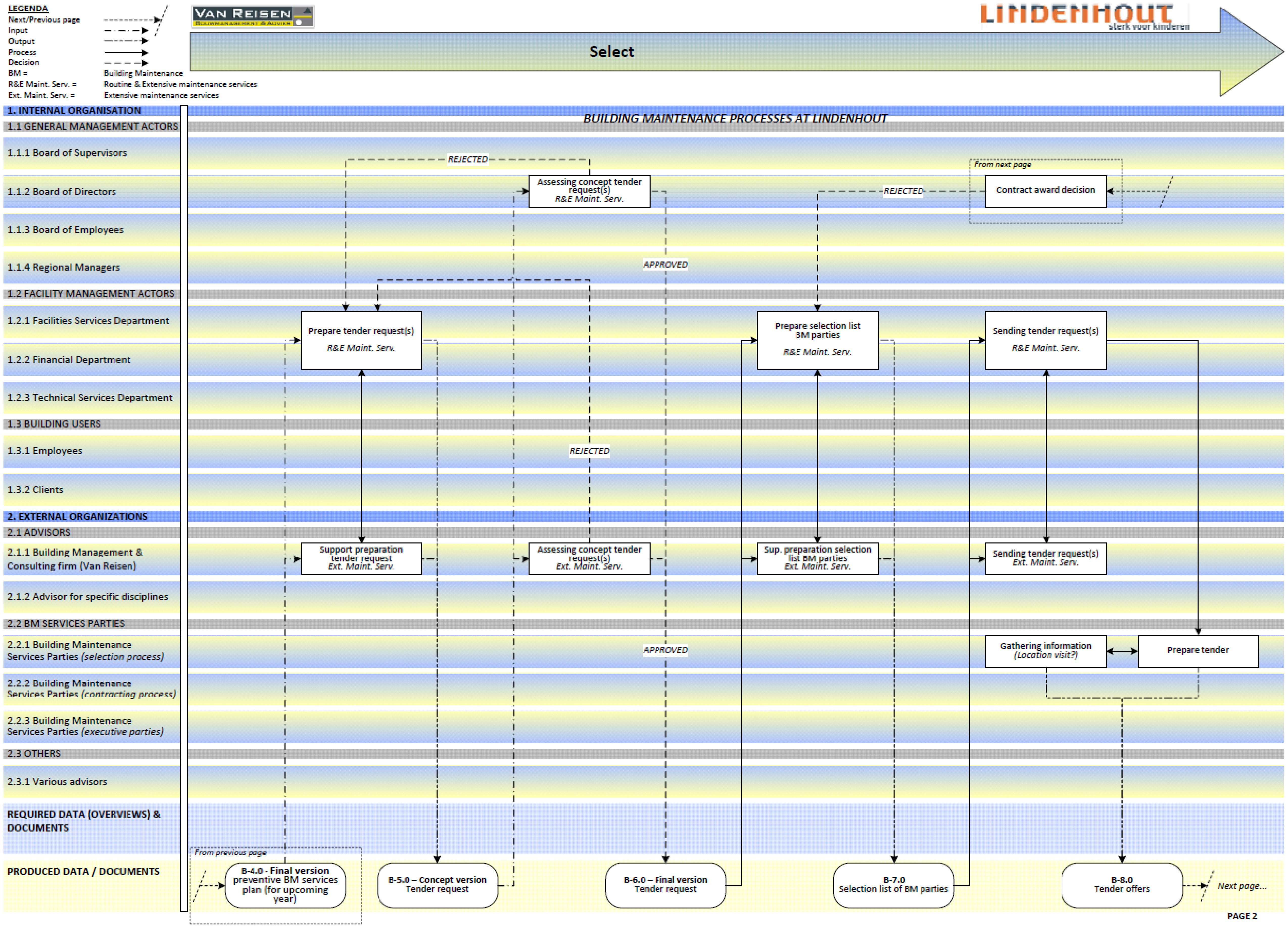
Organizational chart Lindenhout

HKZ-certified; Certification in healthcare sector to quality management systems



Appendix D: Main FMM process identified in case study




LEGENDA
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Input
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Process
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BM = Building Maintenance
R&E Maint. Serv. = Routine & Extensive maintenance services
Ext. Maint. Serv. = Extensive maintenance services
VAN REISEN
LINDENHOUT sterk voor kinderen
Select
BUILDING MAINTENANCE PROCESSES AT LINDENHOUT
1. INTERNAL ORGANISATION
1.1 GENERAL MANAGEMENT ACTORS
1.1.1 Board of Supervisors
1.1.2 Board of Directors
1.1.3 Board of Employees
1.1.4 Regional Managers
1.2 FACILITY MANAGEMENT ACTORS
1.2.1 Facilities Services Department
1.2.2 Financial Department
1.2.3 Technical Services Department
1.3 BUILDING USERS
1.3.1 Employees
1.3.2 Clients
2. EXTERNAL ORGANIZATIONS
2.1 ADVISORS
2.1.1 Building Management & Consulting firm (Van Reisen)
2.1.2 Advisor for specific disciplines
2.2 BM SERVICES PARTIES
2.2.1 Building Maintenance Services Parties (selection process)
2.2.2 Building Maintenance Services Parties (contracting process)
2.2.3 Building Maintenance Services Parties (executive parties)
2.3 OTHERS
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Contract award decision
Prepare tender request(s) R&E Maint. Serv.
Prepare selection list BM parties R&E Maint. Serv.
Sending tender request(s) R&E Maint. Serv.
REJECTED
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Sending tender request(s) Ext. Maint. Serv.
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Gathering information (Location visit?)
Prepare tender
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B-4.0 - Final version preventive BM services plan (for upcoming year)
B-5.0 – Concept version Tender request
B-6.0 – Final version Tender request
B-7.0 Selection list of BM parties
B-8.0 Tender offers
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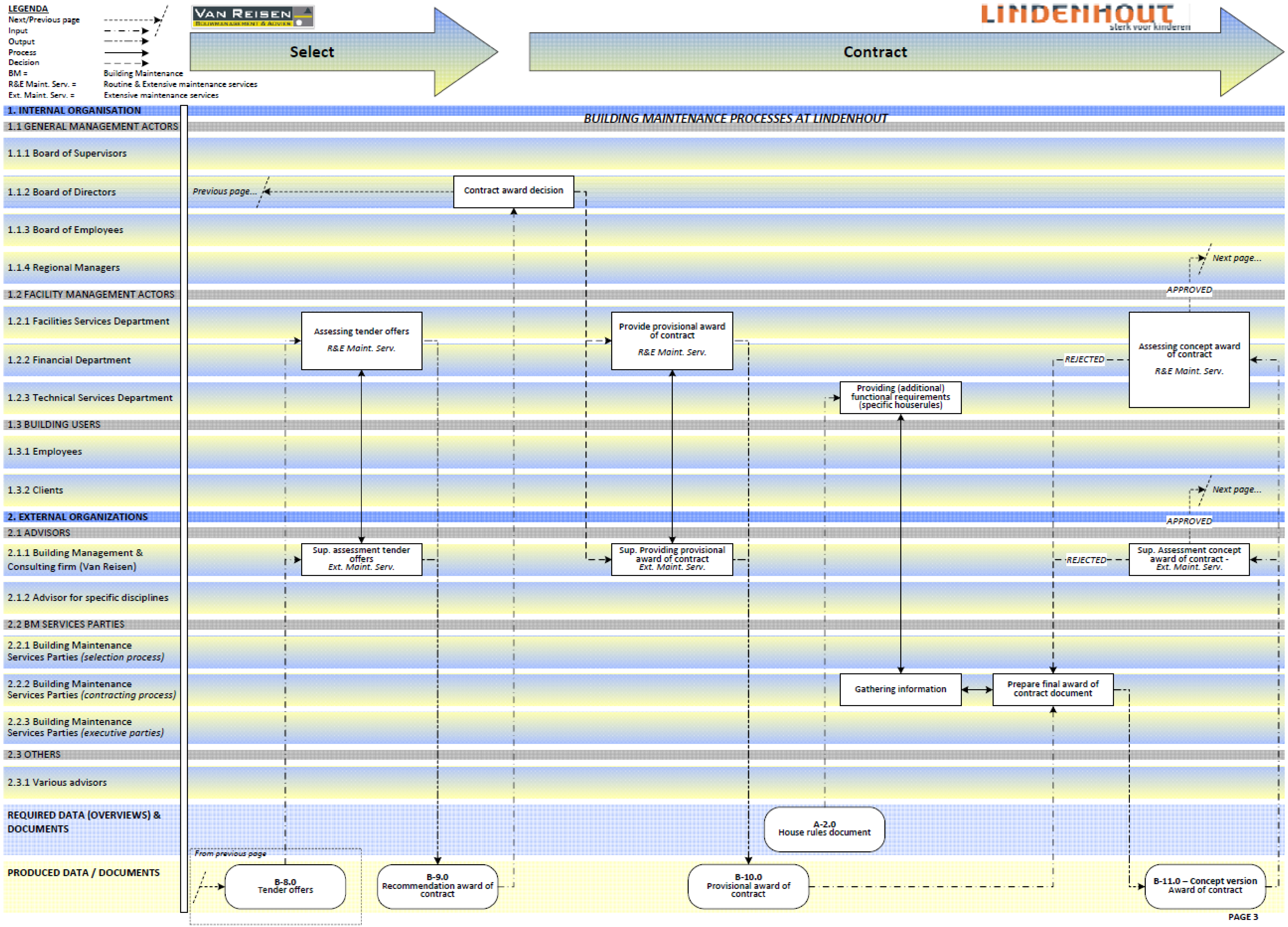
PAGE 2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Contract award decision
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Provide provisional award of contract
R&E Maint. Serv.
REJECTED
Assessing concept award of contract
R&E Maint. Serv.
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APPROVED
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Ext. Maint. Serv.
Sup. Providing provisional award of contract
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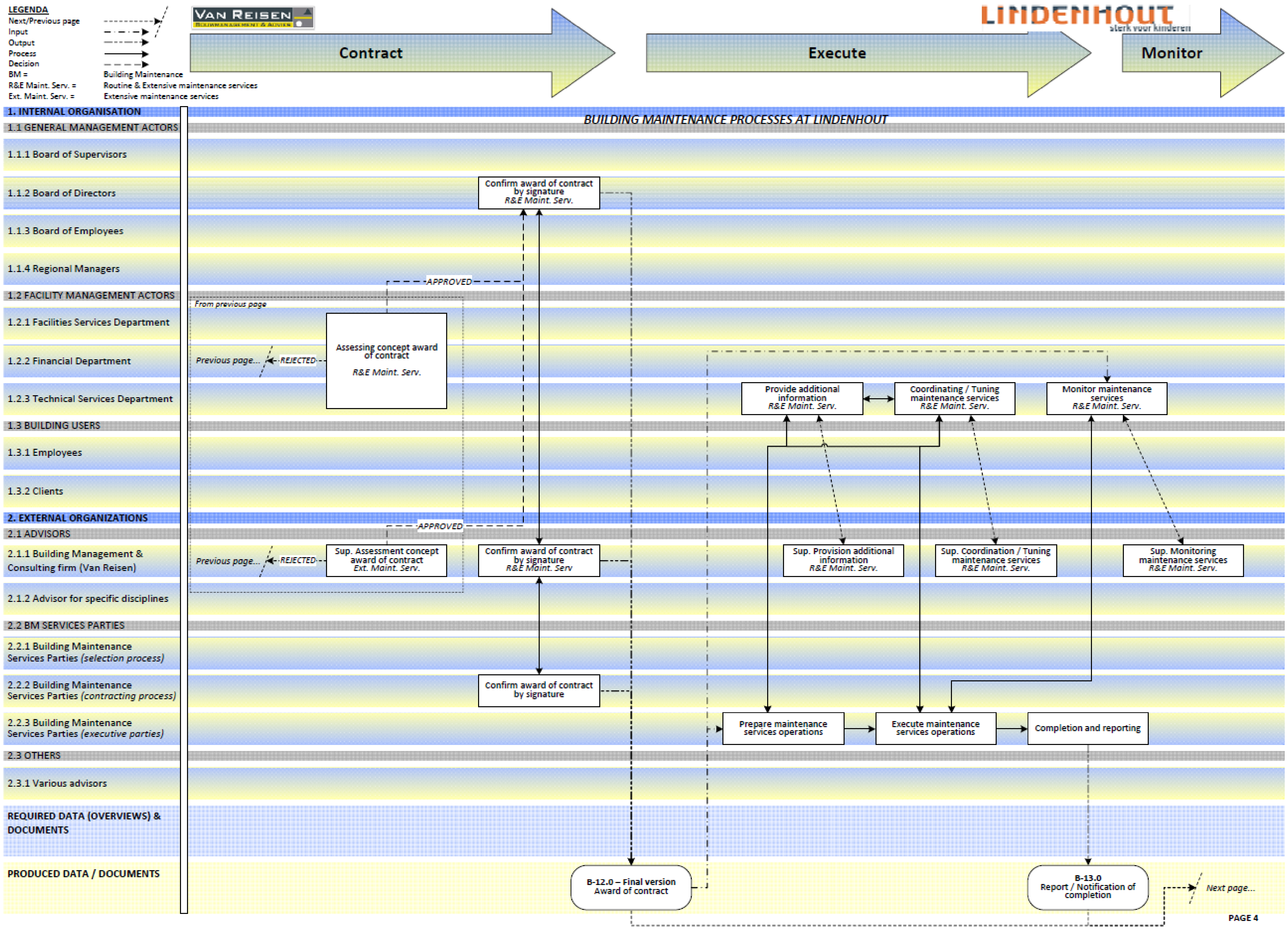
Provisional award of contract
B-11.0 – Concept version Award of contract
PAGE 3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Confirm award of contract by signature
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Coordinating / Tuning maintenance services R&E Maint. Serv.
Monitor maintenance services R&E Maint. Serv.
Sup. Provision additional information R&E Maint. Serv.
Sup. Coordination / Tuning maintenance services R&E Maint. Serv.
Sup. Monitoring maintenance services R&E Maint. Serv.
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Execute maintenance services operations
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B-13.0 Report / Notification of completion
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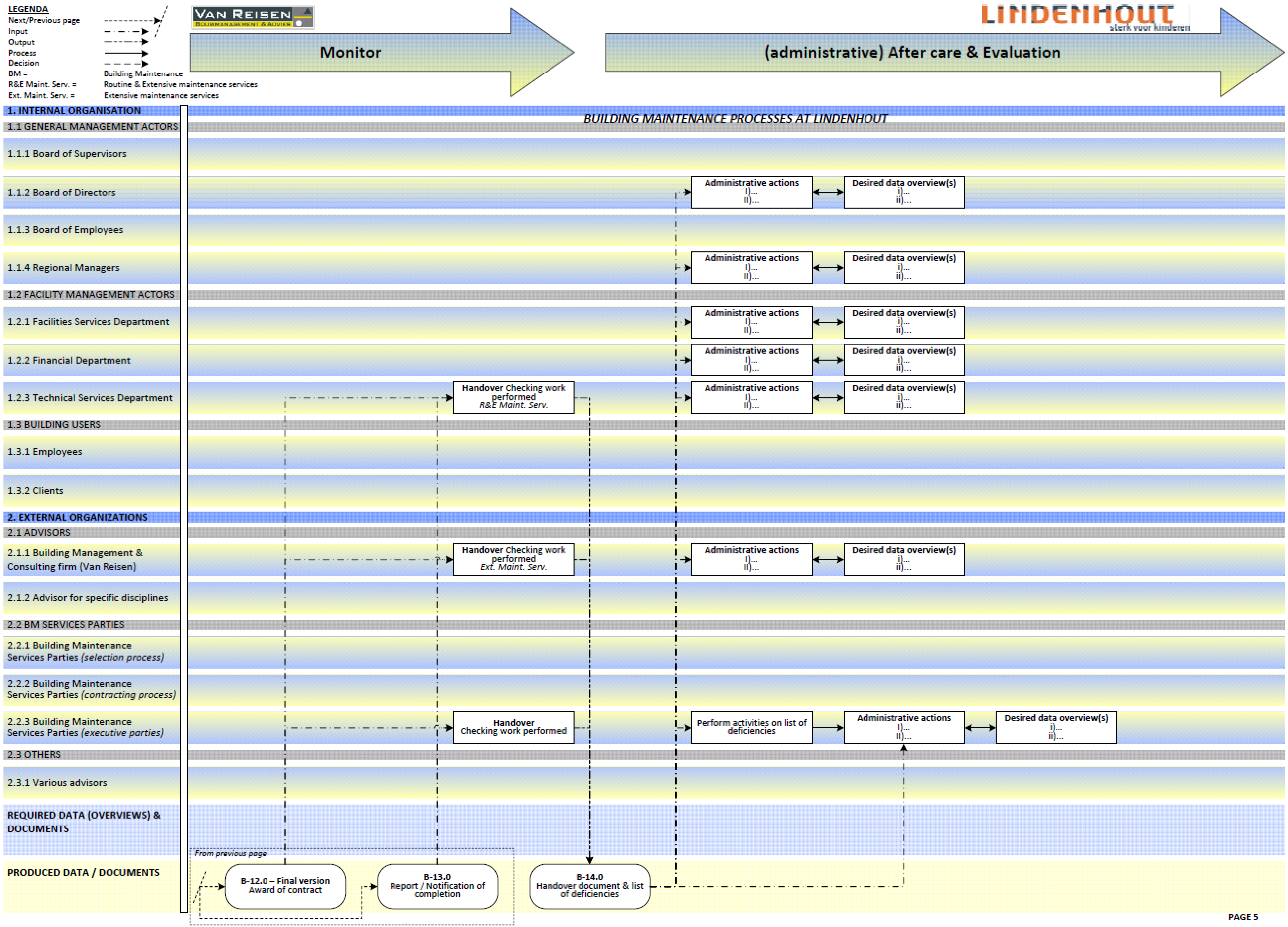
PAGE 4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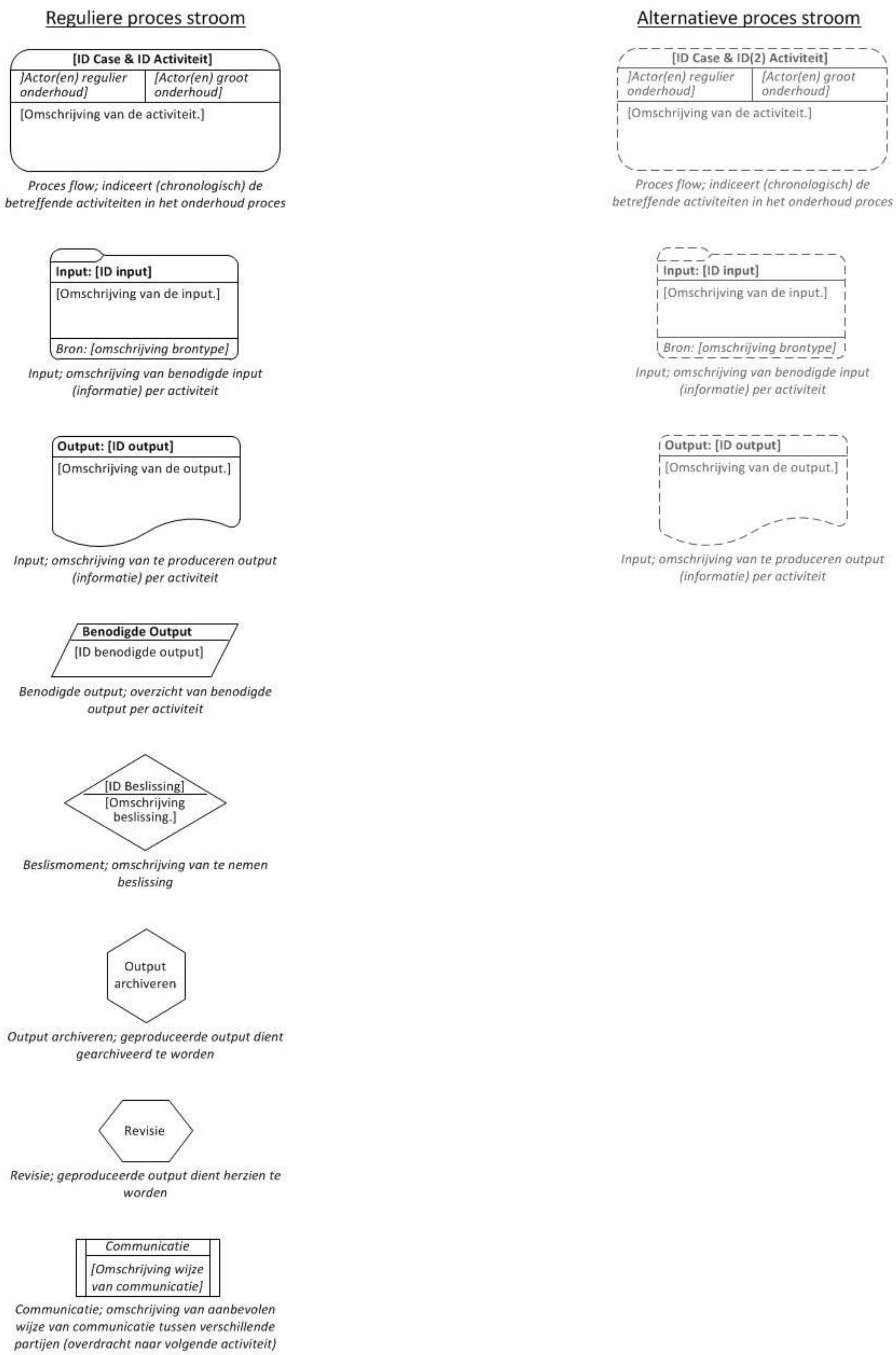
(administrative) After care & Evaluation
BUILDING MAINTENANCE PROCESSES AT LINDENHOUT
1. INTERNAL ORGANISATION
1.1 GENERAL MANAGEMENT ACTORS
1.1.1 Board of Supervisors
1.1.2 Board of Directors
1.1.3 Board of Employees
1.1.4 Regional Managers
1.2 FACILITY MANAGEMENT ACTORS
1.2.1 Facilities Services Department
1.2.2 Financial Department
1.2.3 Technical Services Department
1.3 BUILDING USERS
1.3.1 Employees
1.3.2 Clients
2. EXTERNAL ORGANIZATIONS
2.1 ADVISORS
2.1.1 Building Management & Consulting firm (Van Reisen)
2.1.2 Advisor for specific disciplines
2.2 BM SERVICES PARTIES
2.2.1 Building Maintenance Services Parties (selection process)
2.2.2 Building Maintenance Services Parties (contracting process)
2.2.3 Building Maintenance Services Parties (executive parties)
2.3 OTHERS
2.3.1 Various advisors
REQUIRED DATA (OVERVIEWS) & DOCUMENTS
PRODUCED DATA / DOCUMENTS
Administrative actions i)... ii)...
Desired data overview(s) i)... ii)...
Handover Checking work performed R&E Maint. Serv.
Handover Checking work performed Ext. Maint. Serv.
Handover Checking work performed
Perform activities on list of deficiencies
From previous page
B-12.0 – Final version Award of contract
B-13.0 Report / Notification of completion
B-14.0 Handover document & list of deficiencies
PAGE 5

Appendix E: Activity analysis and Information flow

ACTIVITEITEN & INFORMATIE STROOM

Onderzoek stap	4	**Onderhoud proces**	Aanvragen (vrijblijvende) offerte(s)	**Werkgroep**	Lindenhout (29 April, 13 Mei, 20 Mei 2014)
Case id	2.A & 2.B	**Type onderhoud**	Regulier- & Groot onderhoud		Roofing Service Nederland (28 Mei, 6 Juni 2014)

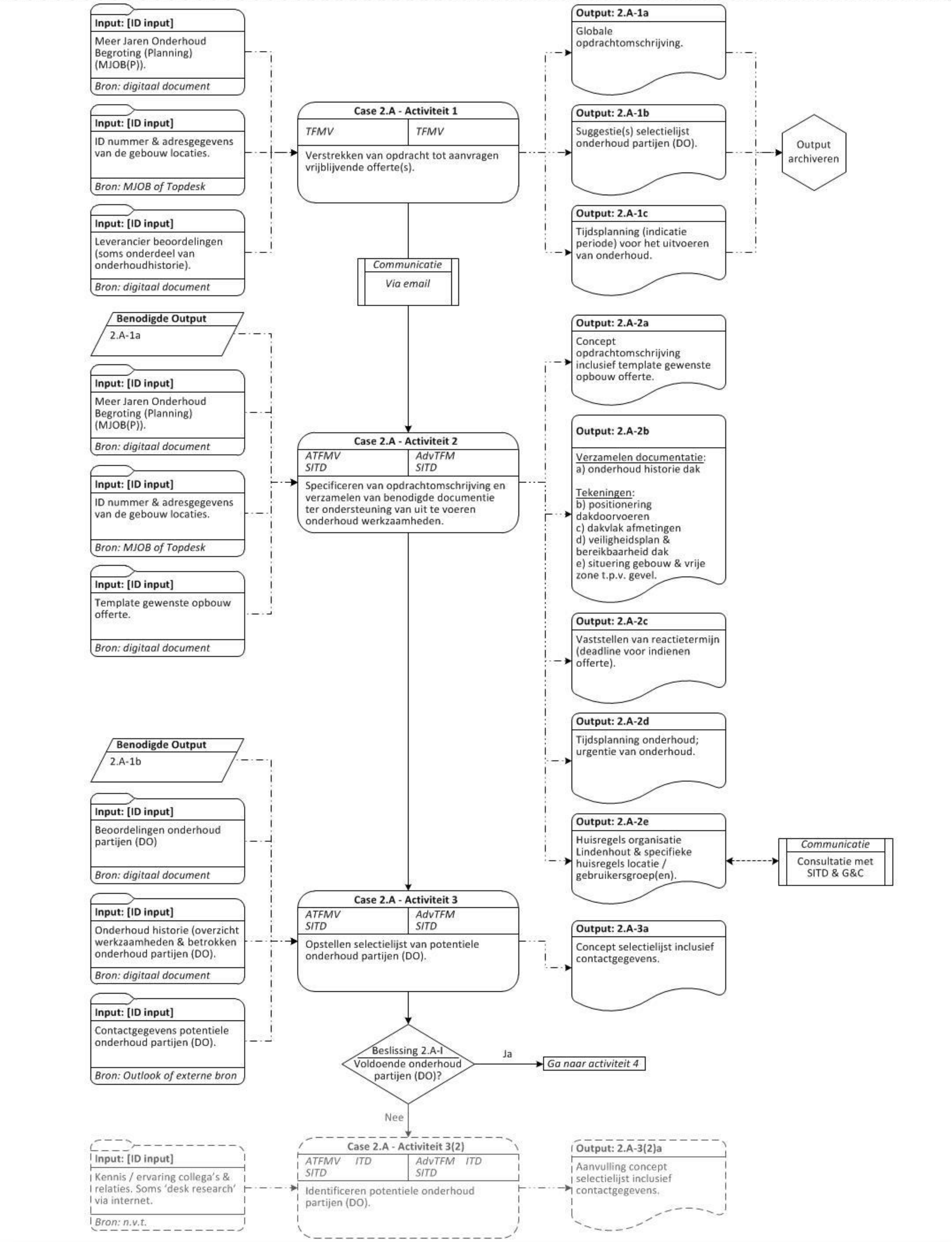
LEGENDA



MASTER THESIS – M.J.A. BREEDIJK PAGINA 1 VAN 5

ACTIVITEITEN ANALYSE

Onderzoek stap	4	**Onderhoud proces**	Aanvragen (vrijblijvende) offerte(s)	**Werkgroep**	Lindenhout (29 April, 13 Mei, 20 Mei 2014)
Case id	2.A & 2.B	**Type onderhoud**	Regulier- & Groot onderhoud		Roofing Service Nederland (28 Mei, 6 Juni 2014)



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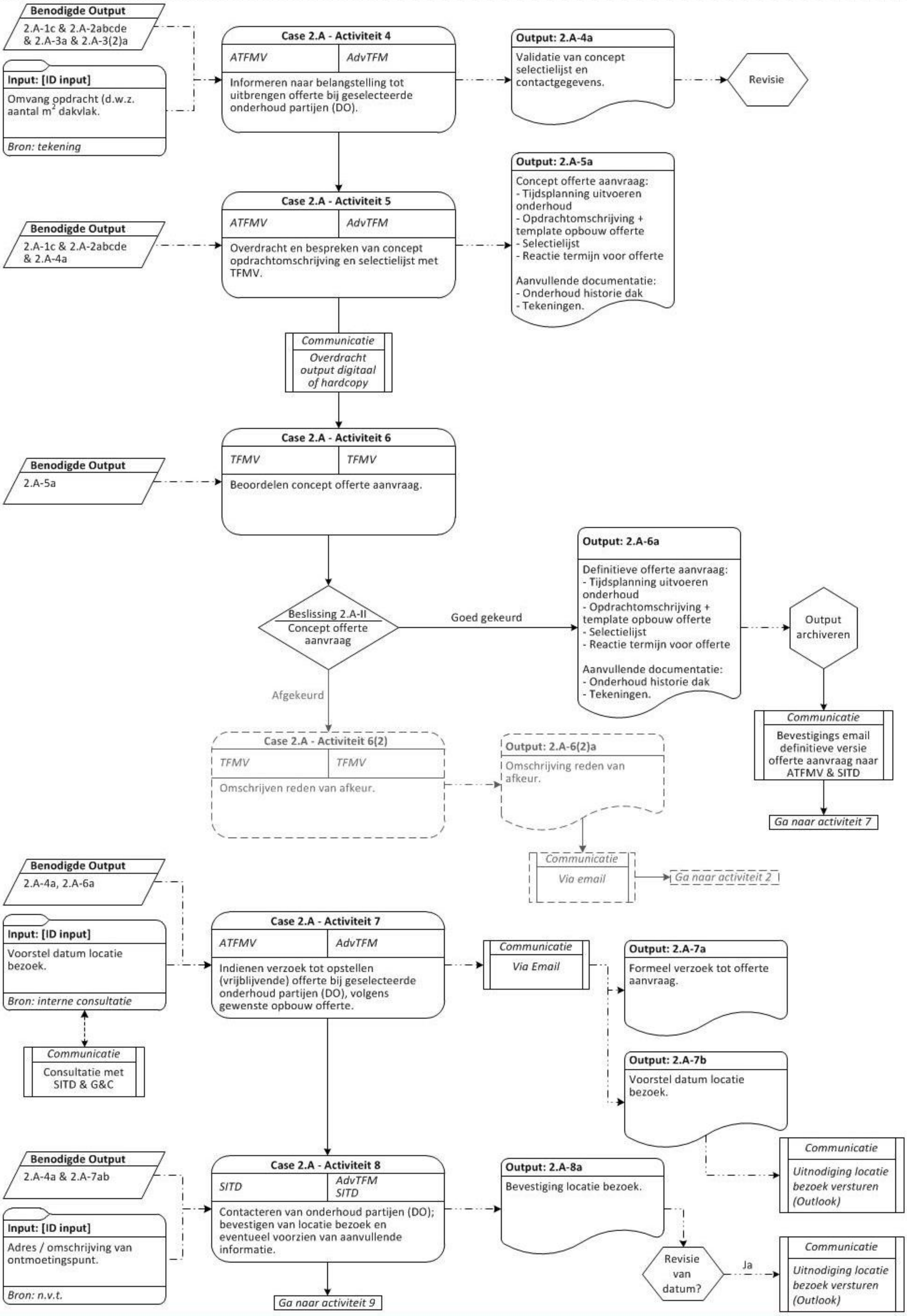
ACTIVITEITEN ANALYSE

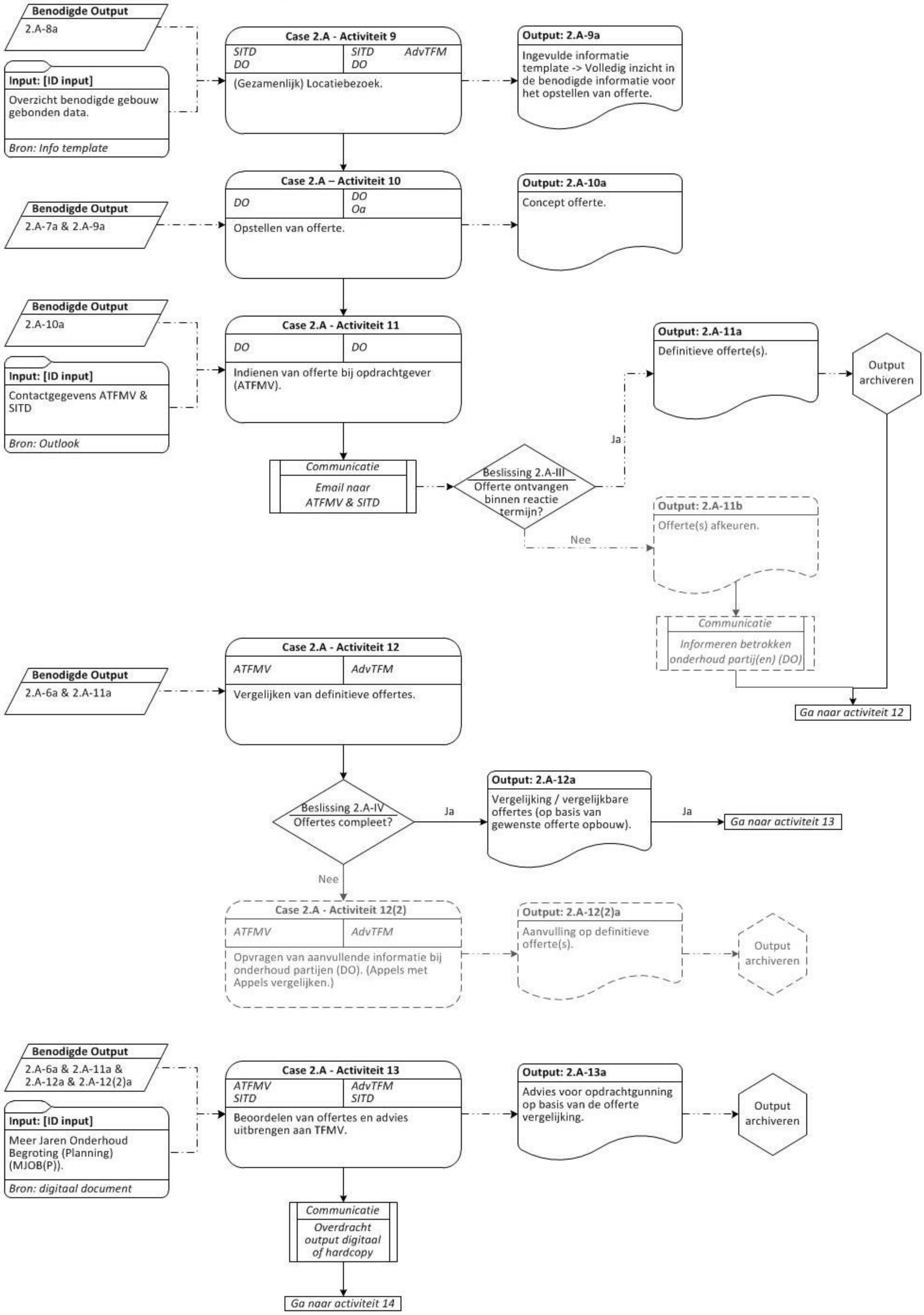
Onderzoek stap	4	**Onderhoud proces**	Aanvragen (vrijblijvende) offerte(s)	**Werkgroep**	Lindenhout (29 April, 13 Mei, 20 Mei 2014)
Case id	2.A & 2.B	**Type onderhoud**	Regulier- & Groot onderhoud		Roofing Service Nederland (28 Mei, 6 Juni 2014)



MASTER THESIS – M.J.A. BREEDIJK PAGINA 3 VAN 5

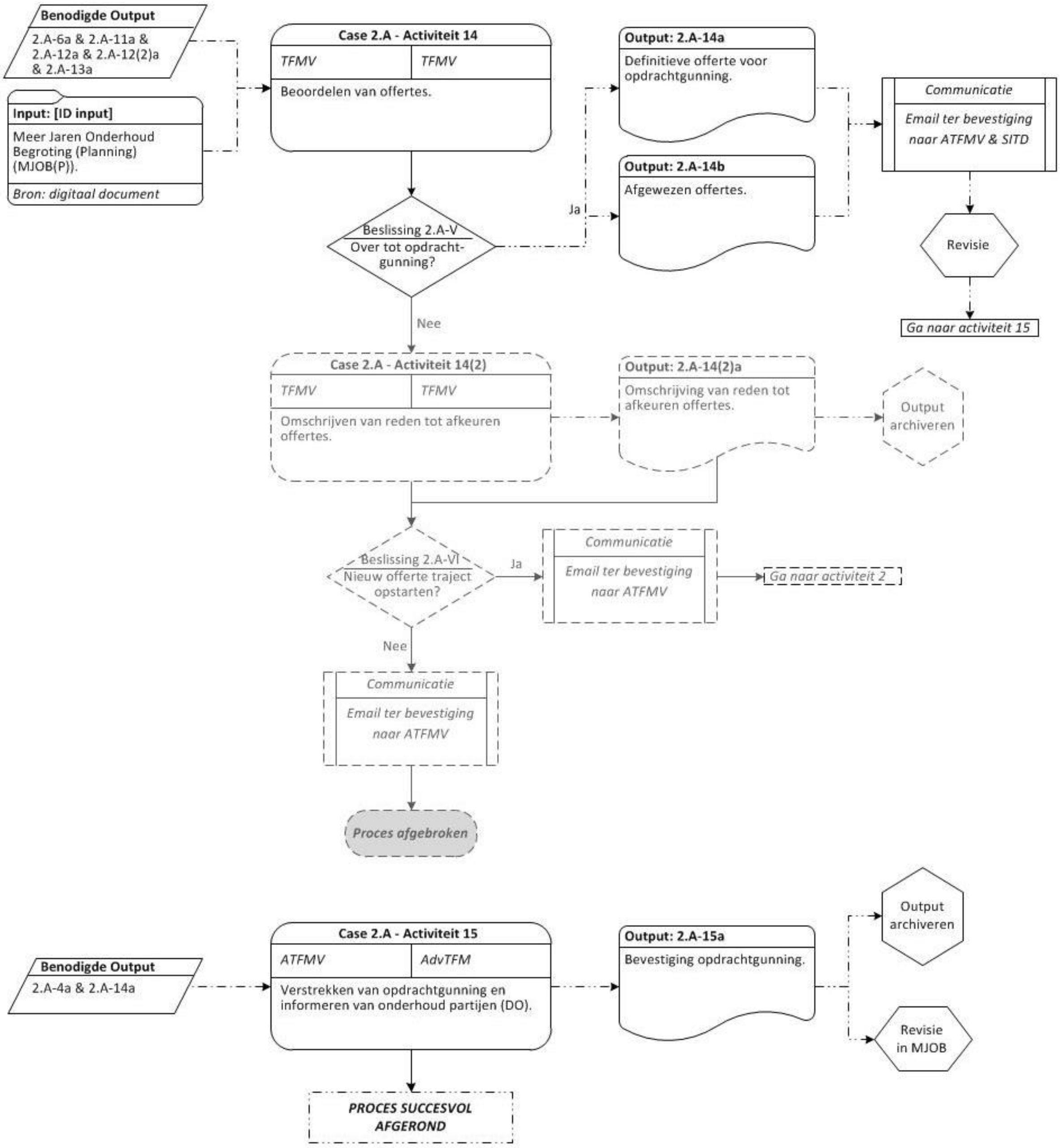
ACTIVITEITEN ANALYSE

Onderzoek stap	4	**Onderhoud proces**	Aanvragen (vrijblijvende) offerte(s)	**Werkgroep**	Lindenhout (29 April, 13 Mei, 20 Mei 2014)
Case id	2.A & 2.B	**Type onderhoud**	Regulier- & Groot onderhoud		Roofing Service Nederland (28 Mei, 6 Juni 2014)



ACTIVITEITEN & INFORMATIE STROOM

Onderzoek stap	4	**Onderhoud proces**	Aanvragen (vrijblijvende) offerte(s)	**Werkgroep**	Lindenhout (29 April, 13 Mei, 20 Mei 2014)
Case id	2.A & 2.B	**Type onderhoud**	Regulier- & Groot onderhoud		Roofing Service Nederland (28 Mei, 6 Juni 2014)



Appendix F: Results of the information requirements analyses

Informatie template - Gebouw & Locatie gebonden data Use case: 1 & 2 & 3
Onderzoekstap: 4

LOCATIE	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
Algemeen	ID Nummer pand	*Nummer*															
	Risicovolle gebruiksfuncties (m.b.t. luchtvochtigheid)?	*Ja / Nee*															
	Verwachte levensduur dak(bedekking)	*x aantal jaren*															
	Interval regulier onderhoud (schoonmaak + inspectie)	*x keer per jaar*															
Bereikbaarheid	Plaatsnaam & Adres van het Pand	*tekst*															
	Parkeergelegenheid op het terrein	*Ja / Nee*															
	Betaald parkeren?	*Ja / Nee*															
Aard van de locatie	Bosrijk	*Ja / Nee*															
	Beschikbaarheid van een eigen (plaatselijke) container?	*Ja / Nee*															
	Heeft container voldoende capaciteit?	*Ja / Nee*															
Opstelplaats tijdelijke bouwgerelateerde objecten	Opstelplaats direct naast gevel?	*Ja / Nee*															
	Opstelplaats permanent vrij van objecten?	*Ja / Nee*															
	Opstelplaats op openbaar terrein?	*Ja / Nee*															
	Vergunning / Melding plicht?	*Ja / Nee*															
	Gebruik maken van een stortkoker	*Ja / Nee*															
Bereikbaarheid dak(vlakken)	Melden alvorens betreden dak(vlakken)	*Ja / Nee*															
	Indien ja, contactgegevens contactpersoon	*Omschrijving*															
	Dak(vlakken) hoger dan 8m?	*Ja / Nee*															
	Dak(vlak) is bereikbaar via	*Omschrijving /tek.*															
	Extern materieel benodigd?	*Ja / Nee + omschr.*															

KENMERKEN - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
Dakbeveiliging	Dakbeveiliging vereist? (dak(vlak) hoger dan 2,5m?)	*Ja / Nee*															
	Bliksembeveiliging aanwezig?	*Ja / Nee*															
	Leverancier / onderhoudspartner bliksembeveiliging?	*Omschrijving*															
Permanente dakbeveiliging aanwezig	Collectieve dakbeveiliging aanwezig?	*Ja / Nee*															
	Persoonlijke dakbeveiliging aanwezig?	*Ja / Nee*															
	Veiligheidsharnas op locatie aanwezig?	*Ja / Nee*															
	Datum eerst volgende keuring (t.b.v. Keuringsgeldigheid)	*Datum*															
	Keuren dakbeveiliging bij regulier onderhoud?	*Ja / Nee*															
Geen permanente dakbeveiliging	In aanvullende offerte ook het plaatsen van permanente dakbeveiliging + certificatie opnemen?	*Ja / Nee*															
Vervuilings type(s)	Bladeren	*....% van dakvlak*															
	Algen / Mos	*....% van dakvlak*															
	Onkruid	*....% van dakvlak*															
	Vogelpoep	*....% van dakvlak*															
	Grof vuil	*....% van dakvlak*															
	Anders, namelijk...	*....% van dakvlak*															
	Vervuiling van dakgoten	*....% van dakgoten*															
Methode afvoeren organisch materiaal	Optie 1: Middels bladblazer over de dakrand	*Ja / Nee*															
	Optie 2: Centraal verzamelen en afvoeren in zakken	*Ja / Nee*															
	Optie 3: beide opties aanbieden in offerte	*Ja / Nee*															
Geometrie	Oppervlakte dak(vlak)	*...m2*															
	Lengte dakranden	*....mm -> tekening*															
	positionering dakdoorvoeren en permanente objecten (lichtkoepels, installaties, e.d.) + afstanden tot dakrand	*Tekening*															
	Hoogte dakvlak vanaf de grond	*mm*															

Informatie template - Gebouw & Locatie gebonden data
Onderzoekstap: 4

Use case: 1 & 2 & 3

DAKPAKKET - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
Type dak	Koud dakconstructie	*Ja / Nee*															
	Warm dakconstructie	*Ja / Nee*															
Ballast laag: Tegels	Type / Soort	*Omschrijving*															
	Omvang	*...% van dakvlak*															
	Afmeting tegels	*Omschrijving*															
	Beschadigde tegels	*...Stuks*															
Ballast laag: Grind	Type / Soort	*Omschrijving*															
	Grind gradatie	*Omschrijving*															
	Omvang	*...% van dakvlak*															
	Laag dikte	*...mm*															
Ballast laag: Extensief groendak	Type / Soort	*Omschrijving*															
	Omvang	*...% van dakvlak*															
	Laag opbouw	*Omschrijving*															
	Laagdikte	*...mm*															
Toplaag / Dakbedekking	Type / Soort	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	omvang	*...% van dakvlak*															
	Eerste toplaag?	*Ja / Nee*															
Isolatie	Type / Soort	*Omschrijving*															
	Laag dikte	*...mm*															
	Rc-waarde	*Omschrijving*															
Onder constructie: Type / Soort	Hout of houtachtig	*Ja / Nee*															
	Steenachtig	*Ja / Nee*															
	Staal	*Ja / Nee*															

DAKRAND - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
Algemeen	Dakrand hoogte vanaf dakvlak	*....mm*															
	Mastiekschroot toegepast?	*Ja / Nee*															
	afmetingen mastiekschroot	*Omschr. / schets*															
Afwerking: Daktrim & Kraal	Type / Soort / Materiaal	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Afmetingen daktrim	*Omschrijving*															
	Aantal m1	*....m1*															
	Aan vervanging toe	*... m1*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort / Materiaal	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Afmetingen daktrim	*Omschrijving*															
Afwerking: Afdekkap	Type / Soort / Materiaal	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Afmetingen afdekkap	*Omschrijving*															
	Aantal m1	*....m1*															
	Aan vervanging toe	*... m1*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort / Materiaal	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Afmetingen afdekkap	*Omschrijving*															

Informatie template - Gebouw & Locatie gebonden data — Use case: 1 & 2 & 3

Onderzoekstap: 4

DOORVOEREN & OBJECTEN - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bijisoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bijisoleren
Kanalen en afvoeren	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Aantal stuks	*...Stuks*															
	Leverancier & servicecontract	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Betrokken leverancier & servicecontract?	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
Lichtkoepels	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Aantal stuks	*...Stuks*															
	Leverancier & servicecontract	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Betrokken leverancier & servicecontract?	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
Installatie technische units	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Aantal stuks	*...Stuks*															
	Leverancier & servicecontract	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
Zonnepanelen	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Aantal stuks	*...Stuks*															
	Leverancier & servicecontract	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
Anders, namelijk	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Aantal stuks	*...Stuks*															
	Leverancier & servicecontract	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Betrokken leverancier & servicecontract?	*Omschrijving*															
	Bevestigingswijze	*Omschrijving*															
	Demontabel	*Ja / Nee*															

Informatie template - Gebouw & Locatie gebonden data — Use case: 1 & 2 & 3

Onderzoekstap: 4

HEMELWATERAFVOEREN EN TOEBEHOREN - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
HWA afvoer: Stadsuitloop	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Ja / Nee*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
HWA afvoer: Onderuitloop	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
HWA afvoer: Spuwer	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
HWA afvoer: Anders, namelijk	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
HWA roosters en afdekkappen	Type / Soort / Materiaal	*Omschrijving*															
	Afmetingen	*Omschrijving*															
	Positionering op dak	*Tekening*															
	Totaal Aantal	*...Stuks*															
	Aan vervanging toe / ontbreken van	*... Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Aanvullend; na constatering potentieel gebrek	Type / Soort	*Omschrijving*															
	Afmetingen	*Omschrijving*															
Dakgoot	Type / Soort	*Omschrijving*															
	Afmetingen	*...mm*															
	Positionering op dak	*Tekening*															
	Aantal m1	*...m1*															

Informatie template - Gebouw & Locatie gebonden data   Use case: 1 & 2 & 3
Onderzoekstap: 4

ANDERE POTENTIELE GEBREKEN EN CONSTATERINGEN - DAKVLAK [nummer]	Input	Eenheid	Case 1: Inspectie rapporten	t.b.v. technische staat dak	t.b.v. ontwerp dakbeveiliging	Case 2: Opstellen offertes	Regulier onderhoudscontract	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren	Case 3: Uitvoeren onderhoud	Regulier onderhoud	Aanvullende calamiteiten	Overlagen dakbedekking	Vervangen dakbedekking	Bij isoleren
Dakbedekking: Blaarvorming	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Hoog / Middel / Laag*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Dakbedekking: Plooivorming	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Hoog / Middel / Laag*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Dakbedekking: Kaalslag	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*% van dakvlak*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Dakbedekking: Verharding toplaag	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*% van dakvlak*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Dakbedekking: Craquele vorming	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*% van dakvlak*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Dakbedekking: Scheurvorming	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Hoog / Middel / Laag*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Randafwerking: Scheurvorming bij stuiknaden	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Hoog / Middel / Laag*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Randafwerking: gebrek m.b.t. loodafwerkingen	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*...m1*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Randafwerking: ontbreken en/of beschadigde randstroken	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*...m1*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
HWA: afvoeren niet verdiept uitgevoerd	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*...Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto van gebrek	*Ja / Nee*															
Dakdoorvoeren: Ontbreken of beschadigde rozettering	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*...Stuks*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Overige: Mechanische beschadigingen	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Omschrijving*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Overige: Koude bruggen door krimp van isolatie	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*...mm bij ...mm*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Overige: Andere gebreken / beschadigingen	Gebrek geconstateerd	*Ja / Nee*															
	Indicatie van omvang	*Hoog / Middel / Laag*															
	Exacte locatie van gebrek	*Tag op tekening*															
	Foto en/of omschrijving van gebrek	*Ja / Nee*															
Constateringen	Voldoende HWA afvoerpunten	*Ja / Nee*															
	Voldoende afschot t.b.v. HWA	*Ja / Nee*															

Informatie template - Gebouw & Locatie gebonden data — Use case: 1 & 2 & 3

Onderzoekstap: 4

Bronnen gebruikt voor het opstellen van de informatie template

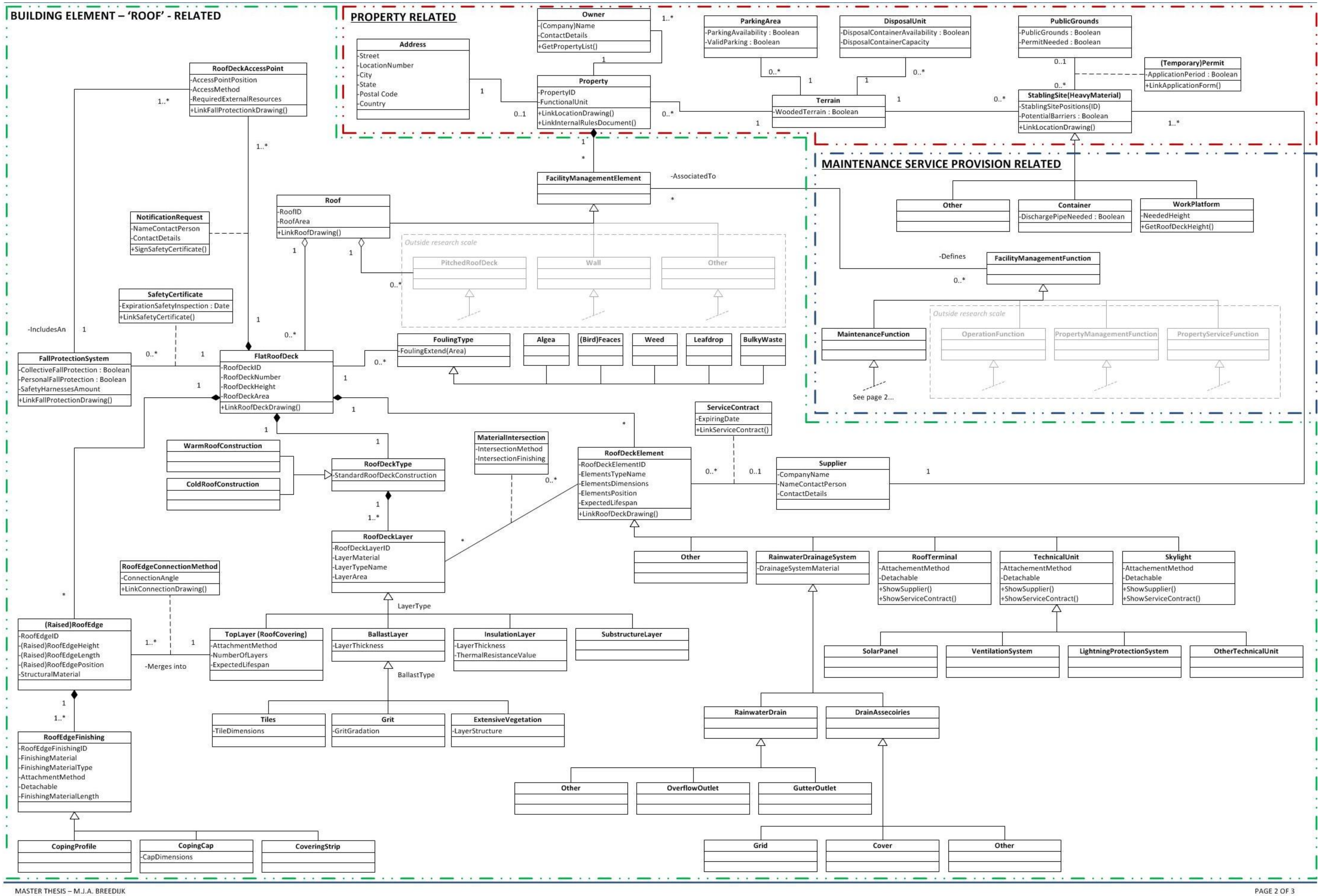
BRONNEN — Informatie behoefte	t.b.v. Formulieren input & Eenheid gegevens	Case 1: Inspectie rapporten	t.b.v. Technische staat dak	t.b.v. Ontwerp dakbeveiliging	Case 2: Opstellen offerte	t.b.v. regulier onderhoud	t.b.v. groot onderhoud	Case 3: Uitvoeren onderhoud	t.b.v. regulier onderhoud	t.b.v. groot onderhoud
Werkgroepen										
A. Bosch & M. Homeijer - Roofing Service Nederland, persoonlijke communicatie, Mei 28, 2014										
A. Bosch & servicemedewerkers - Roofing Service Nederland, persoonlijke communicatie, Juni 6, 2014										
Documenten										
Roofing Service Nederland, Van dakopname tot meerjarenbegroting, Brummen										
Protect (2008), Informatie voor gebouweigenaren; zorg voor een veilig en gezond dak, Brummen										
Arbouw, Veilig werken op hoogte, verkregen op juni 10, 2014, van http://www.arbouw.nl/producten/adviezen/arbouw-advies-veilig-werken-op-hoogte										
Rapportages										
Roofing Service Nederland (November 29, 2012), Inspectierapport dakbedekking; Heijenoordseweg 1 Arnhem - Gebouw 1 Lindenhout										
Roofing Service Nederland (November 30, 2012), Inspectierapport dakbedekking; Heijenoordseweg 1 Arnhem - Gebouw 2 Lindenhout										
Roofing Service Nederland (November 28, 2012), Inspectierapport dakbedekking; Heijenoordseweg 1 Arnhem - Gebouw 3 Lindenhout										
Roofing Service Nederland (November 23, 2012), Inspectierapport dakbedekking; Heijenoordseweg 1 Arnhem - Gebouw 4 Lindenhout										
Roofing Service Nederland (November 25, 2012), Inspectierapport dakbedekking; Heijenoordseweg 1 Arnhem - Gebouw 5 Lindenhout										
VEBIDAK (Mei 18, 2010), Beoordelingsrapport dakbedekkingsconstructie, Heijenoordseweg 1 Arnhem Gebouw 3 & 4 Lindenhout										
Roofing Service Nederland (Sept. 2008), Dak Risico en Evaluatie; Heijenoordseweg 1 Arnhem - Gebouw 1 Lindenhout										
Roofing Service Nederland (Sept. 2008), Dak Risico en Evaluatie; Heijenoordseweg 1 Arnhem - Gebouw 2 Lindenhout										
Roofing Service Nederland (Sept. 2008), Dak Risico en Evaluatie; Heijenoordseweg 1 Arnhem - Gebouw 5 Lindenhout										
Offertes										
Roofing Service Nederland (Juli 1, 2008), Offerte; Renovatie dakbedekkingsconstructie, Heijenoordseweg 1 Arnhem - Gebouw 3 Lindenhout										
Roofing Service Nederland (Juli 1, 2008), Offerte; Renovatie dakbedekkingsconstructie, Heijenoordseweg 1 Arnhem - Gebouw 4 Lindenhout										
Roofing Service Nederland (April 29, 2013), Offerte; Vernieuwen dakbedekking, Kastanjelaan 4 en 6 Ellecom - Lindenhout										
Roofing Service Nederland (April 18, 2013), Offerte; Vernieuwen dakbedekking, Anton Mauvestraat 8b&c - Lindenhout										
Formulieren										
Roofing Service Nederland, praktijk formulier: dak opname										
Roofing Service Nederland, praktijk formulier: inspectierapport dakbedekking										
Lindenhout, Instructiekaart veilig betreden daken; Heijenoordseweg 1 Arnhem - Gebouw 1,3,4										

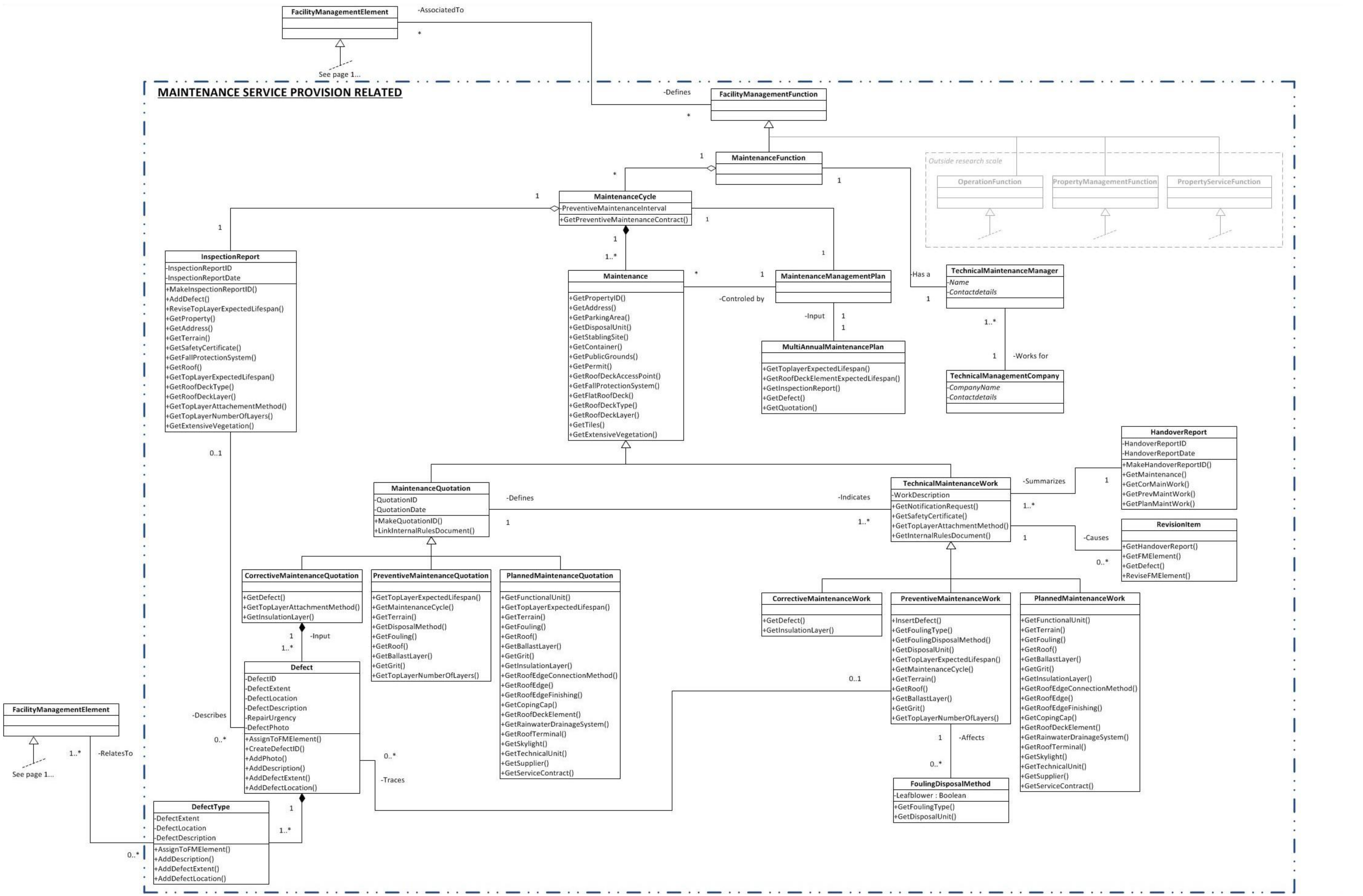
* Onder case 3: uitvoeren onderhoud valt zowel het fysiek uitvoeren van de onderhoud werkzaamheden als de werkvoorbereiding (als inplannen werkzaamheden & benodigd materieel, bestellen materialen, e.d.)

* Voor het ontwerpen van de dakbeveiliging, is de uitgangssituatie dat er geen permanente dakbeveiliging aanwezig is op het dak

* Bij aanvullende calamiteiten onderhoud, heb ik voor ieder dakelement en/of afwerkings materiaal gekeken naar de benodigde informatie wanneer er een gebrek is geconstateerd m.b.t. dat specifieke dakelement en/of afwerkingsmateriaal.

Appendix G: Class Model




FacilityManagementElement
-AssociatedTo
*
See page 1...
MAINTENANCE SERVICE PROVISION RELATED
-Defines
*
FacilityManagementFunction
MaintenanceFunction
1
*
1
Outside research scale
OperationFunction
PropertyManagementFunction
PropertyServiceFunction
1
MaintenanceCycle
-PreventiveMaintenanceInterval
+GetPreventiveMaintenanceContract()
1
1
1..*
1
InspectionReport
-InspectionReportID
-InspectionReportDate
+MakeInspectionReportID()
+AddDefect()
+ReviseTopLayerExpectedLifespan()
+GetProperty()
+GetAddress()
+GetTerrain()
+GetSafetyCertificate()
+GetFallProtectionSystem()
+GetRoof()
+GetTopLayerExpectedLifespan()
+GetRoofDeckType()
+GetRoofDeckLayer()
+GetTopLayerAttachementMethod()
+GetTopLayerNumberOfLayers()
+GetExtensiveVegetation()
Maintenance
+GetPropertyID()
+GetAddress()
+GetParkingArea()
+GetDisposalUnit()
+GetStablingSite()
+GetContainer()
+GetPublicGrounds()
+GetPermit()
+GetRoofDeckAccessPoint()
+GetFallProtectionSystem()
+GetFlatRoofDeck()
+GetRoofDeckType()
+GetRoofDeckLayer()
+GetTiles()
+GetExtensiveVegetation()
*
1
-Controled by
MaintenanceManagementPlan
1
-Input
1
1
MultiAnnualMaintenancePlan
+GetToplayerExpectedLifespan()
+GetRoofDeckElementExpectedLifespan()
+GetInspectionReport()
+GetDefect()
+GetQuotation()
-Has a
1
TechnicalMaintenanceManager
-Name
-Contactdetails
1..*
1
-Works for
TechnicalManagementCompany
-CompanyName
-Contactdetails
HandoverReport
-HandoverReportID
-HandoverReportDate
+MakeHandoverReportID()
+GetMaintenance()
+GetCorMainWork()
+GetPrevMaintWork()
+GetPlanMaintWork()
0..1
MaintenanceQuotation
-QuotationID
-QuotationDate
+MakeQuotationID()
+LinkInternalRulesDocument()
-Defines
1
-Indicates
1..*
TechnicalMaintenanceWork
-WorkDescription
+GetNotificationRequest()
+GetSafetyCertificate()
+GetTopLayerAttachmentMethod()
+GetInternalRulesDocument()
-Summarizes
1
1..*
1
-Causes
0..*
RevisionItem
+GetHandoverReport()
+GetFMElement()
+GetDefect()
+ReviseFMElement()
CorrectiveMaintenanceQuotation
+GetDefect()
+GetTopLayerAttachmentMethod()
+GetInsulationLayer()
PreventiveMaintenanceQuotation
+GetTopLayerExpectedLifespan()
+GetMaintenanceCycle()
+GetTerrain()
+GetDisposalMethod()
+GetFouling()
+GetRoof()
+GetBallastLayer()
+GetGrit()
+GetTopLayerNumberOfLayers()
PlannedMaintenanceQuotation
+GetFunctionalUnit()
+GetTopLayerExpectedLifespan()
+GetTerrain()
+GetFouling()
+GetRoof()
+GetBallastLayer()
+GetGrit()
+GetInsulationLayer()
+GetRoofEdgeConnectionMethod()
+GetRoofEdge()
+GetRoofEdgeFinishing()
+GetCopingCap()
+GetRoofDeckElement()
+GetRainwaterDrainageSystem()
+GetRoofTerminal()
+GetSkylight()
+GetTechnicalUnit()
+GetSupplier()
+GetServiceContract()
CorrectiveMaintenanceWork
+GetDefect()
+GetInsulationLayer()
PreventiveMaintenanceWork
+InsertDefect()
+GetFoulingType()
+GetFoulingDisposalMethod()
+GetDisposalUnit()
+GetTopLayerExpectedLifespan()
+GetMaintenanceCycle()
+GetTerrain()
+GetRoof()
+GetBallastLayer()
+GetGrit()
+GetTopLayerNumberOfLayers()
PlannedMaintenanceWork
+GetFunctionalUnit()
+GetTerrain()
+GetFouling()
+GetRoof()
+GetBallastLayer()
+GetGrit()
+GetInsulationLayer()
+GetRoofEdgeConnectionMethod()
+GetRoofEdge()
+GetRoofEdgeFinishing()
+GetCopingCap()
+GetRoofDeckElement()
+GetRainwaterDrainageSystem()
+GetRoofTerminal()
+GetSkylight()
+GetTechnicalUnit()
+GetSupplier()
+GetServiceContract()
1
-Input
1..*
Defect
-DefectID
-DefectExtent
-DefectLocation
-DefectDescription
-RepairUrgency
-DefectPhoto
+AssignToFMElement()
+CreateDefectID()
+AddPhoto()
+AddDescription()
+AddDefectExtent()
+AddDefectLocation()
-Describes
0..*
0..*
-Traces
0..1
1
-Affects
0..*
FoulingDisposalMethod
-Leafblower : Boolean
+GetFoulingType()
+GetDisposalUnit()
FacilityManagementElement
See page 1...
1..*
-RelatesTo
0..*
DefectType
-DefectExtent
-DefectLocation
-DefectDescription
+AssignToFMElement()
+AddDescription()
+AddDefectExtent()
+AddDefectLocation()
1
1..*

Appendix H: IFC check

INDUSTRY FOUNDATION CLASSES RELEASE 4 (IFC4)

De 'Industry Foundation Classes' (Ifc) beschrijven een open specificatie voor 'Building Information Modeling' (BIM) data/informatie dat kan worden uitgewisseld en gedeeld tussen de verschillende partijen in een bouw en/of facility management project. IFC's zijn de internationale openBIM standaard, als beschreven door buildingSMART.

Middels een standaard modeleertaal (EXPRESS) definieert IFC een zogenaamde 'entity-relationship model'. Dit model is opgebouwd uit vele verschillende object-georiënteerde entiteiten (gebouw elementen), zoals bijvoorbeeld: muren (IfcWall) of daken (IfcRoof). Deze Ifc specificatie bevat termen, concepten en data/informatie specificaties die voortkomen uit de verschillende disciplines en processen van de bouw- en facility management sector. (buildingSMART (2014, 3-5 December). Industry Foundation Classes - IFC4 Official Release. Retrieved from: http://www.buildingsmart-tech.org/ifc/IFC4/final/html/index.htm)

De benodigde informatie dient gemodelleerd te worden in een centraal model. In de bouwsector wordt hiervoor (vaak) een 3D model gemodelleerd op basis van gebouw elementen. Aan de gebouwelementen kan data gekoppeld worden en ze kunnen onderlinge relaties aangegaan (Bijv. een koppeling tussen wanden en vloeren van een brandcompartiment). De wijze waarop de informatie/data wordt vastgelegd is gedefinieerd in het conceptuele schema 'Industry Foundation Classes Release 4', ofwel IFC4 (is nu de meest recente versie).

INLEIDING

Met het uitvoeren van een casestudy zijn de gegevens geïdentificeerd die benodigd zijn om te voorzien in een gestructureerd onderhoudsproces voor platte daken. Een eerste analyse van de opbouw van het IFC4 dataschema, heeft laten zien dat IFC alle soorten gegevens kan ondersteunen en opnemen. Soorten gegevens als; tekstueel, numeriek, geometrie, labels, documenten, e.d.

De wijze waarop het object georiënteerde model (3D model gebouw) wordt gemodelleerd, het toewijzen van informatie/data aan de afzonderlijke gebouwelementen, hangt samen met de wijze waarop het uiteindelijke IFC bestand is opgebouwd. Vervolgens kunnen betrokken project partners dit IFC bestand 'uitlezen' in hun eigen software programma. Deze 'eigen' software is er op gericht om de specifieke (werk)processen van een project partner te ondersteunen. Dit betekent dat niet alle Ifc gekoppelde gegevens van een gebouw dienen te worden ondersteunt door het software programma, enkel de gegevens die voor de specifieke (werk)processen van een projectpartner benodigd zijn.

Een verdere analyse van het IFC4 schema, laat zien dat er voor verschillende gegevens (afkomstig uit de casestudy) geen standaard data item, attribuut, eigenschap(lijst) of hoeveelheid(lijst) beschikbaar is. Mede hierdoor, maar ook door de verschillende manieren waarop een 3D model gemodelleerd kan worden, ontstaan er geen eenduidige IFC bestanden.

Een voorbeeld, voor de thermische warmteweerstand van een materiaal is als een standaard 'item' opgenomen in de IFC schema, namelijk 'IfcThermalResistanceMeasure'. Echter, voor het opnemen van een gebouwnummer is geen standaard 'item' opgenomen. Wanneer deze parameter wordt toegevoegd aan een project, dan zijn er binnen IFC meerdere opties waarop het gebouwnummer kan worden toegekend. Bijvoorbeeld onder 'IfcBuilding -> Name of Description', of onder 'IfcBuilding -> IfcIdentity -> IfcText'. Bij het uitlezen van de IFC bestanden door een projectpartner in zijn eigen software programma, kan hierdoor gegevens verlies ontstaan. Doordat voor het software programma een ander 'Ifc item' is voorgeschreven voor het uitlezen van een gebouwnummer, dan waaronder deze informatie is gemodelleerd. Voor de projectpartner kunnen er hierdoor bepaalde gegevens niet zichtbaar zijn.

In deze Ifc check wil ik nagaan voor welke benodigde onderhoudsgegevens voor platte daken, er geen standaard 'Ifc item' is gedefinieerd. Dit biedt inzicht in de omvang en specifieke punten waarin Ifc geen eenduidigheid verschaft en dus aanvullende acties benodigd zijn om tot een gestructureerde wijze van modeleren en opbouw van de IFC bestanden te komen. Tevens geeft het inzicht in de wijze waarop een Ifc gekoppeld onderhoudsprogramma opgebouwd dient te worden;
- welke gegevens worden 'uitgelezen' vanuit de Ifc en zijn hier al standaard Ifc 'items' / 'propertysets' voor aangemaakt;
- en welke gegevens zijn dusdanig onderhoud specifiek, dat deze niet opgenomen worden in de Ifc (overbodig informatie voor in de Ifc, ter voorkoming van een informatie overvloed), en kunnen hierdoor beter worden beheerd en opgeslagen in de database van het betreffende onderhoudsprogramma.

Deze Ifc check is op basis van het opgestelde klassenmodel.

ALGEMENE UITGANGSPUNTEN (tabel waarden)

Specificatie gegevens: benodigde informatie t.b.v. het voorzien in een gestructureerd onderhoudsproces voor platte daken. Deze gegevens zijn voortgekomen uit een casestudy.

Ifc Check: indicatie of deze informatie 'standaard' is opgenomen en gedefinieerd binnen Ifc. Dat wil zeggen, dat er binnen Ifc een voor opgestelde informatie-; item/attribuut/eigenschap(lijst)/hoeveelheid(lijst) beschikbaar is om deze specifieke informatie in op te nemen.

Ifc Specificatie: geeft de specificatie van het Ifc schema, waarnaar de benodigde gegevens weggeschreven kunnen worden. Indien er nog geen 'standaard Ifc item' beschikbaar is zal er een mogelijke Ifc specificatie gegeven worden waaraan een modeleur deze gegevens kan koppelen. Echter, dit is subjectief en persoons/situatie- afhankelijk.

Onderhoud specifiek: indicatie of het onderhoud specifieke informatie betreft. Dit geeft inzicht in de wijze waarop men gegevens kan clusteren tijdens het modeleren. Niet onderhoud specifieke gegevens zijn voor meerdere doeleinden bruikbaar, hier is het van belang dat men niet meerdere keren deze gegevens gaat modeleren (voorkomen van overtollige informatie voorziening). Let op: renovatie is ook onderhoud specifiek, alsmede de valbeveiliging (W. Kraan - persoonlijke communicatie).

Opnemen in Ifc (nieuwbouw): geeft een indicatie van de gegevens die een architect in de ontwerpfase, of aannemer in de werkvoorbereiding kan modeleren. Wanneer deze gegevens bekend zijn en al voor het in gebruik nemen van het gebouw gemodeleerd kunnen worden, draagt dit bij aan het uiteindelijk efficiënt beheren en onderhouden van een gebouw. Dit zijn dan ook de gegevens die dienen te worden ondersteund door Ifc.

Opnemen in OB-Tool (Onderhoud & Beheer): dit betreft specifieke onderhoud technische informatie, welke hoofdzakelijk tot stand komt tijdens de beheer- en onderhoudsfase van een gebouw. Deze specifieke informatie zal door een technisch onderhoud manager beheerd worden in een eigen software programma (OB-Tool). De communicatie van deze gegevens vindt (eenzijdig) plaats tussen de technisch beheerder en de opdrachtgever (bijvoorbeeld overzichten van gemaakte onderhoudskosten en verwachtte onderhoudsactiviteiten). Het is daarom een overbodige stap (en overtollige informatie voorziening) om deze gegevens op te nemen in een IFC bestand. Echter, in het geval van bijvoorbeeld een calamiteit of uitgevoerd onderhoud, is het wel van belang om het kenmerk (ID-code) van de calamiteit of uitgevoerd onderhoud te koppelen aan het betreffende gebouw element. Op deze wijze kunnen er snel relaties worden gelegd tussen- en informatie overzichten gecreëerd worden van calamiteiten / uitgevoerd onderhoud en bijbehorende gebouw elementen.

PAND GERELATEERDE GEGEVENS

SPECIFICATIE GEGEVENS	Ifc Check	Ifc Specificatie	Onderhoud specifiek	Opnemen in Ifc (nieuwbouw)	Opnemen in OB-Tool	Opmerkingen
Eigenaar						
(Bedrijfs)Naam	✓	IfcActor & IfcRelAssignsToActor	×	✓		Je wilt deze gegevens toekennen aan het element 'gebouw'. (Zie ook Note 2)
Contactgegevens	✓	IfcActorResource	×	✓		
Technische Dienst (TD)						
Naam contactpersoon	✓	IfcActor & IfcRelAssignsToActor	✓	✓	✓	In principe zijn dit onderhoud specifieke gegevens, maar indien de TD wordt betrokken in de ontwerpfase dan kunnen deze gegevens ook worden opgenomen in de Ifc. Je wilt deze gegevens dan toekennen aan het element 'gebouw'. (Zie ook Note 2)
Contactgegevens	✓	IfcActorResource	✓	✓	✓	
Pand						
Pand ID code	✓	IfcBuilding -> IfcGloballyUniqueId & Pset_BuildingCommon -> BuildingID -> P_SINGLEVALUE / IfcIdentifier	×	✓	✓	IfcGloballyUniqueId is een automatisch gekoppeld ID kenmerk aan het 'element' gebouw. Maar men wilt ook een eigen ID code (gebruiker interpretabel) toe kennen, voor eigen administratieve doeleinden, daarom Pset_BuildingCommon -> BuildingID. Voor administratieve doeleinden kan het noodzakelijk zijn om een eigen pand-ID code op te stellen in de OB-Tool, de opbouw van de code kan opdrachtgever/gebruiker afhankelijk zijn. (Zie ook Note 3)
(Hoofd)Gebruiksfuncties	✓	IfcBuilding -> Pset_BuildingUse -> Property: MarketCategory -> P_SINGLEVALUE / IfcLabel	×	✓		Bij IfcLabel kan je slechts 1 gebruiksfunctie opgeven (keuzelijst), maar een pand kan meerdere (hoofd)gebruiksfuncties bevatten. Meerdere labels zijn dus wenselijk. (Zie ook Note 4)
Adresgegevens	✓	IfcAddressTypeEnum & IfcPostalAddress Site -> IfcSiteAdress	×	✓		Je wilt deze gegevens toekennen aan het element 'locatie' en niet aan het element 'gebouw', want één locatie met hetzelfde adres kan meerdere gebouwen bevatten.
Gebouwnummer	×	IfcBuilding -> Pset_BuildingCommon -> Gewenst: *Property item: 'BuildingNumber' (IfcText)*	×	✓		Pset_BuildingCommon bevat geen standaard optie om een gebouwnummer toe te kennen aan het pand.

SPECIFICATIE GEGEVENS	Ifc Check	Ifc Specificatie	Onderhoud specifiek	Opnemen in Ifc (nieuwbouw)	Opnemen in OB-Tool	Opmerkingen
Link; locatie tekening	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcProductExtension -> IfcSite Of kan verkregen worden uit het modeleren (geometrie van model) van de locatie.	×	✓		Ifc kan een link opnemen naar een extern bestand, daarnaast ondersteunt Ifc ook geometrische kenmerken waaruit een 3D/2D weergave verkregen kan worden. Echter, externe software moet dan ook geometrische kenmerken kunnen herkennen en verwerken. Tevens moet in dit geval er naast het pand, ook geometrische gegevens gemodeleerd worden t.b.v. de locatie. (Zie ook Note 1)
Link; huisregelsdocument	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcProductExtension -> IfcBuilding	×	✓		Je wilt deze gegevens toekennen aan het element 'gebouw'. (Zie ook Note 1)
Locatie						
Bosrijk terrein (Ja/Nee)	×	Wanneer in Ifc toepassen dan een property toekennen onder: IfcSite -> Pset_SiteCommon	✓		✓	Onderhoudspecifieke informatie en daarmee overtollige informatie voor in de Ifc.
Eigen terrein						
Parkeergelegenheid (Ja/Nee)	✓	IfcProductExtension -> Pset_SpaceParking -> Property: ParkingUse & ParkingUnits	×	✓		
Afvalcontainer aanwezig (Ja/Nee)	×	Wanneer in Ifc toepassen dan: IfcObject -> IfcObjectType	✓		✓	Ifc ondersteunt de mogelijkheid om een object aan te maken en bijbehorende properties te koppelen aan een specifiek object type. Voor een afvalcontainer is dit nog niet voorgedefinieerd. Echter het betreft onderhoudspecifieke informatie en is daarmee overtollige informatie voor in de Ifc. (Tenzij ook van belang voor facilitaire doeleinden)
Capaciteit Afvalcontainer	×		✓		✓	
Openbaar terrein						
Afstand tot parkeerplaats	×		✓		✓	Dit valt buiten de scope van een Ifc project en valt dus ook niet te modeleren zodat hier informatie aan toegekend kan worden. Het zou wel als zogenaamde 'NarrativeText -> IfcText' kunnen worden opgenomen in de PropertySet; Pset_SpaceParking. Daarnaast betreft het onderhoudspecifieke informatie en is daarmee overtollige informatie voor in de Ifc. (Tenzij ook van belang voor facilitaire doeleinden)
Betaald parkeren (Ja/Nee)	×		✓		✓	

SPECIFICATIE GEGEVENS	Ifc Check	Ifc Specificatie	Onderhoud specifiek	Opnemen in Ifc (nieuwbouw)	Opnemen in OB-Tool	Opmerkingen
Opstelplaats (Bouw gerelateerde) objecten						
Locatie aanduiding	×	IfcSpatialZoneType & IfcSpatialZoneTypeEnum Gewenst: *Property items (for 'Temporary Stabling Site'): 'Location', 'Potential Barriers', 'Temporary Permit', 'Application Period'*	×	✓		Dit kan zowel voor onderhoudspecifieke als voor facilitair gerelateerde doeleinden van toepassing zijn. In de ontwerp- / voorbereidingsfase kunnen deze gegevens al worden gemodeleerd. Ifc ondersteunt wel de mogelijkheid om zogenaamde Spatialzones te benoemen, maar er is nog geen vaste propertyset (enumaration) voor opstelplaatsen (bouw gerelateerde) objecten. (Zie ook Note 5)
Potentiële barrières	×		×	✓		
Vergunning benodigd (Ja/Nee)	×		×	✓		
Aanvraagduur vergunning	×		×	✓		
Link; vergunning aanvraag	×	IfcExternalReferenceResource -> IfcDocumentReference Gewenst: *Link to property items for 'Temporary Stabling Site'.*	×	✓		Je wilt deze gegevens toekennen aan het element 'Opstelplaats objecten', zie bovenstaande opmerking. (Zie ook Note 1) Eventueel op te nemen als URL link naar website gemeente.

BOUWDEEL GERELATEERDE GEGEVENS

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Dak						
Dak ID Code	✓	IfcGroup -> collection of all objects as part of related roofdeck groups ('Totalen plat dak') IfcRoot -> IfcGloballyUniqueId & IfcText	×	✓		Je wilt deze gegevens toekennen aan het object 'dak'. Hieronder vallen alle elementen/objecten die toebehoren tot alle dakvlakken van het pand. Dit kan binnen Ifc bereikt worden door het groeperen van de betreffende elementen/objecten. Voor administratieve doeleinden kan het wenselijk zijn om naast een automatisch gegenereerde code (IfcGloballyUniqueId), ook een gebruikers interpretabele Id code te koppelen aan het dak (bijvoorbeeld een NlSfb of STABU code). Dit kan middels de IfcRoot item. (Zie ook Note 3)
Dak oppervlakte	✓	IfcAreaMeasure within IfcRelSpaceBoundary & IfcRelVoidsElement	×	✓		Boundary defined by IfcGroup & IfcBuildingElement -> IfcRoof
Link; dak tekening	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcKernel -> IfcGroup ('Totalen plat dak') Of kan verkregen worden uit het modeleren (geometrie van model) van alle dakvlakken.	×	✓		Ifc kan een link opnemen naar een extern bestand, daarnaast ondersteunt Ifc ook geometrische kenmerken waaruit een 3D/2D weergave verkregen kan worden. Echter, externe software moet dan ook geometrische kenmerken kunnen herkennen en verwerken. (Zie ook Note 1)
Plat dak						
Plat dak ID Code	×	IfcGroup -> collection of all objects (being products, processes, controls, resources, actors or other groups) as part of a single roofdeck. Or IfcSpatialStructureElement (zie note 13.) IfcRoot -> IfcGloballyUniqueId & IfcLabel & IfcText	×	✓		Je wilt alle bouwdeel elementen van een specifiek dakvlak toekennen aan het corresponderende dakvlak(nummer). Dit kan binnen Ifc bereikt worden door het groeperen van de betreffende 'objecten'. Middels de standaard IfcRoot klasse kan je hier vervolgens een ID code, een specifieke naam (bijv. dakvlaknummer) en een omschrijving aan toekennen. Echter dient dit dan wel op deze wijze gemodeleerd te worden, alsmede juist 'uitgelezen' kunnen worden door externe software.
Plat dak nummer	×		×	✓		
Plat dak oppervlakte	✓	IfcAreaMeasure within IfcRelSpaceBoundary & IfcRelVoidsElement	×	✓		Is een 'property' die je wilt toekennen aan het specifieke dakvlak(nummer). Boundary defined by IfcGroup & IfcBuildingElement -> IfcRoof
Plat dak hoogte	✓	IfcBuildingStorey -> Qto_BuildingBaseQuantities	×	✓		Dit is in de Ifc opgenomen als hoogte van een 'Complex: Building Storey'. Hier dient met modeleren rekening gehouden te worden, toekennen van (verschillende) verdiepingen. (Zie ook Note 7.)
Opbouw plat dak (dak-type)	×	IfcRoof -> Pset_RoofCommon	×	✓		Is een 'property' die je wilt toekennen aan het object 'dak'.
Vervuilingstype	×		✓		✓	Is onderhoudspecifiek en hierdoor overbodig om in Ifc op te nemen.
Link; plat dak tekening	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcKernel -> IfcGroup ('Dakvlak, *nummer*') Or IfcSpatialStructureElement Of kan verkregen worden uit het modeleren (geometrie van model) van alle dakvlakken.	×	✓		Ifc kan een link opnemen naar een extern bestand, daarnaast ondersteunt Ifc ook geometrische kenmerken waaruit een 3D/2D weergave verkregen kan worden. Echter, externe software moet dan ook geometrische kenmerken kunnen herkennen en verwerken. (Zie ook Note 1)

SPECIFICATIE GEGEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Valbeveiligingssysteem						
Collectieve valbeveiliging aanwezig (Ja/Nee)	×	IfcZone -> IfcSpatialZoneTypeEnum & Pset_ZoneCommon Gewenst: *Additional SafetyTypeEnum & PropertySet*	✓	✓		Je wilt aan een dakvlak een veiligheidszone (dakbeveiliging) koppelen. Een zone voor valbeveiliging kan binnen Ifc worden toegekend middels IfcZone. Echter bestaan er nog geen voor gedefinieerde property set voor een valbeveiliging- systeem / zone. (Zie ook Note 9). Het aantal veiligheidsharnassen is een (intern) facilitair gegeven en overbodige informatie voor in de Ifc.
Individuele valbeveiliging aanwezig (Ja/Nee)	×		✓	✓		
Aantal beschikbare veiligheidsharnassen	×		✓		✓	
Vervaldatum veiligheidskeurmerk	×		✓	✓		
Link; dakbeveiligingstekening	×	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcZone -> IfcSpatialZoneType	✓	✓		Vaak wordt er een 2D tekening (inclusief te ondertekenen certificaat) van het dakvlak beveiliging systeem meegegeven aan de onderhoudsmonteur. Hiervoor kan een pdf bestand opgesteld en gekoppeld worden aan de beveiligingszone van het betreffende dakvlak. (Zie ook Note 1)
Toegangspunt						
Locatie toeganspunt	×	IfcZone -> IfcSpatialZoneTypeEnum & Pset_ZoneCommon Gewenst: *AccessibilityTypeEnum (or description) & PropertySet*	✓	✓		Net als voor de valbeveiligingszone wil je voor het betreffende dakvlak ook een zone voor dak toetreding toekennen, inclusief genoemde eigenschappen. (Zie ook Note 9) Ifc bevat ook hier nog geen voor gedefinieerde property set.
Toegangsmethode	×		✓	✓		
Benodigd extern materieel	×		✓	✓		
Meldingsplicht bij betreden						
Meldingsplicht (Ja/Nee)	×	IfcSharedMgmtElements -> Pset_Permit -> Property: EscortRequirement	✓	✓		Deze gegevens wil je koppelen aan boven genoemde zonering voor dak toetreding. Wellicht is de property 'EscortRequirement', 'te zwaar' voor deze informatie. Een nieuwe property met 'meldingsplicht' kan hier uitkomst bieden. (Zie ook Note 10)
Naam contactpersoon	✓	IfcActor & IfcRelAssignsToActor	×		✓	
Contact gegevens	✓	IfcActorResource	×		✓	
Link; veiligheidscertificaat	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcZone ('Dakvlak beveiliging')	✓	✓		Vaak wordt er een 2D tekening (inclusief te ondertekenen certificaat) van het dakvlak beveiliging systeem meegegeven aan de onderhoudsmonteur. Hiervoor kan een pdf bestand opgesteld en gekoppeld worden aan de beveiligingszone van het betreffende dakvlak. (Zie ook Note 1)

SPECIFICATIE GEGEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Daklagen						Het is van belang dat er aan iedere daklaag aparte properties kunnen worden toegekend. Ifc ondersteunt de benodigde properties. Het is voor de modelleur om dit op een gestructureerde wijze te modeleren en eventueel te groeperen tot één en/of enkele dak-pakketten behorende bij een specifiek dakvlak.
Daklaag ID	✓	IfcElement -> IfcGloballyUniqueId	×	✓		IfcGloballyUniqueId is een automatisch gekoppeld ID kenmerk aan een 'element', bijvoorbeeld daklaag. Als men voor administratieve doeleinden een eigen ID code (gebruiker interpretabel) wilt toekennen, zal hiervoor een aparte property aangemaakt moeten worden.
Materialisering	✓	For example: IfcMaterialLayer = Insulation IfcMaterial = EPS	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 11)
(Leveranciers)Type	✓	IfcSharedFacilitiesElements -> Pset_ManufacturerTypeInformation -> Property: Manufacturer & ArticleNumber & ModelLabel	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 6)
Daklaag oppervlakte	✓	IfcAreaMeasure	×	✓		Ifc ondersteunt geometische kenmerken, mits goed gemoleerd kunnen deze gegevens automatisch worden berekend. Voor het modeleren dient men iedere specifieke daklaag als een aparte (unieke) daklaag te modeleren.
↑ Toplaag						
Bevestigingsmethode	×	IfcRelConnectsElements Gewenst: *PropertySet 'bevestigingsmethode' (IfcText)*	×	✓		Indien van toepassing, ondersteunt Ifc het creëren van een connectie (verbinding van twee elementen) + bijbehorende geometrische kenmerken. (Zie ook Note 12) Hier gaat het echter om het beschrijven van de wijze waarop de toplaag is / dient te worden aangebracht. Je wilt deze gegevens uiteindelijk koppelen als een property aan de specifieke daklaag (de toplaag).

SPECIFICATIE GEGEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Aantal (her)overlagingen	✓	For example: IfcMaterialLayer = (2e/3e/…) Toplayer IfcMaterial = Bitumen	✓		✓	Dit betreft onderhoudspecifieke informatie, dat gecreerd wordt tijdens de gebruiksfase van een gebouw, het is hierdoor overbodige informatie voor in de Ifc. Wanneer toch opnemen in Ifc model, dan kan dit op twee manieren: Men kan bij het overlagen van dakbedekking een nieuwe materiaallaag toevoegen aan het model. Of men kan een property aan de toplaag toevoegen (1e/2e/… toplaag).
Verwachtte levensduur	✓	IfcElement -> Pset_ServiceLife -> Properties: MeanTimeBetweenFailure & ServiceLifeDuration: -> Ifc Duration	✓	✓		Je wilt vanuit de architect / leverancier weten wat de verwachtte levensduur is van een product ('ServiceLifeDuration'). Tijdens het gebruik wil je dit kunnen bijstellen naar verwachtte levensduur ('MeanTimeBetweenFailure'). (Zie ook Note 8.)
↑ Ballastlaag						
Laagdikte	✓	IfcMaterialLayer -> Attribute: LayerThickness	×	✓		Ifc ondersteunt geometerische kenmerken. Indien het dakpakket als afzonderlijke lagen is gemodeleerd, kan de dikte per daklaag automatisch worden berekend.
Grind						
Grind gradatie	×	IfcMaterialLayer Gewenst: *PropertySet 'grind gradatie'*	×	✓		De grindgradatie is geen standaard property. Dient handmatig te worden beschreven.
Tegels						
Afmetingen	×	IfcMaterialLayer Gewenst: *PropertySet 'enkele tegel afmeting'*	×	✓		De afmetingen van de losse tegel elementen is geen standaard property. Dient handmatig te worden beschreven. IfcLengthMeasure beschrijft enkel de lengte(s) van de gehele ballastlaag.
Vegetatiedak						
Lagen opbouw incl. dikte	✓	IfcMaterialLayer & IfcMaterial -> Attribute: LayerThickness	×	✓		Net als voor de verschillende daklagen van een dakpakket, kan het vegetatiedak worden opgebouwd uit verschillende vegetatie lagen, welke vervolgens gegroepeerd worden tot één vegetatie (dak)vlak. Aan de verschillende lagen kunnen properties gekoppeld worden, zoals de laagdikte.

SPECIFICATIE GEGEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
↑ Isolatielaag						
Laagdikte	✓	IfcMaterialLayer -> Attribute: LayerThickness	×	✓		Ifc ondersteunt geometerische kenmerken. Indien het dakpakket als afzonderlijke lagen is gemodeleerd, kan de dikte per daklaag automatisch worden berekend.
Thermische weerstand (Rc)	✓	Ifcroof -> Pset_RoofCommon -> Property: IfcThermalTransmittanceMeasure	×	✓		Dit beschrijft alleen de totale Rc waarde van het dakpakket, dus niet enkel van de isolatielaag. Dit zou wel mogelijk moeten zijn wanneer het dakpakket als afzonderlijke lagen wordt gemodeleerd.
↑ Onderconstructie						
-						
Dakrand						
Dakrand ID Code	✓	IfcElement -> IfcGloballyUniqueId	×	✓		IfcGloballyUniqueId is een automatisch gekoppeld ID kenmerk aan een 'element', bijvoorbeeld dakrand. Als men voor administratieve doeleinden een eigen ID code (gebruiker interpretabel) wilt toekennen, zal hiervoor een aparte property aangemaakt moeten worden.
Constructief materiaal	✓	For example: IfcMaterialLayer = RoofEdgeConstruction IfcMaterial = Wood	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 11) Mits het als een unieke (materiaal)laag/element is gemodeleerd.
Hoogte (vanaf dakvlak)	×	Gewenst: *PropertySet -> IfcLengthMeasure voor 'hoogte dakrand (gemeten vanaf dakvlak)*	×	✓		Ifc ondersteunt het berekenen van bepaalde hoogtes. Echter bestaat er nog geen voor gedefinieerd propertyset / item voor het berekenen van de hoogte van de dakrand, gemeten vanaf het dakvlak. (Dit kan wellicht ondervangen worden door op een specifieke wijze de dakrand te modeleren)
Lengte	✓	IfcLengthMeasure Gewenst: *IfcLengtMeasure per 'type' dakrand*	×	✓		Wordt vaak weergeven als de lengte van de buitenste contouren van een (dak)vlak. Echter, indien er verschillende dakranden zijn (verschillend van materialisering of dimensionering), dan wil je per 'type' dakrand de lengte kunnen opvragen.
Positionering	✓	IfcLocalPlacement	×	✓		Ifc ondersteunt de geometische positionering van een element in relatie tot andere elementen en/of de gehele project context. Zo kan er een ruimtelijke vormgeving (visualisatie) worden gecreëerd.

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Dakrand afwerking						
Dakrand afwerking ID code	✓	IfcElement -> IfcGloballyUniqueId	×	✓		IfcGloballyUniqueId is een automatisch gekoppeld ID kenmerk aan een 'element', bijvoorbeeld dakrandafwerking. Als men voor administratieve doeleinden een eigen ID code (gebruiker interpretabel) wilt toekennen, zal hiervoor een aparte property aangemaakt moeten worden.
Lengte	✓	IfcLengthMeasure	×	✓		Wordt vaak weergeven als de lengte van de buitenste contouren van een (dak)vlak. Echter, indien er verschillende dakrand afwerkingen zijn (verschillend van materialisering of dimensionering), dan wil je per 'type' dakrand afwerking de lengte kunnen opvragen.
Materialisering	✓	IfcMaterial	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 11)
(Leveranciers)Type	✓	IfcSharedFacilitiesElements -> Pset_ManufacturerTypeInformation -> Property: Manufacturer & ArticleNumber & ModelLabel	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 6)
Profiel afmetingen	×	IfcLengthMeasure / IfcText	×	✓		De afmetingen voor profielen is geen standaard property(set). Het is de vraag of je dit in detail wilt modeleren (tekenen). Zo ja, dan kan Ifc deze gegevens automatisch uitrekenen. Zo niet, dan dient er een omschrijving (IfcText) voor de afmetingen opgenomen te worden.
Bevestigingsmethode	×	IfcRelConnectsElements Gewenst: *PropertySet 'bevestigingsmethode' (IfcText)*	×	✓		Indien van toepassing, ondersteunt Ifc het creëren van een connectie (verbinding van twee elementen) + bijbehorende geometrische kenmerken. (Zie ook Note 12) Hier gaat het echter om het beschrijven van de wijze waarop de dakrandafwerking is / dient te worden aangebracht. Tevens wil je kunnen aangeven of het (profiel) demontabel is.
Demontabel (Ja/Nee)	×	IfcRelConnectsElements Gewenst: *PropertySet 'demontabel' (IfcBoolean)*	✓	✓		
Aansluiting; Daklaag & Dakrand(afwerking)						
Aansluitingshoek (℃)	✓	IfcRelConnectsElements -> IfcConnectionGeometry -> IfcCurveOrEdgeCurve	×	✓		Ifc ondersteunt de berekening van de aansluitingshoek tussen twee gekoppelde elementen. Echter is er geen standaard property item om een beschrijving van deze aansluiting te geven.
Hoekafwerking	×	Gewenst: *PropertySet 'Hoekafwerking' (IfcText)*	×	✓		

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Plat dakelementen						
Element ID Code	✓	IfcProductExtension -> IfcBuildingElement -> IfcGloballyUniqueId	×	✓		IfcGloballyUniqueId is een automatisch gekoppeld ID kenmerk aan een 'element'. Als men voor administratieve doeleinden een eigen ID code (gebruiker interpretabel) wilt toekennen, zal hiervoor een aparte property aangemaakt moeten worden.
Materialisering	✓	IfcMaterial	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 11)
(Leveranciers)Type	✓	IfcSharedFacilitiesElements -> Pset_ManufacturerTypeInformation -> Property: Manufacturer & ArticleNumber & ModelLabel	×	✓		Is een voor gedefinieerde item in de Ifc. (Zie ook Note 6)
Afmetingen	×	IfcLengthMeasure Gewenst: *Propertyset 'Element dimensions'*	×	✓		Ifc kent geen standaard property(set) items voor de dimensionering (HxBxL) van (dak)elementen. Het ondersteunt wel de geometrisch kenmerken (IfcLengthMeasure). De elementen kunnen ook in het model met gewenste dimensies worden gemodelleerd. Maar er moet een koppeling gemaakt worden tussen het modeleren en de Ifc, zodat er op eenduidige wijze de element dimensies (HxBxL) automatisch worden berekend en opgenomen in de Ifc.
Positionering op dakvlak	✓	IfcLocalPlacement & IfcObjectPlacement	×	✓		Ifc ondersteunt de geometische positionering van een element in relatie tot andere elementen en/of de gehele project context. Zo kan er een ruimtelijke vormgeving (visualisatie) worden gecreëerd.
Verwachtte levensduur	✓	IfcElement -> Pset_ServiceLife -> Properties: MeanTimeBetweenFailure & ServiceLifeDuration: -> Ifc Duration	✓	✓		Je wilt vanuit de architect / leverancier weten wat de verwachtte levensduur is van een product ('ServiceLifeDuration'). Tijdens het gebruik wil je dit kunnen bijstellen naar verwachtte levensduur ('MeanTimeBetweenFailure'). Zie ook Note 8.
Geindexeerde kosten voor vervangen element	✓	IfcCostValue Gewenst: *Propertyset 'Geindexeerde kosten'*	✓	✓		Aan de hand van de kosten voor een nieuw element kan er een schatting worden gemaakt (d.m.v. indexeren) van de toekomstige herstelkosten. Dit op basis van de verwachtte levensduur van het element. Indien gewenst kan een architect / leverancier deze gegevens invoeren in het (Ifc)model.

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Link; plat dak tekening	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: IfcKernel -> IfcGroup ('Dakvlak, *nummer*') Or IfcSpatialStructureElement Of kan verkregen worden uit het modeleren (geometrie van model) van alle dakvlakken.	×	✓		Ifc kan een link opnemen naar een extern bestand, daarnaast ondersteunt Ifc ook geometrische kenmerken waaruit een 3D/2D weergave verkregen kan worden. Echter, externe software moet dan ook geometrische kenmerken kunnen herkennen en verwerken. (Zie ook Note 1)
Servicecontract						
Servicecontract (Ja/Nee)	×	IfcElement -> Pset_Warranty -> Property: WarrantyEndDate -> IfcDate	✓	✓		Ifc ondersteunt de benodigde invoer gegevens betreffende servicecontracten. Behalve een invoerveld dat aangeeft of er wel of geen servicecontract aan een element verbonden is. Een dergelijk invoerveld is nodig om expliciet aan te geven of er een servicecontract is opgenomen, om zo onduidelijkheden te voorkomen. (Zonder dit invoerveld, kan er onduidelijkheid zijn over de reden van niet ingevulde gegevens. Dit kan zijn omdat er daadwerkelijk geen servicecontract aan het element is verbonden, of omdat die gegevens (nog) niet bekend zijn.) Deze gegevens wil je opnemen in de Ifc, voornamelijk omdat er bij nieuwbouw ontwikkelingen al servicecontracten aan elementen kunnen worden verbonden. Zodoende kan een architect / leverancier deze gegevens al voor de gebruiksfase invoeren in het model.
Vervaldatum servicecontract	✓		✓	✓		
Leveranciersnaam	✓	IfcElement -> Pset_Warranty -> Property: PointOfContact -> IfcOrganization & IfcActorRole	✓	✓		
Contact gegevens leverancier	✓		✓	✓		
Link; servicecontract	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Servicecontracten'	✓	✓		
↑ Hemelwaterafvoer systeem						
-						
↑ Kleine dakdoorvoeren* ↑ Technische Units* ↑ Daklichten*						
Bevestigingsmethode	×	IfcRelConnectsElements Gewenst: *PropertySet 'bevestigingsmethode' (IfcText)*	×	✓		Indien van toepassing, ondersteunt Ifc het creëren van een connectie (verbinding van twee elementen) + bijbehorende geometrische kenmerken. (Zie ook Note 12) Hier gaat het echter om het beschrijven van de wijze waarop het dakelement is / dient te worden bevestigd op het dakvlak. Tevens wil je kunnen aangeven of het element demontabel is.
Demontabel (Ja/Nee)	×	IfcRelConnectsElements Gewenst: *PropertySet 'demontabel' (IfcBoolean)*	✓	✓		

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Aansluiting; Daklagen & Dakelementen						
Aansluitingsmethode / Wijzen van afwerking	×	IfcRelConnectsElements Gewenst: *PropertySet 'aansluiting- en afwerkings methode' (IfcText)*	×	✓		Indien van toepassing, ondersteunt Ifc het creëren van een connectie (verbinding van twee elementen) + bijbehorende geometrische kenmerken. (Zie ook Note 12) Hier gaat het echter om het beschrijven van de wijze waarop het dakelement is / dient te worden afgewerkt ter plaatse van de daklagen (met name de toplaag). Kortom: waarborgen van waterdichtheid

*
- **Kleine dakdoorvoeren** zijn doorvoeren door de dakvlak lagen heen (van binnen naar buiten en vice versa).
- **Technisch units** zijn alle units die op het dak 'staan' en dus niet door de dakvlak lagen heen gaan.
- **Daklichten** zijn alle soorten daklichten, dus voorzieningen t.b.v. daglicht toetreding.

ONDERHOUD (PROCES) GERELATEERDE GEGEVENS

De hieronder beschreven gegevens zijn allen onderhoudspecifiek en komen hoofdzakelijk tot stand tijdens de beheer- en onderhoudsfase van een gebouw. Deze specifieke informatie zal in de meeste gevallen door een technisch onderhoud manager beheerd worden in een eigen software programma (OB-Tool). (W. Kraan - Persoonlijke communicatie)

Echter, net als voor product specifieke informatie ondersteunt Ifc ook proces gerelateerde informatie. Beide soorten gegevens zijn ook meegenomen in het klassenmodel. Wanneer je het Ifc model als een volledig holistisch systeem wilt gebruiken, zullen ook de proces gerelateerde gegevens worden opgenomen in het Ifc model. Daarom zal ik net als voor de product (gebouw/object) gerelateerde gegevens een Ifc check uitvoeren.

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Technisch onderhoud beheerder						
Bedrijfsnaam	✓	IfcActor & IfcRelAssignsToActor	✓	✓		In principe zijn dit onderhoud specifieke gegevens, maar indien de technisch onderhoud beheerder wordt betrokken in de ontwerpfase dan kunnen deze gegevens ook worden opgenomen in de Ifc. Je wilt deze gegevens dan toekennen aan het element 'gebouw'. (Zie ook Note 2)
Contactpersoon	✓		✓	✓		
Contactgegevens	✓	IfcActorResource	✓	✓		
Onderhoudscyclus						
Onderhoudsinterval preventief onderhoud	×	IfcDuration Gewenst: *PropertySet 'onderhoudsinterval'*	✓		✓	Deze gegevens dienen gekoppeld te worden aan een specifiek dakvlak(nummer).
Link; onderhoudscontract	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Onderhoudscyclus'	✓		✓	

SPECIFICATIE GEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Gebreken (beheer)						Ieder gebrek wil je kunnen koppelen aan één of meerdere gebouwobjecten. Hiervoor wil je eigenlijk een soort unieke 'IfcEvent' (calamiteiten event) aanmaken, waarbij onderstaande gegevens zijn vastgelegd in een vooropgestelde PropertySet. (Zie ook Note 15)
Gebrek ID Code	✓	IfcLabel & IfcIdentifier	✓		✓	IfcLabel kan gebruikt worden voor het benoemen van een ID-code die door gebruikers interpretabel is. IfcIdentifier kan gebruikt worden voor software matige doeleinden, het koppelen van bijbehorende gegevens aan een specifiek gebrek. (Zie ook Note 14)
Gerelateerd gebouw object	✓	IfcRelAssignsToProcess	×		✓	Het gebrek dient gekoppeld te worden aan de betreffende gebouw elementen.
Omschrijving	×	IfcElement -> Pset_Condition -> Property: AssessmentDescription -> IfcText	✓		✓	Deze gegevens zijn wel beschikbaar voor een gebouw element. Maar er is geen voorgedefinieerde property(set) item voor een gebrek.
Omvang	×	IfcRatioMeasure Gewenst: *IfcText*	✓		✓	Het gaat hier om de omvang van een gebrek. In de praktijk kan dit op verschillende manieren uitgedrukt worden (bijvoorbeeld: op 3 plaatsen craquele vorming, of 25cm toplaag onthecthing). Hier valt dus geen standaard eenheid (% of m2) aan te koppelen en zal opgenomen moeten worden als omschrijving.
Status gebrek	×	IfcElement -> Pset_Condition -> Property: AssessmentCondition -> IfcLabel	✓		✓	Deze gegevens zijn wel beschikbaar voor een gebouw element. Maar er is geen voorgedefinieerde property(set) item voor een gebrek.
Datum van constateren	×	IfcElement -> Pset_Condition -> Property: AssessmentDate -> IfcDateTime	✓		✓	
Herstelurgentie	×	IfcDuration	✓		✓	
Verwachtte herstelkosten	×	IfcCostValue	✓		✓	
Link; foto's	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Gebreken'	✓		✓	Ifc ondersteunt het koppelen van externe documenten aan een element of proces. Deze optie dient opgenomen te worden onder de propertyset voor gebreken.
Link; offerte	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Gebreken'	✓		✓	

SPECIFICATIE GEGEGEVENS	IFC Check	IFC Specificatie	Onderhoud specifiek	Opnemen in IFC	Opnemen in OB-Tool	Opmerkingen
Onderhoudshistorie						Iedere onderhouds taak wil je koppelen aan één of meerdere gebouwobjecten en wanneer van toepassing aan één of meerdere vastgelegde gebreken. Hiervoor wil je eigenlijk een soort unieke 'IfcTask' (Onderhouds taak) aanmaken, waarbij onderstaande gegevens zijn vastgelegd in een vooropgestelde PropertySet. (Zie ook Note 16)
Onderhoudswerk ID Code	✓	IfcLabel & IfcIdentifier	✓		✓	IfcLabel kan gebruikt worden voor het benoemen van een ID-code die door gebruikers interpretabel is. IfcIdentifier kan gebruikt worden voor software matige doeleinden, het koppelen van bijbehorende gegevens aan een specifiek gebrek. (Zie ook Note 14)
Gerelateerd gebouw object	✓	IfcRelAssignsToProcess	✗		✓	Het gebrek dient gekoppeld te worden aan de betreffende gebouw elementen.
Omschrijving werkzaamheden	✗	IfcElement -> Pset_Condition -> Property: AssessmentDescription -> IfcText	✓		✓	Wel beschikbaar voor een element, maar niet voor een specifieke onderhoudstaak
Datum van onderhoud	✗	IfcDate	✓		✓	Deze gegevens zijn wel beschikbaar voor een gebouw element. Maar er is geen voorgedefinieerde property(set) item voor een onderhoudstaak. IfcTaskTypeEnum is wel benoemd maar (nog) niet uitgwerkt.
Onderhoudspartner	✗	IfcActor & IfcRelAssignsToActor	✓		✓	
Onderhoudskosten	✗	IfcCostValue	✓		✓	
Link; foto's	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Onderhoudswerk'	✓		✓	Ifc ondersteunt het koppelen van externe documenten aan een element of proces. Deze optie dient opgenomen te worden onder de propertyset voor onderhoudswerk.
Link; offerte	✓	IfcExternalReferenceResource -> IfcDocumentReference Link to: PropertySet 'Onderhoudswerk'	✓		✓	

CONCLUSIE

Het is gewenst om standaard opties voor gegevensverwerking aan te bieden. Op deze manier kan er, mits aanwezigheid van een modeleer protocol, op een eenduidige wijze gemodeleerd worden. Hierdoor worden gegevens naar een vast IfcPrppertySet item weggeschreven en wordt de kans op gegevens verlies bij het uitlezen van een Ifc bestand verkleind.

Het is dus van belang dat de gegevens waarbij er nog geen vast item is in de Ifc, dat er daar of
1) Een vast item voor wordt gemaakt in de Ifc, of
2) dat er hier een heel duidelijk modeleer protocol voor komt.
Zodat deze gegevens op een eenduidige manier gemoleerd en uiteindelijk beheerd kunnen worden zonder gegevens verlies.

Daarnaast geeft het overzicht weer dat er meerdere onderhoudspecifieke gegevens zijn. Deze gegevens dienen niet persé in een Ifc model opgenomen te worden (uit oogpunt van bruikbaarheid). Met dit inzicht kan er worden nagedacht over hoe men Ifc modelen, modeleer protocollen en gekoppelde software dient op te bouwen en te ontwerpen, ter ondersteuning van een gestructureerd onderhoudsproces.

NOTES

Onderstaande notities zijn omschrijvingen van de verschillende Ifc entiteiten, attributen, propertysets, e.d. Als omschreven op de website van buildingSMART, IFC4 Official Release.
Reference: buildingSMART (2014, 3-5 December). *Industry Foundation Classes - IFC4 Official Release* . Retrieved from: http://www.buildingsmart-tech.org/ifc/IFC4/final/html/index.htm

Note 1: The IfcExternalReferenceResource provides the means to access or use information from external sources including documents. Reference to a document is by its location (address) to enable access through mechanisms such as the World Wide Web. This is done through the IfcDocumentReference class. This is a type of IfcExternalReference that has a label (which can be the reference address) and identifier. Additionally, a name attribute provides the document with a human readable extension or qualifier to the location. Information concerning the document itself can also be stored as an attribute of the document reference and can be captured in the IfcDocumentInformation class. This identifies and names the document and document owner. It may also include for the document: description, revision identifier, creation and revision times, duration of document validity.

Note 2: "The IfcActor defines all actors or human agents involved in a project during its full life cycle. The IfcActorResource schema within the IFC model enables representation of information concerning a person or an organization that will undertake work or hold responsibility. The classes and attributes within the IfcActorResource schema supports the identification of properties of persons and organizations whose services may be used. Additionally it supports relating persons to organizations, and relationships between organizations, such as to form hierarchical organization structures."

Note 3: "The IfcBuilding is used to build the spatial structure of a building (that serves as the primary project breakdown and is required to be hierarchical). An IfcGloballyUniqueId holds an encoded string identifier that is used to uniquely identify an IFC object. An IfcGloballyUniqueId is a Globally Unique Identifier (GUID) which is an auto-generated 128-bit number. Pset_BuildingCommon describes properties common to the definition of all instances of IfcBuilding. BuildingID is an unique identifier assigned to a building. An Ifcidentifier is an alphanumeric string which allows an individual thing to be identified. IfcRoot is the most abstract and root class for all IFC entity definitions that roots in the kernel or in subsequent layers of the IFC object model. Name is an optional name for use by the participating software systems or users.

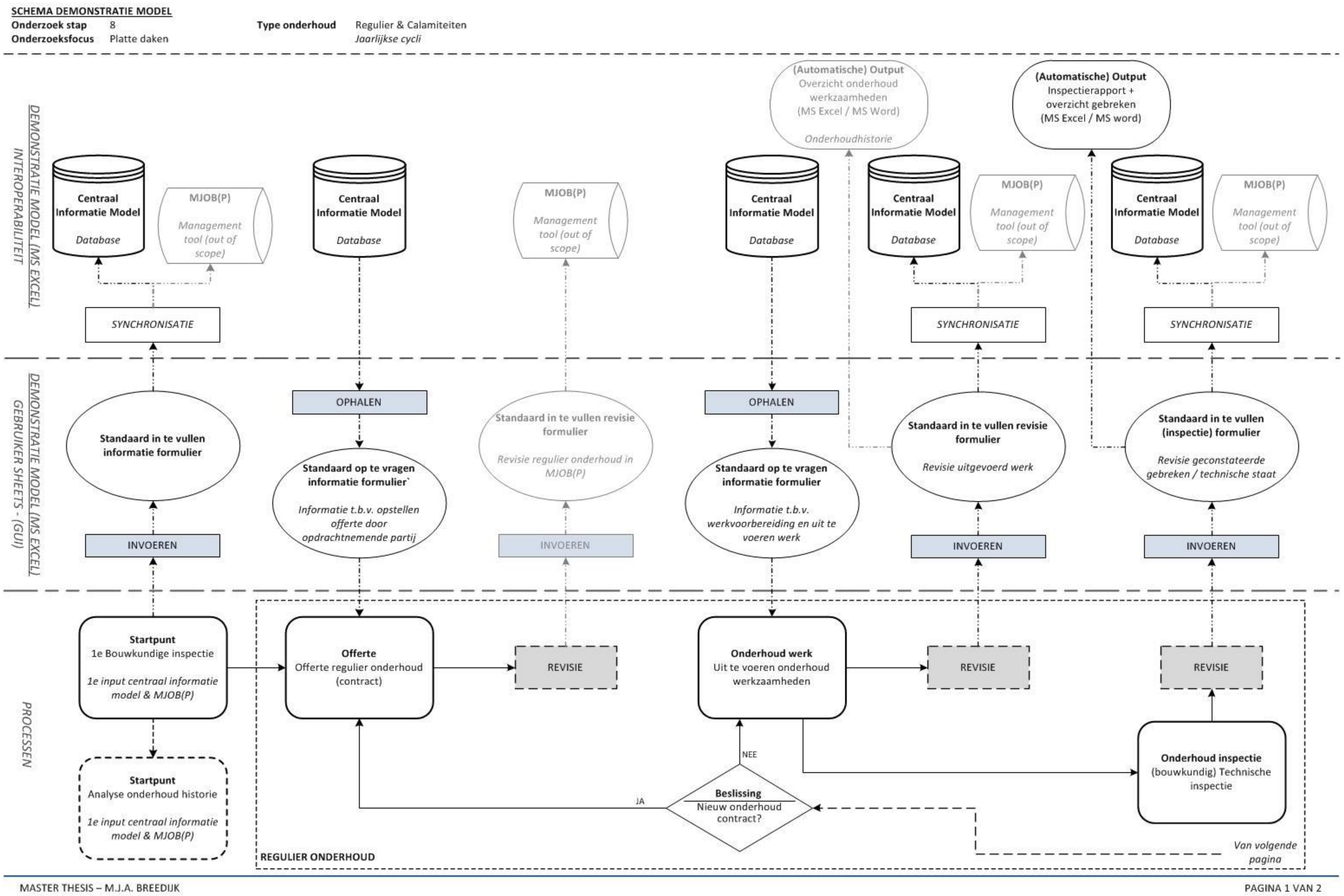
Note 4: "Pset_BuildingUse provides information on on the real estate context of the building of interest both current and anticipated. Property: MarketCategory is a category of use e.g. residential, commercial, recreation etc."

Note 5: A space represents an area or volume bounded actually or theoretically. Spaces are areas or volumes that provide for certain functions within a building. A space is associated to a building storey (or in case of exterior spaces to a site). A spatial zone is a non-hierarchical and potentially overlapping decomposition of the project under some functional consideration. A spatial zone might be used to represent a thermal zone, a construction zone, a lighting zone, a usable area zone. A spatial zone might have its independent placement and shape representation. The IfcSpatialZoneType defines a list of commonly shared property set definitions of a space and an optional set of product representations. It is used to define a space specification (i.e. the specific space information, that is common to all occurrences of that space type).

Note 6: The IfcSharedFacilitiesElements schema defines basic concepts in the facilities management (FM) domain. This schema, along with IfcProcessExtension and IfcSharedMgmtElements, provide a set of models that can be used by applications needing to share information concerning facilities management related issues.
Pset_ManufacturerTypeInformation defines characteristics of types (ranges) of manufactured products that may be given by the manufacturer.

Note 7: IfcBuildingStorey; The building storey has an elevation and typically represents a (nearly) horizontal aggregation of spaces that are vertically bound. A storey is (if specified) associated to a building. A storey may span over several connected storeys. Therefore storey complex provides for a collection of storeys included in a building. A storey can also be decomposed in (horizontical) parts, where each part defines a partial storey. This is defined by the composition type attribute of the supertype IfcSpatialStructureElements which is interpreted as follow: COMPLEX: building storey complex ELEMENT: building storey PARTIAL: partial building storey Qto_BuildingBaseQuantities describes quantities that are common to the definition of all occurrences of building. Property: Height describes the standard gross height of this building, from the top surface of the construction floor, to the top surface of the construction floor or roof above.
Note 8: Pset_ServiceLife captures the period of time that an artifact will last. ServiceLifeDuration: The length or duration of a service life. The lower bound indicates pessimistic service life, the upper bound indicates optimistic service life, and the setpoint indicates the typical service life. MeanTimeBetweenFailure: The average time duration between instances of failure of a product.
Note 9: IfcZone is a group of spaces, partial spaces or other zones. Zone structures may not be hierarchical, i.e. one individual IfcSpace may be associated with zero, one, or several IfcZone's. IfcSpatialZoneTypeEnum defines the range of different types of spatial zones that can further specify an IfcSpatialZoneTypeEnum. (Available enumartions; construction, firesafety, lighting, occupancy, security, thermal, ventilation, userdefined, notdefined.) Pset_ZoneCommon defines properties common to the definition of all occurrences of IfcZone.
Note 10: Pset_Permit, a permit is a document that allows permission to gain access to an area or carry out work in a situation where security or other access restrictions apply. HISTORY: IFC4 EndDate added. PermitType, PermitDuration, StartTime and EndTime are deleted. EscortRequirement indicates whether or not an escort is required to accompany persons carrying out a work order at or to/from the place of work (= TRUE) or not (= FALSE). NOTE - There are many instances where escorting is required, particularly in a facility that has a high security rating. Escorting may require that persons are escorted to and from the place of work. Alternatively, it may involve the escort remaining at the place of work at all times.
Note 11: IfcMaterialLayer is a single and identifiable part of an element which is constructed of a number of layers (one or more). IfcMaterial is a homogeneous or inhomogeneous substance that can be used to form elements (physical products or their components). Further, it is the basic entity for material designation and definition; this includes identification by name and classification (via reference to an external classification), as well as association of material properties (isotropic or anisotropic) defined by (subtypes of) IfcMaterialProperties.
Note 12: The IfcRelConnectsElements objectified relationship provides the generalization of the connectivity between elements. It is a 1 to 1 relationship. The concept of two elements being physically or logically connected is described independently from the connecting elements. The connectivity may be related to the shape representation of the connected entities by providing a connection geometry.
Note 13: IfcSpatialStructureElement is a spatial structure element (IfcSpatialStructureElement) is the generalization of all spatial elements that might be used to define a spatial structure. That spatial structure is often used to provide a project structure to organize a building project.
Note 14: IfcLabel is the term by which something may be referred to. It is a string which represents the human-interpretable name of something and shall have a natural-language meaning. An IfcIdentifier is an alphanumeric string which allows an individual thing to be identified. It may not provide natural-language meaning.
Note 15: An IfcEvent is something that happens that triggers an action or response. It is used to capture information about particular things that happen or that may happen. Particularly used in work plans (or process maps) they identify e.g. a point at which a message containing information may be issued or at which a rule or constraint is invoked.
Note 16: IfcTask is typically used to describe an activity for the construction or installation of products, but is not limited to these types. For example it might be used to describe design processes, move operations and other design, construction and operation related activities as well.

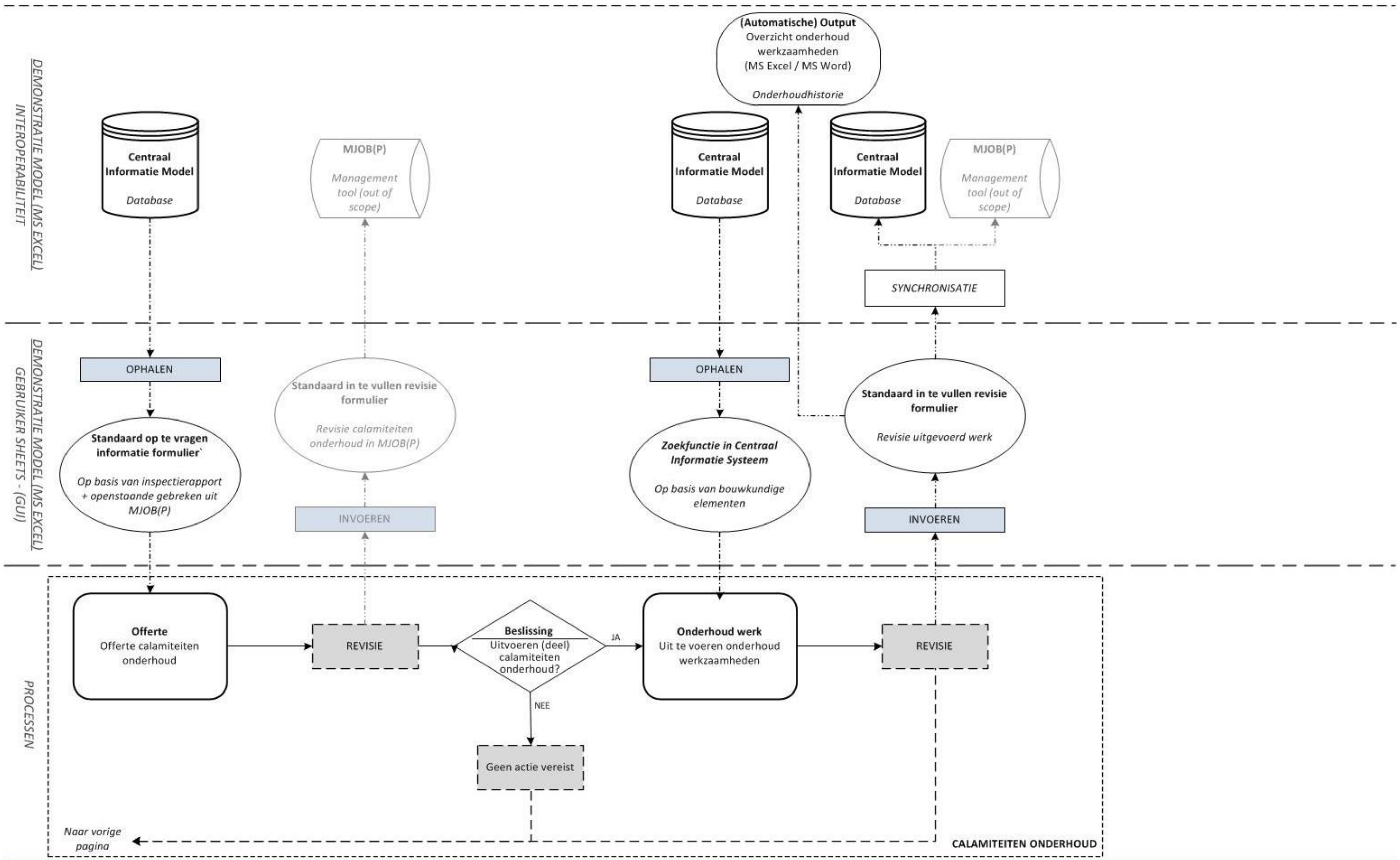
Appendix I: Visualization of the prototype functions and defined information modules (outputs)



SCHEMA DEMONSTRATIE MODEL

Onderzoek stap 8 **Type onderhoud** Regulier & Calamiteiten

Onderzoeksfocus Platte daken *Jaarlijkse cycli*



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Appendix J: Prototype validation

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

PAND GERELATEERDE GEGEVENS

SPECIFICATIE GEGEGEVENS	Opgenomen in Prototype	Opmerkingen
Eigenaar		
(Bedrijfs)Naam	✓	
Contactgegevens	✓	
Technische Dienst (TD)		
Naam contactpersoon	✓	
Contactgegevens	✓	
Pand		
Pand ID code	✓	Voor ieder nieuw pand genereerd het prototype model een unieke pand ID-code op basis van; eigenaarsnaam, deelgebied, adres en gebouwnummer.
(Hoofd)Gebruiksfuncties	✓	In prototype niet gekozen voor een keuzelijst, maar voor een tekstuele omschrijving. Zo kunnen er meerdere (hoofd)gebruiksfuncties aan een pand worden toegekend.
Adresgegevens	✓	
Gebouwnummer	✓	Naast adresgegevens dient er in het prototype model een gebouwnummer aan het pand toegekend te worden.
Link; locatie tekening	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar de locatie tekening is opgeslagen. Met één druk op de knop kan zo een tekening (bijvoorbeeld een pdf bestand) worden geopend. Het prototype model ondersteunt echter geen geometrische kenmerken.
Link; huisregelsdocument	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar het huisregeldocument is opgeslagen.
Locatie		
Bosrijk terrein (Ja/Nee)	✓	
Eigen terrein		
Parkeergelegenheid (Ja/Nee)	✓	Bij de locatie gegevens kan er worden aangegeven of er parkeergelegenheid is op het eigen terrein.
Afvalcontainer aanwezig (Ja/Nee)	✓	In de module 'Algemeen beheer', kunnen deze gegevens beheerd worden onder het kopje 'facilitair gerelateerde gegevens'.
Capaciteit Afvalcontainer	✓	
Openbaar terrein		
Afstand tot parkeerplaats	✓	In de module 'Algemeen beheer', kunnen deze gegevens beheerd worden onder het kopje 'facilitair gerelateerde gegevens'.
Betaald parkeren (Ja/Nee)	✓	
Opstelplaats (Bouw gerelateerde) objecten		
Locatie aanduiding	✓	In het prototype model is dit opgenomen als een tekstuele omschrijving.
Potentiële barrières	✓	
Vergunning benodigd (Ja/Nee)	✓	
Aanvraagduur vergunning	✓	
Link; vergunning aanvraag	✓	In het prototype model kan een link worden opgenomen met het 'pad - > URL' waar de vergunningsaanvraag kan worden gedownload (gemeente website).

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

BOUWDEEL GERELATEERDE GEGEVENS

SPECIFICATIE GEGEGEVENS	Opgenomen in Prototype	Opmerkingen
Dak		
Dak ID Code	✓	Het dak ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene NIfsb code voor platte daken (1B 27.21)
Dak oppervlakte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Link; dak tekening	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar de dak tekening is opgeslagen. Met één druk op de knop kan zo een tekening (bijvoorbeeld een pdf bestand) worden geopend. Het prototype model ondersteunt echter geen geometrische kenmerken.
Plat dak		
Plat dak ID Code	✓	Het plat dak ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene NIfsb code voor platte daken (1B 27.21) + het plat dak nummer (bijvoorbeeld L1)
Plat dak nummer	✓	
Plat dak oppervlakte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Plat dak hoogte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Opbouw plat dak (dak-type)	✓	
Vervuilingstype	✓	In de module 'Algemeen beheer', kunnen deze gegevens beheerd worden onder het kopje 'preventief onderhoud cycylus'.
Link; plat dak tekening	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar de plat dak tekening is opgeslagen. Met één druk op de knop kan zo een tekening (bijvoorbeeld een pdf bestand) worden geopend. Het prototype model ondersteunt echter geen geometrische kenmerken.
Valbeveiligingssysteem		
Collectieve valbeveiliging aanwezig (Ja/Nee)	✓	In het prototype model zijn deze gegevens gekoppeld aan het betreffende dakvlak.
Individuele valbeveiliging aanwezig (Ja/Nee)	✓	
Aantal beschikbare veiligheidsharnassen	✓	
Vervaldatum veiligheidskeurmerk	✓	
Link; dakbeveiligingstekening	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar de dakbeveiligingstekening is opgeslagen. Met één druk op de knop kan zo een tekening (bijvoorbeeld een pdf bestand) worden geopend. Het prototype model ondersteunt echter geen geometrische kenmerken.

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

SPECIFICATIE GEGEGEVENS	Opgenomen in Prototype	Opmerkingen
Toegangspunt		
Locatie toeganspunt	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Wanneer gewerkt wordt met een Ifc model kan deze locatie aanduiding gemodeleerd worden zodat het toegangspunt bijvoorbeeld zichtbaar is met een gekleurd vlak.
Toegangsmethode	✓	
Benodigd extern materieel	✓	
Meldingsplicht bij betreden		
Meldingsplicht (Ja/Nee)	✓	
Naam contactpersoon	✓	
Contact gegevens	✓	
Link; veiligheidscertificaat	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar het veiligheidscertificaat is opgeslagen. Met één druk op de knop kan zo een document (bijvoorbeeld een pdf bestand) worden geopend.
Daklagen		
Daklaag ID	✓	De daklaag ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene Nlfsb code voor dakafwerkingen (1C 47.11) & en speficieke laag type (bijvoorbeeld 1C 47.11_10 voor een toplaag) + het plat dak nummer (bijvoorbeeld L1)
Materialisering	✓	Deze gegevens kunnen per type daklaag worden opgegeven. Het prototype model ondersteunt de invoer van 3 unieke daklagen per daklaag type van 1 dakvlak. (Bijvoorbeeld de invoer van 3 verschillende toplagen)
(Leveranciers)Type	✓	
Daklaag oppervlakte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
↑ Toplaag		
Bevestigingsmethode	✓	Deze gegevens kunnen per type daklaag worden opgegeven middels een omschrijving. Het prototype model ondersteunt de invoer van 3 unieke daklagen per daklaag type van 1 dakvlak. (Bijvoorbeeld de invoer van 3 verschillende toplagen) Het prototype model ondersteunt geen geometrische kenmerken zodat het aantal (her)overlagingen automatisch geteld worden.
Aantal (her)overlagingen	✓	
Verwachtte levensduur	✓	
↑ Ballastlaag		
Laagdikte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Grind		
Grind gradatie	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd per type daklaag.
Tegels		
Afmetingen	✓	
Vegetatiedak		
Lagen opbouw incl. dikte	✓	Middels een omschrijving (opsomming) kunnen deze gegevens worden opgenomen in het prototype model. Het model ondersteunt echter niet een aparte laagopbouw voor een vegetatiedak, zoals dat wel mogelijk is bij een (Revit) model.

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

SPECIFICATIE GEGEGEVENS	Opgenomen in Prototype	Opmerkingen
↑ Isolatielaag		
Laagdikte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Thermische weerstand (Rc)	✓	
↑ Onderconstructie		
-		
Dakrand		
Dakrand ID Code	✓	De dakrand ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene Nlfsb code voor dakranden (1C 27.11) + het plat dak nummer (bijvoorbeeld L1)
Constructief materiaal	✓	
Hoogte (vanaf dakvlak)	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Lengte		
Positionering	×	Het prototype model ondersteunt geen geometrische kenmerken. Zodoende kan er geen specifieke positionering van de elementen worden opgenomen en weergegeven. De positionering van elementen blijft beperkt tot het aangeven van het betreffende dakvlak (nummer), waarop het element zich bevind.
Dakrand afwerking		
Dakrand afwerking ID code	✓	De dakrandafwerking ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene Nlfsb code voor aansluitingen dakafwerkingen (1C 47.17) + het plat dak nummer (bijvoorbeeld L1)
Lengte	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Materialisering	✓	Het prototype model ondersteunt de invoer van maximaal 3 verschillende soorten dakrandafwerkingen. Het is echter niet mogelijk om een dakrandafwerking aan een specifieke stuk dakrand te koppelen.
(Leveranciers)Type	✓	
Profiel afmetingen	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Bevestigingsmethode	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Per dakvlak (nummer) kunnen er tot een maximum van 3 verschillende soorten dakranden en dakrandafwerkingenworden ingevoerd.
Demontabel (Ja/Nee)	✓	
Aansluiting; Daklaag &		
Aansluitingshoek (°C)	×	Het prototype model ondersteunt geen geometrisch kenmerken, zodoende is de aansluitingshoek tussen daklaag(vlak) en dakrand niet opgenomen. Echter, de wijze van hoekafwerking tussen deze twee elementen kan wel worden opgenomen in het model, hier zou eventueel ook de aansluitingshoek (ºC) in meegenomen kunnen worden.
Hoekafwerking	✓	

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

SPECIFICATIE GEGEVENS	Opgenomen in Prototype	Opmerkingen
Plat dakelementen		
Element ID Code	✓	De element ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het pand Id code + de algemene NIfsb code voor het betreffende element (Bijvoorbeeld 2B-56.23 voor zonnepanelen) + het plat dak nummer (bijvoorbeeld L1)
Materialisering	✓	Per type dakelement (technische units, daklichten, e.d.) kunnen er maximaal 3 verschillende soorten worden ingevoerd. Deze worden vervolgens gekoppeld aan het betreffende dakvlak(nummer).
(Leveranciers)Type	✓	
Afmetingen	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd. Het prototype model ondersteunt geen geometrisch kenmerken, zodoende kunnen deze gegevens niet automatisch worden berekend.
Positionering op dakvlak	×	Het prototype model ondersteunt geen geometrische kenmerken. Zodoende kan er geen specifieke positionering van de elementen worden opgenomen en weergegeven. De positionering van elementen blijft beperkt tot het aangeven van het betreffende dakvlak (nummer), waarop het element zich bevind.
Verwachtte levensduur	×	Deze gegevens zijn naar voren gekomen bij het valideren van het onderhoudsproces & prototype model met R. Bulk & W. Kraan. Dit zijn belangrijke gegevens voor het opstellen van een MJOB, dit maakt echter geen onderdeel uit van het huidige prototype model.
Geindexeerde kosten voor vervangen element	×	
Link; plat dak tekening	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar de plat dak tekening is opgeslagen. Met één druk op de knop kan zo een tekening (bijvoorbeeld een pdf bestand) worden geopend. Het prototype model ondersteunt echter geen geometrische kenmerken.
Servicecontract		
Servicecontract (Ja/Nee)	✓	Aan ieder soort en type dakelement kan een eigen servicecontract worden verbonden. Tevens is het mogelijk om een gezamenlijk servicecontract toe te kennen voor meerdere elementen van hetzelfde soort. Dit is dan wel per dakvlak(nummer)
Vervaldatum	✓	
Leveranciersnaam	✓	
Contact gegevens	✓	
Link; servicecontract	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar het servicecontract is opgeslagen. Met één druk op de knop kan zo een document (bijvoorbeeld een pdf bestand) worden geopend.
↑ Hemelwaterafvoer systeem		
-		
↑ Kleine dakdoorvoeren* ↑ Technische Units* ↑ Daklichten*		
Bevestigingsmethode	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd, per soort/type dakelement en per dakvlak(nummer).
Demontabel (Ja/Nee)	✓	
Aansluiting; Daklagen &		
Aansluitingsmethode / Wijzen van afwerking	✓	Middels een omschrijving kunnen deze gegevens worden ingevoerd, per soort/type dakelement en per dakvlak(nummer).

*
- **Kleine dakdoorvoeren** zijn doorvoeren door de dakvlak lagen heen (van binnen naar buiten en vice versa).
- **Technisch units** zijn alle units die op het dak 'staan' en dus niet door de dakvlak lagen heen gaan.
- **Daklichten** zijn alle soorten daklichten, dus voorzieningen t.b.v. daglicht toetreding.

Validatie van prototype model
Beheer & Informatie modules onderhoud (Platte daken)
Indeling op basis van het klassen model (Master thesis - Maurice Breedijk)

ONDERHOUD (PROCES) GERELATEERDE GEGEVENS

SPECIFICATIE GEGEGEVENS	Opgenomen in Prototype	Opmerkingen
Technisch onderhoud		
Bedrijfsnaam	✓	
Contactpersoon	✓	
Contactgegevens	✓	
Onderhoudscyclus		
Onderhoudsinterval preventief onderhoud	✓	In de module 'Algemeen beheer', kunnen deze gegevens beheerd worden onder het kopje 'preventief onderhoud cyclus'. Deze informatie is gekoppeld aan een specifiek dakvlak(nummer).
Link; onderhoudscontract	✓	In het prototype model kan een link worden opgenomen met het 'pad' waar hetonderhouscontract is opgeslagen. Met één druk op de knop kan zo een document (bijvoorbeeld een pdf bestand) worden geopend.
Gebreken (beheer)		
Gebrek ID Code	✓	De gebrek ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het specifieke gebouw element ID Code + de toevoeging van een gebrek nummer (Bijvoorbeeld 'C1')
Gerelateerd gebouw object	✓	In het prototype model is dit bereikt door de specifieke gebouw element ID Code mee te nemen in de ID Code van het gebrek. Wanneer men vraagt om de gegevens van een specifiek gebrek, dan wordt de ID Code van het betreffende element uitgelezen en de benodigde gegevens weergegeven.
Omschrijving	✓	In de module 'calamiteiten beheer' kunnen deze gegevens bekeken en uitgeprint worden. In de module 'Algemeen Beheer' kunnen er nieuwe calamiteiten worden toegekend aan specifieke gebouw elementen, hier kunnen gegevens van bestaande gebreken ook worden gewijzigd (revisie). Ook kunnen er externe documenten worden (als foto's en offertes) worden toegekend aan een specifiek gebrek.
Omvang	✓	
Status gebrek	✓	
Datum van constateren	✓	
Herstelurgentie	✓	
Verwachtte herstelkosten	✓	
Link; foto's	✓	
Link; offerte	✓	
Onderhoudshistorie		TaskTypeEnum Maintenance wel benoemd maar is niet uitgewerkt?
Onderhoudswerk ID Code	✓	De onderhoudswerk ID Code is in het prototype model gebruikers interpretabel en is opgebouwd uit het specifieke gebouw element ID Code + de toevoeging van een onderhoudswerk nummer (Bijvoorbeeld 'M1')
Gerelateerd gebouw object	✓	In het prototype model is dit bereikt door de specifieke gebouw element ID Code mee te nemen in de ID Code van het onderhoudswerk. Wanneer men vraagt om de gegevens van een specifiek onderhoudswerk, dan wordt de ID Code van het betreffende element uitgelezen en de benodigde gegevens weergegeven.
Omschrijving werkzaamheden	×	Deze gegevens zijn (nog) niet volledig meegenomen in het prototype model. Het invoeren en wijzigen van onderhoudwerkzaamheden is wel meegenomen in het prototype, te vinden onder de module 'algemeen beheer'. Echter de informatie overzichten, zoals bijvoorbeeld in de module 'calamiteiten beheer', zijn voor de onderhoudswerkzaamheden niet uitgewerkt. Dit kan echter op dezelfde wijze functioneren als de module 'calamiteiten beheer'.
Datum van onderhoud	×	
Onderhoudspartner	×	
Onderhoudskosten	×	
Link; foto's	×	
Link; offerte	×	