GIMA

Geographical Information Management and Applications

# A research towards completing the asset information life cycle

*An analysis of the relationships between data exchange, BIM and the asset life cycle and the solutions to overcome existing issues at Amsterdam Airport Schiphol.*


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*"You are not going to do research until half the people say it is not possible."*

Burt Rutan

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# Preface

This thesis report is concludes my work for the Masters of Science programme Geographical Information Systems and Applications. During the four years I have been a student for this programme I have learned a lot. However, I think the most important thing I learned was getting acquainted with my own borders. During this thesis research, that started in September 2011, I suffered from a burn-out. As a result I have not been doing anything for my thesis research between March and June 2012. After that I slowly built up my thesis work and having it finalized by half-a-year later than originally planned.

Reflecting towards my study period, I do not know how I managed to fulfil a full-time job at Heijmans, do a part-time study for this Masters of Science programme and to be a good husband for my wife and a father for my son. Tight deadlines, working over nights and weekends, studying in between and also participating in the household. I learned a lot, made many new friends and got regularly inspired by all the new and existing GIS concepts we learned.

Off course would it not have been possible to conduct this programme without the support of my wife, Mirjam de Boer who has been very patient with me, but who also had to miss me. My son will be a little disappointed now that I am ready, since he will have to miss all the day trips my wife made with him, so I could study in a quite surrounding. Instead he will get my attention and I will probably take him for day trips now, only not as often.

I would also like to thank my employer, Heijmans, who have been willing to give me the opportunity to join this programme. Especially my manager Edwin van Osch and my project coordinator Pieter van Dueren den Hollander, who always supported me and were willing to help me where ever needed.

A special thanks for all my colleague students with whom I did the projects in the first two years of the programme. I hope that we can stay in touch and that we will meet in the future where ever you are on this planet.

Related to my thesis research I would like to thank everybody at Schiphol for that contributed to my research in any way and the fact that everybody is willing to help. A special thanks for Mohamed El-Morabit for our lunch and coffee discussions. I also want to thank my supervisors Nico Wasserman (Schiphol) and Sisi Zlatanova (TU Delft) for supervising my research and also Peter van Oosterom for his role as Professor.

Although I will miss the contact with my fellow students from all over the world and the inspiring contact weeks at the Universities of Utrecht, Delft, Wageningen and Twente, I am also glad I have finished this wonderful expedition. I look forward to spending my time with family and friends who had to miss me in the past four years. Thank you for your patience.

Lars de Vries

Eindhoven, March 2013.

# Management summary

This thesis research for the Master of Science programme Geographical Information Management and Applications looks at the possibilities of completing the asset information life cycle at Amsterdam Airport Schiphol. Therefor an analysis was made of the current situation, after a literature research was conducted towards the subjects of data exchange and Building Information Modelling (BIM).

The insights in data exchange principles are needed to understand the potential problems in completing the asset information life cycle. At the moment as-built information is delivered to SGIS, but not re-used in new projects. The most important problems are caused by systems that are not able to communicate with each other and data structures that are different by nature because of its native software.

BIM is a topic that currently gets much attention in the world of design and construction. From their perspective BIM deals with another way of executing design and construction, where collaboration and integration are the key words. In practice BIM has a broader scope and can be defined as, being a process in which relevant actors collaborate on creating, analysing and managing multiple dimension data within a dynamic model representing one or more assets throughout its/their life cycle.

For this thesis research the new data model for asset information at Amsterdam Airport Schiphol, Schiphol GIS or SGIS, was analysed. SGIS replaces four other systems that contained all asset information at Schiphol, but that also contained double and inconsistent information. With SGIS these problems must belong to the past. The data model mostly contains 2D or 2½D data of all assets, including the most relevant information on the asset. SGIS also communicates, or will do so within two years, with three other systems that as a complex are the back bone of the asset management process at Amsterdam Airport Schiphol.

There are currently two problems with completing the asset information life cycle. The first problem is getting the information from the 3D model to SGIS. To solve this problem a workflow is suggested. This workflow includes an export to the open standard IFC from the original 3D AEC modelling software. A small addition to SGIS has to be made therefor, to be able to support the 3D geometries that are coming from that software.

The second problem is to get the information back from the operations and maintenance phase to a new design phase. Currently the most optimal solution seems to re-use the received IFC file and to add a DWG containing the changed geometries. Thereby it needs to be mentioned that the multi-patch objects from SGIS will be exploded to individual faces.

The preferred solution would have been to work from one central (spatial) database, but that is technically not possible yet. The problems are caused by the fact that AEC (3D modelling) software and GIS do not share a common geometric data model.

Additionally it needs to be researched what the actual information demand is for the design phase. In the current situation information gets lost after the exchange from construction to operations and maintenance, because the information need in those phases is less detailed.

With the suggested solutions and changes/additions to SGIS it is possible to complete the asset information life cycle for Schiphol and the relevant stakeholders and main-contractors. An inventory of the necessary resources to plan these changes still needs to be made.

# Summary

This thesis research for the Master of Science programme Geographical Information Management and Applications focusses on solutions completing the asset information life cycle in general and to apply a selection of the offered solutions at Amsterdam Airport Schiphol. Currently the as-built information is added to SGIS, but it cannot be re-used in new projects. To be able to complete the asset information life cycle, it is first important to look at gaps that are present. Therefor three subjects have been researched, 1) data exchange, 2) BIM and 3) Schiphol GIS.

The asset information life cycle cannot be not completed at this moment because of differences within the asset information life cycle. The two most important differences are the use of software and the life cycle approach.

To understand the differences in software and the problems that arise in data exchange, first an analysis was made of data exchange. Beside the different use of terminology, the biggest differences can be found within data itself. Data exists of three components, 1) the file format/encoding (syntactic), 2) the meaning (semantic) and 3) the data model including attributes and geometry (structure). There exist different data exchange strategies that can support the possibilities to overcome these differences. And besides the strategy, also tooling is needed to convert the data. It also needs to be considered that a data exchange is a transaction between a sender and a receiver. The data itself can be seen as the message that is being transacted and it is important that both sender and receiver have a mutual understanding of the message. The message can be communicated direct or indirect, depending on the situation. Another aspect that plays a role is the way that different systems are able to use the same data, because they are integrated. The level of integration can be of influence on the ease to exchange a particular dataset. The mutual understanding of the message is needed on different levels and not only on the data or the system/software level. The organizational and people level are as important to make a data exchange successful.

An important part of the life cycle deals with design and construction. Within that sector currently much attentions is paid to something that is called BIM. BIM or Building Information Modelling can be seen as the process of creating a multiple dimension model, that is being analysed, updated and managed by different stakeholders who work together throughout the asset information life cycle with the purpose of efficiency and a decrease of information loss. Many people seem to have a different view on BIM, often caused by the activities those people execute and the environment they are acting in e.g. a specific phase of the asset life cycle. Most people think that BIM is something that only applies to design and construction, whilst the clear aim of BIM is to support the full life cycle of an asset. Despite the fact that within design & construction so-called AEC software is used and within operations and maintenance mostly GIS software is used, it can be called remarkable that BIM shows a lot of parallels with GIS concepts. Spatial Data Infrastructures (SDIs) is one of those concepts and shows a lot of overlap with BIM, with the remark that have their own application domain.

The second half of the asset life cycle deals with operations and maintenance. This research was conducted at Amsterdam Airport Schiphol and the data model, Schiphol GIS or SGIS, of Schiphol was taken at a closer look. The data model covers a wide variety of themes and replaced four other systems that contained a total of 77 themes, but that also contained double information that showed different truths. SGIS was developed to replace the former systems and to create a single source of truth. The data is made available to over 800 stakeholders by a view and, if necessary, an edit portal. Looking at the way SGIS is used within Schiphol, it can be stated that it is an application of BIM, with the remark that it is only applied to the operations and maintenance phase.

The biggest problems for completing the asset information life cycle can be found at where the construction is being followed by the operations phase and where the design phase is the follow up of the maintenance phase. These locations stand out, because the aim and use of the data is differently, but most of all because the software types are different. The different software types make that the data models are not easy to convert at those to locations and solutions have to be brought up.

The most ideal solution exists of a single spatial database that is used to store the 3D geometry model and that can be accessed by both the AEC and the GIS software. Other information can be stored in separate databases that can interact based on unique identifiers that consequently are used for all assets. Therefor a common 3D geometry model needs to be developed between AEC and GIS vendors, where each type of software can be used at its own strengths.

Since the previous solution is technically not yet applicable, because there does not exist a common geometric model for AEC (3D modelling) software and GIS, more practical scenarios have been looked at. Especially the exchange of building designs is troublesome, whilst the exchange between AEC and GIS software for infrastructural projects does not seem to cause as many problems with the conversion of 3D geometries as is the case with building data. The solution exists of the application of two different scenarios. The first scenario looks at the step from construction to operations. The best solution is to choose for a conversion strategy, where the native 3D building model is converted into the open standard IFC. The IFC data can than easily be converted into the SGIS data model, although it is necessary to add additional representations to the feature classes to the current data model, because the current model is not capable of handling 3D primitives. This research did not look towards the additional attribute information, since it is not expected that the exchange of that information will cause troubles as long as the unique identifier is maintained over all information sources. Other solutions include the export directly from the 3D AEC modelling software to GIS (but those exports are not supported yet) or the export via an ODBC connection to a (spatial) database (but unfortunately I was not able to test those and do not know whether a GIS or other software is capable of handling the (geometric) data).

The second step is to offer the 3D AEC modelling software the last received IFC file of a certain asset. Possible changes are added in a DWG drawing that contains all faces of the 3D model of SGIS in a classification that needs to be agreed upon with those stakeholders that are responsible for the design. At this moment it is not yet possible to export the SGIS data into an IFC dataset, although both data models show a lot of similarities. Exporters from GIS data to IFC are not yet available. An export to IFC would favour over an export to DWG, because in the last case relevant asset information gets lost due to the fact that DWG drawings do not support attribute information. However, little changes are expected in the geometry, meaning that the original IFC file will remain its value. Other solutions include the use of a 3D web feature service (WFS; but those are not supported by the 3D AEC modelling software) or a direct conversion to the native format of the 3D AEC modelling software (but those conversions are also not supported, just like the export to IFC).

At this moment it is partly possible to complete the asset information life cycle, but it is necessary to add additional geometry to the SGIS data model first and an agreement has to be made on how the changes to the 3D SGIS model will be offered in the DWG drawing.

## Samenvatting (Dutch)

Dit thesis onderzoek voor het Master of Science programma 'Geographical Information Management and Applications' focust op oplossingen voor het rond maken van de asset informatie levenscyclus en om een selectie er van toe te passen op de situatie van Amsterdam Airport Schiphol. Om de asset levenscyclus te completeren is het belangrijk om eerst te kijken naar waar de gaten zitten. Daarvoor zijn drie onderwerpen onderzocht, 1) Data uitwisseling, 2) BIM en 3) Schiphol GIS.

De asset informatie levenscyclus kan op dit moment nog niet compleet gemaakt worden door verschillen binnen de asset informatie levenscyclus. De twee meest belangrijke verschillen zijn het gebruik van software en de benadering van de levenscyclus.

Om de verschillen in software en de problemen die naar voren komen in data uitwisseling te kunnen begrijpen, is eerst een analyse gemaakt van data uitwisseling. Naast het gebruik van verschillende terminologie, zit het grootste verschil in de data zelf. Data bestaat uit drie componenten, 1) het bestands formaat/codering, (syntaxis), 2) de betekenis/strekking (semantiek) en 3) het data model, inclusief de attributen en geometrie (structuur). Er bestaan verschillende strategieën voor data uitwisseling die kunnen helpen om deze verschillen te overbruggen. Naast strategie zijn er ook hulpmiddelen benodigd om de data om te zetten. Het is belangrijk te beseffen dat data uitwisseling moet worden gezien als een transactie tussen een zender en een ontvanger. De data zelf kan worden gezien als de boodschap die wordt uitgewisseld en het is dan ook belangrijk dat zender en ontvanger de verzonden boodschap op dezelfde manier interpreteren. De boodschap kan via een direct of via een indirect communicatiemiddel zijn verstuurd, afhankelijk van de situatie. Een ander aspect dat een rol speelt is de manier waarop verschillende systemen overweg kunnen met dezelfde dataset, doordat ze geïntegreerd samenwerken. Het niveau van integratie kan van invloed zijn op het gemak waarmee een bepaalde dataset wordt uitgewisseld. De gelijke interpretatie van de boodschap is nodig op verschillende niveaus en niet alleen op het niveau van systemen en software. Het organisatorische en menselijke niveau zijn even belangrijk om de data uitwisseling tot een succes te maken.

Een belangrijk onderdeel van de levenscyclus draait om ontwerpen en bouwen. Binnen die sector wordt momenteel veel aandacht besteed aan iets dat 'BIM' wordt genoemd. BIM (Building Information Modelling) of Bouw Informatie Model(leren) kan worden gezien als het proces van het creëren van een model met meerdere dimensies, dat wordt geanalyseerd, bijgewerkt en bijgehouden door verschillende belanghebbenden die samenwerken door de hele asset informatie levenscyclus heen, met als doel efficiency en het inperken van informatie verlies. Veel mensen lijken een andere kijk te hebben op het begrip BIM, vaak veroorzaakt door de werkzaamheden waar die persoon zich mee bezig houdt en de omgeving waarin hij of zij werkzaam is, bijvoorbeeld een specifieke fase van de levenscyclus. De meeste mensen denken dat BIM iets is dat alleen maar van doen heeft met ontwerpen en bouwen, terwijl het doel van BIM duidelijk is om de hele levenscyclus van een asset te ondersteunen. Ondanks het feit dat binnen ontwerp en bouw vooral de zogenaamde AEC software wordt gebruikt en bij beheer en onderhoud vooral GIS software, kan het opmerkelijk genoemd worden dat BIM veel parallellen vertoond met bepaalde GIS concepten. SDI's (Geografische Informatie Infrastructuren) is een van die concepten en vertoond veel overlap met BIM, waarbij moet worden opgemerkt dat BIM een bredere scope omvat.

De tweede helft van de asset levenscyclus gaat over beheer en onderhoud. Dit onderzoek is uitgevoerd op Amsterdam Airport Schiphol en het data model, Schiphol GIS of SGIS, is dan ook nader bekeken. Het data model bevat een grote diversiteit aan thema's en heeft vier voormalige systemen vervangen die tezamen 77 thema's bevatten, maar waar ook veel informatie dubbel aanwezig was en dat verschillende waarheden presenteerde. SGIS is ontwikkeld om die voormalige systemen te vervangen en om nog maar een waarheid te tonen. De data in SGIS is beschikbaar voor meer dan 800 belanghebbenden in een

raadpleeg portaal en, als het nodig blijkt, in een muteer omgeving. Kijkend naar de manier waarop SGIS binnen Schiphol wordt gebruikt, zou gezegd kunnen worden dat het een toepassing is van BIM, waarbij opgemerkt dient te worden dat het hier alleen op de beheer- en onderhoudsfase wordt toegepast.

Het grootste problemen voor het completeren van de asset informatie levenscyclus liggen op grens waar bouwen wordt opgevolgd door beheer en daar waar ontwerp wordt vooraf gegaan door onderhoud. Deze overgangen vallen op, omdat het doel en het gebruik van de data verschillen, maar vooral omdat op deze locaties een overgang van software gebruik plaats heeft. De verschillende software typen maken dat de data modellen niet gemakkelijk om te zetten zijn en hiervoor zullen oplossingen bedacht moeten worden.

De meest ideale situatie zou zijn wanneer er alle 3D geometrie in dezelfde ruimtelijke database opgeslagen zou worden en benaderd kan worden door zowel de AEC alsook door de GIS software. Andere informatie kan in aparte databases worden opgeslagen die dan communiceren op basis van unieke identificatie van de objecten, die consequent worden toegepast voor alle assets. Om dit te kunnen bewerkstelligen zal een gezamenlijk 3D geometrie model moeten worden ontwikkeld door de makers van zowel AEC en GIS software, waarbij beide typen software gebruikt kunnen blijven worden waarvoor ze eigenlijk ontwikkeld zijn.

Omdat de vorige oplossing voorlopig nog niet toepasbaar zal zijn, zijn ook meer praktische scenario's ontwikkeld. Hierbij is vooral gekeken naar het ontwerp van gebouwen, omdat er zich bij de uitwisseling tussen AEC en GIS software in de GWW sector veel minder problemen voordoen. De oplossing bestaat uit het toepassen van twee scenario's. Het eerste scenario kijkt naar de stap van bouwen naar beheer. De beste oplossing op dit punt is om te kiezen voor een conversie scenario, waarbij het originele 3D model wordt omgezet naar de open standaard IFC. De IFC data kan dan gemakkelijk worden geconverteerd naar het SGIS model, alhoewel het noodzakelijk is om hiervoor representaties toe te voegen aan de feature classes van het bestaande model. In dit onderzoek is niet gekeken naar het converteren van attribuut informatie, omdat niet wordt verwacht dat dit zoveel problemen op zal leveren, zolang de unieke identificatie code maar behouden blijft bij alle datasets. Andere mogelijke oplossingen zijn het direct exporteren vanuit de 3D AEC modelleer software naar GIS (maar deze exports worden nog niet ondersteund) of de export via een ODBC verbinding naar een (ruimtelijke) database (maar helaas is het mij niet gelukt om dit te testen en weet ik ook niet of de GIS software de geëxporteerde data kan lezen).

De tweede stap omvat het terug aanbieden van het laatst ontvangen IFC bestand aan de 3D AEC modelleer software van een bepaalde asset. Mogelijke wijzigingen kunnen worden aangeboden in een DWG bestand die dan alle vlakken van het 3D model uit SGIS bevat. Hiervoor moet nog wel overeenstemming worden gezocht met de ontwerpers, om duidelijkheid te scheppen in classificatie die gebruikt dient te worden. Op dit moment is het nog niet mogelijk om vanuit SGIS direct naar IFC te exporteren, ondanks dat beide data modellen wel veel overlap vertonen. Er bestaat op dit moment simpelweg geen export functionaliteit van GIS naar IFC. Een export (van de verschillen) naar IFC zou de voorkeur hebben boven een export naar een DWG bestand, omdat in het laatste geval alle relevante asset informatie verloren gaat daar DWG bestanden geen attribuut informatie ondersteunen. Echter is het de verwachting dat er maar beperkte verschillen zullen zijn in de geometrie, waardoor het originele IFC bestand zijn waarde behoud en kan worden hergebruikt. Een andere oplossing is het gebruik van een 3D web feature service (WFS; maar die worden niet ondersteund door de 3D AEC modelleer software) of een directe conversie vanuit GIS naar het formaat dat bij de 3D AEC modelleer software behoort (maar ook deze conversies worden nog niet ondersteund).

Op dit moment is het (gedeeltelijk) mogelijk om de asset informatie levenscyclus te completeren, maar daarvoor is het wel noodzakelijk om het datamodel van SGIS uit te breiden met 3D geometrie en zal overeenstemming moeten worden bereikt met de ontwerpers over hoe de veranderingen van geometrie in SGIS aan hun zal worden aangeboden.

# Inhoud

# 1 Introduction

Amsterdam Airport Schiphol, from this point forward also referred to as Schiphol, has set herself the ambition of becoming Europe's preferred airport. The numbers that are the foundation for this ambition can be found in table 1. To achieve this ambition activities such as design, build, operate and maintain must be executed in the most efficient and effective manner. An emergency situation several years ago showed that information about assets was not easily accessible. There were over 70 information themes in four different systems and the information in those systems was not consistent. Also it was necessary to switch between different systems to get a complete overview of a situation. Information was kept up-to-date within different departments, each with their own focus.

| Subject | Amount |
|---|---|
| Passengers | 48,3 million |
| Cargo | 1,512 million tons |
| Profit | € 168,9 million |
| Investments (2011) | € 400,0 million |
| Employees Schiphol Group | 2,328 FTE |
| People working at Schiphol | 60,000 |

*Table 1. Overview of the quantities of people and freight that yearly pass at Schiphol (Schiphol Group, 2011a; Schiphol Group, 2011b)*

The emergency situation led to the discovery that the previously described situation was no longer workable and a project called 'Facilities Unveiled in a Spatial Environment' was started. The project resulted in a centralization of information departments into the department 'Asset Information Management' and initialized a new system that should replace most of the existing information systems, i.e. 'Schiphol Geographical Information System' or SGIS. The department has four focus areas and each focus area has its own section:

- Asset Geographical Information (AGI)
- Asset Maintenance Information (AOI)
- Asset Document Information (ADI)
- Asset Consumption Information (AVI)

The aim of the new department is to simplify the system architecture as much as possible and to integrate and link both systems and data as much as possible. This should finally result in an information system with one central access point, offering "*one view for all*".

Recent developments in the department have shown that both the delivery and the processing of changes are not optimal and should be approached as a total process from design to build to maintenance and back to design, i.e. asset information life cycle.

Secondly, Schiphol has become interested in a new development within the building industry, called BIM (Building Information Modelling). Schiphol would like to know what BIM means and what it entails for the purpose of developing a strategy on how to deal with it and to make a choice to adopt it or not.

## 1.1 Research questions

The objective of this research is to find an answer to the question: "What is necessary to complete the asset information life cycle in terms of data exchange, related to BIM and the current situation at Amsterdam Airport Schiphol?"

The main research question will be answered by researching the following sub-questions:

- What is data exchange and which relevant aspects can be distinguished?
- What does BIM encompass?
- What is SGIS and how can it be related to the asset information life cycle and BIM?
- Which problems should be overcome in completing the asset information life cycle?
- What are possible data exchange solutions to complete the asset information life cycle?
- What is needed for Schiphol to make the proposed solutions effective?

The outcomes of the first three questions will be of great influence on researching the answers for the last three questions.

## 1.2 Methodology

This research is not conducted according to a standardized methodology, such as agile of prince2. However each step was carefully considered and is described hereunder.

1. The first step is a literature research towards the basic principles of data exchange. The aim of the research as such is not to come up with a new solution, but to present what needs to be taken into account when data is exchanged and to come up with multiple strategies applicable for specific situations.
2. Secondly a literature research towards the meaning and contents of the concept BIM is conducted. Attention is paid towards the history of BIM, explanation of the acronym BIM, literally and figural, applicable standards and future developments.
3. SGIS is/will be the centre of information exploration at Amsterdam Airport Schiphol. Within this step it will become clear what SGIS is and how it relates to the daily tasks of Schiphol. The data model is looked at and also the ideas behind the past and future developments as well as the goal and aim of SGIS. The last two topics are researched by studying available documentation and by having conversations[1] with those currently responsible for SGIS within Schiphol.
4. Based on the outcomes of the three previous steps, an analysis is made on how a system setup like SGIS can be related to the asset information life cycle. Knowing how such a system relates to the asset information life cycle will also give information on where the problems are located that need to be overcome to complete the cycle.
5. With the input from steps 1, 2 and 4, possible solution(s) will be proposed to overcome the encountered problem(s). The offered solution(s) will be compared, if necessary, and the solution that suits the situation at Schiphol best will be selected.
6. The last step researches what is needed to implement the suggested solution(s) for completing the asset information life cycle.

## 1.3 Other research

At the start of this thesis research, two students from the faculty of Architecture of the TU Delft have conducted a research at the department 'Terminal Real Estate', resulting in a possible strategy direction for the adoption of BIM (Vollebregt & Vos, 2012). Both this research and the research by Vollebregt and Vos were conducted partly parallel, but fully independently from each other. This has caused different views on a few topics, due to different backgrounds and experiences.

The research question Vollebregt and Vos looked at was: "*How can Building Information Modelling be a mean to optimise and to integrate the building process and the Facility Management during the complete*

[1] The conversations have not been recorded and no transcript has been made. Some notes were made during the conversations. A list of the people spoken with, including their role and a short explanation of the topics spoken about, is available in Appendix A.

*life cycle of a building in a dynamic and complex environment with multiple stakeholders*?" And although their focus was Schiphol wide, the research centred around the department 'Terminal Real Estate'. The solution Vollebregt and Vos propose is to purchase an 'off-the-shelf' BIM system that will replace all the current systems within Schiphol. Within their research they specifically mention that it needs to be considered to terminate the SGIS implementation, because it does not meet the user requirements on the level of detail.

The BIM system they propose in fact is a Central Information System (CIS) and the requirements for the systems have been defined based on seven themes, i.e. Information Flows, Building Life Cycle, Facility Management, Project Management, Complex Environment, Dynamic Environment and Multi-stakeholder, that are compared to two different views, i.e. management and structured information flows. The Central Information System should exist of two copies: a Release-BIM that contains the as-is situation and a Project-BIM that can be mutated during construction projects.

In relation to the implementation of the CIS they mention that the users will not automatically adopt the new system and use it the way it is meant to be used. Secondly they think that it will take a long time before the users have gotten accustomed to the new system. Finally they suggest that it is important to keep listening to the users and their needs, because not listening to the users was one of the main reasons earlier ICT related projects have failed.

Together with this research, another research started within the AGI department that aimed to look at the third dimension. The question was whether there was a need for 3D within the Schiphol GIS data model based on user requirements and on the other side what additional possibilities 3D data offers above 2D data. The last focus on the research should take the technical demands in consideration. Based on these three aspects an advise towards a further development of the third dimension for SGIS should be given. This research was initiated twice, but unfortunately both times the assignment was returned at the start of the research. Although most aspects towards 3D are not within the scope of this research, some elements of 3D will be paid attention to.

## 1.4 Reading instructions

The next chapter (chapter 2) deals with the basic principles of data exchange. The chapter not only offers insight in the different aspects of data exchange, but also offers different strategies for data exchange and a framework for data exchange interaction. Chapter 3 provides an introduction in the concept of BIM. Different views on the topic will be explained and a short history on the emergence of BIM is also provided. Information on SGIS is provided in chapter 4. Here attention is paid towards the past and future ideas of SGIS and how it relates to the asset information life cycle. The following chapter (chapter 5) describes the use case that provided a test dataset for this research and the problems that are encountered in the asset information life cycle. The last chapter (chapter 6) will provide different solutions for the encountered problems. A selection of the proposed solutions is analysed towards the necessities for implementing them. Also an explanation is offered towards the executed prototyping. At the end (chapter 7) conclusions and recommendations are offered.

# 2 Data exchange

It was not long after the introduction of computing that people wanted to start with re-using data. The reasons for re-using data are countless, just like the problems that were, and still are, encountered when data is re-used. It is common knowledge that despite all efforts in standardization and technological evolution, too many barriers still exist for a fluent re-use of data. This chapter looks at the different aspects of data that are of influence in a data exchange and also proposes strategies for data exchange as well as a framework to support the data exchange.

There are two important aspects of data exchange that will not be looked at within this chapter, i.e. data quality and auditability. Auditability refers to the verification of a dataset. It is often hard to find out whether the data has been verified or not, which might cause quality issues. The data quality by itself can be described from many different angles, such as the geometrical accuracy and correctness of the attributes. For the exchange itself, data quality does not have to be an issue, it is the use after the exchange that might cause troubles, especially when data needs to converted (via an automated tool). For the purpose of this chapter we assume that the quality of the data is in order and that the data is verified.

## 2.1 Share or exchange

Within literature two terms are widely used to describe the activity of handing over data with the intention of re-use, i.e. sharing and exchanging. And although both terms have distinct meanings, they seem to be used at random. Both situations deal with giving something as the original owner to another, however in an exchange an equivalent will be expected in return, whilst sharing implies that nothing is expected in return (Merriam-Webster, 2012a, b). From this point forward the term exchange will be used because the use case data within this research comes from a contractual delivery.

## 2.2 Data characteristics

Data exchange is about the re-use of data and information with the purpose of cost savings and quality improvement (Du, Lai, Cheung, & Cui, 2012, p. 90). To enable this multiple use of a single source, datasets have to be shared or exchanged. However, a particular source data set is in a specific file format and has its own characteristics, e.g. it is designed for a certain purpose and gives a predetermined representation of real world phenomena (Heywood, Cornelius, & Carver, 2006, p. 32). The moment this dataset is obtained by others it is possible to re-use the data. However, a Dutch writer and poet stated that "*in between dream and achievement, laws are in the way as are practical objections*" (Elschot, 1910). This also applies to the re-use of data. And although legislation can be a problem in the (international) exchange of data (Angeles, Corritore, Basu, & Nath, 2001), the actual problems (practical objections) lie elsewhere and are complex by nature.

To use a dataset, it must be known what real world phenomena it represents and how they are represented. This information is described by a combination of characteristics of a particular dataset and the objects present within that dataset. The characteristics can be classified in different categories. Bishr (1998, p. 301) presents data as a *3-tuple*, i.e. thematic attributes, geometric attributes and identification, or a *4-tuple* that also includes the temporal dimension. These characterizations can be grouped as the structural elements of a dataset, whereas syntactic and semantic elements complete the description of a dataset (Peachavanish, Karimi, Akinci, & Boukamp, 2006, p. 73). Here the syntactic elements refer to the data- or file format and the semantic elements place the data in a context giving meaning to the objects within the dataset. Van Oosterom and Stoter (2010) suggest that not only space and time should be seen as dimensions, but that scale should also be integrated as one of the dimensions of data. The reason therefor is that a change, in geometry, time or attribute, might only be interesting when the data is looked at from a particular scale. Since many datasets are used over different scales, I think that this argument is valid. Brodeur et al (2005, p. 676) approach the data from its context and distinct the intrinsic properties, i.e. *identification, attributes, geometries, temporalities and domain*, and extrinsic properties, i.e. *semantic, spatial and temporal relationships*, of a dataset. Hereby the intrinsic properties describe the object itself and the extrinsic properties describe how they relate to the external environment. The intrinsic properties are contained in the structural elements described by Peachavanish et al, whilst the extrinsic properties are included within the semantic elements. A suggestion that these semantic elements can be seen as a sixth dimension in multi domain use of a database (Van Oosterom & Stoter, 2010) is understandable, but in my opinion not correct. This is because, by nature, the meaning of an object stays the same only different terminology can be used over multiple domains. I would rather classify semantics as a 'domain'-interpretation than as being a representation of an additional dimension.

Therefor I propose a relationship between the elements of a dataset as is shown in figure 1. In contradiction with Brodeur et al (2005, p. 676) I see *domain* as an extrinsic property instead of an intrinsic property, because *domain* tells something about the original (development and) use of a particular dataset and in that sense it tells something about the exterior of the dataset and not about the object itself. The figure shows that the structural and semantic elements are related, because the context that is provided by the semantics turns the structural elements into information, which makes it possible to use and understand the dataset unambiguously. The syntactic elements put constraints on the structural elements, because the file format limits the structure of the data model in terms of geometry, e.g. the support of 3D primitives, attribute types, e.g. date, integer and text, and software use.

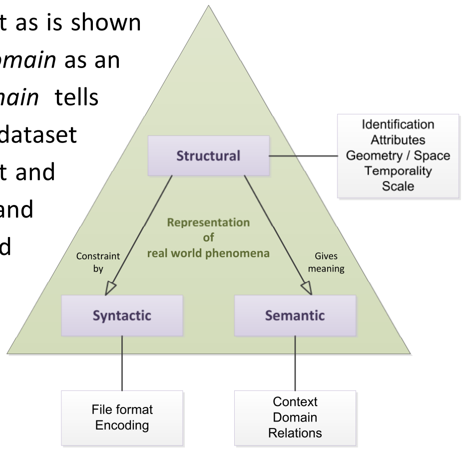


*Figure 1. Overview of the characteristics of a dataset that together create the representation of real world phenomena.*

All datasets are contained in a data model. The data model is the relation between a real-world phenomenon and the characteristics (syntactic, structural and semantic) that describe this phenomenon. A description of a data model is often separated in a technical description, containing the syntactic and structural characteristics as well as how the data is (or needs to be) collected, and a formal description, i.e. the semantic characteristics, of the real-world phenomena it represents. Many data models lack this last description, which makes it harder to interpret and understand the contents of a certain dataset. Having clear knowledge on the meaning of the real-world phenomena *"is crucial in good information flows between various actors"* (Van Oosterom, 2013).

## 2.3 Communication process

Before any dataset can be re-used, it must be exchanged first. The exchange of data can be compared with the human communication process that always consists of three components, i.e. a sender, a receiver and a message (Schramm, 1971; Brodeur, Bédard, & Moulin, 2005). The message in this case is the data. Nedovic-Budic and Pinto (2001, p. 296) look at data exchange as a transaction, where the data itself can be seen as "*currency*". Although the figurative way of explaining the process of data exchange differs, both explanations share the same components, i.e. a sender, a receiver and a message, in the case of data exchange being a dataset. The difference between the communication process and a transaction is that a communication process can be an on-going activity, whilst a transaction is a (recurring) one-time event. In that sense, a communication process can be looked at as a series of transactions. From this point forward a data exchange will be looked at as a transaction.

Farrés (1992, p. 16) does not look at the sender and the receiver as such, but distinguishes four parameters in the data exchange process. Two of those parameters are included in the message, i.e. *encoding/format* and *composition*. The third parameter, *communication*, involves the interactions between sender and receiver. The fourth and last parameter Farrés describes is *process*. The components previously mentioned by Brodeur et al (2005) are all contained within this last parameter. When I combine these four parameters and the previously mentioned components, I get a process that includes the sender and receiver, the communication between both, and the characteristics of the message, as can be seen in figure 2. The proposed setup in the figure supports the functions of data transfer, data transformation and translation, and the interactions between the sending and receiving systems (Banerjee & Golhar, 1994, p. 66).

When I compare the message properties from figure 2 with the characteristics of a dataset in figure 1, it becomes clear that the syntactic characteristics are described as *encoding/format* and the structural and semantic characteristics are included within *composition*, where format and encoding describe the file. In most cases these are the same, especially with native file types, but sometimes a format can have multiple encodings, e.g. IFC can be encoded in STEP or XML.

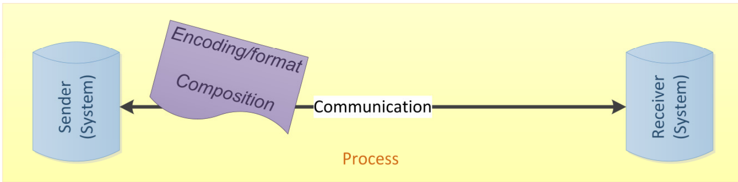


*Figure 2. Overview of the four classification parameters for data exchange, proposed by Farrés (1992, p. 16), integrated in the data exchange process.*

Communication, in terms of data exchange, describes how the message is sent and can be split in two main categories, i.e. direct and indirect. For example, direct communication within a human communication process can be seen as face-to-face or a performance in front of a crowd, whilst indirect communication can be a letter or watching a video or DVD. Direct communication in a data exchange happens via an electronic connection from one system to another, e.g. internet or network connections. Indirect communication implies that there is no direct interaction between a sender and a receiver. As a result data needs to be stored or loaded from a source before it can be used, e.g. files via e-mail or data carriers. Direct data connections can be subdivided in on-demand and real-time connections. The former happens when data is approached at the moment that is needed whilst the latter can be used in, for example, sensor networks. Some examples of different communication means are shown in table 2. Within the table there is no distinction made between on-demand and real-time interactions.

Besides data, the communication means should also contain a description of the data sent. This description can be compared with the non-verbal communication in a human communication process and functions as metadata that inform the receiver about the extrinsic properties of the data(set).

| **Direct communication means** | | **Indirect communication means.** | |
|---|---|---|---|
| (Web) service | Network connection | E-mail | EDMS |
| ODBC connection | Peer-2-peer | USB flash-drive | Download |
| Internet | Live feed | CD-rom / DVD | Hard drive |

*Table 2. An overview of possible communication means, classified to direct or indirect communication.*

The way data is received is of influence on how the data can be used. To know when to use which communication means is one of the keys to success. Within literature these communication means, and others, are often presented as unique concepts. However, terminology to describe these concepts, again, seems to be used randomly. Due to this, it can be expected that problems will arise when sender and receiver do not align their expectations up-front (Benjamin, de Long, & Scott Morton, 1990, p. 31).

## 2.4 Interoperability

It often happens in direct data exchange, that problems arise in the communication between two (intra-/inter-organizational) systems. This kind of problems is often referred to as interoperability (Naudet, Latour, Guedria, & Chen, 2010). Looking at the literal meaning of inter-operate, it implies that two systems can perform operations on each other (Chen, Doumeingts, & Vernadat, 2008), therefor it is necessary that both systems understand each other. When comparing interoperability to the human communication process, as was done with data exchange, interoperability is about an equal understanding of the message (Brodeur, Bédard, & Moulin, 2005, p. 671) or as being "*in* tune" (Schramm, 1971). To achieve this in a direct data exchange, the *encoding* of the message must be "machine readable" and the *composition* must be "well structured" (Banerjee & Golhar, 1994, pp. 65-66; Angeles, Corritore, Basu, & Nath, 2001, p. 329 after: Chen and Williams, 1998). It is obvious that interoperability issues can also occur with indirect data exchanges. In that case demands towards machine readability and structure of the message are less relevant as a particular dataset is not interpreted by a machine directly.

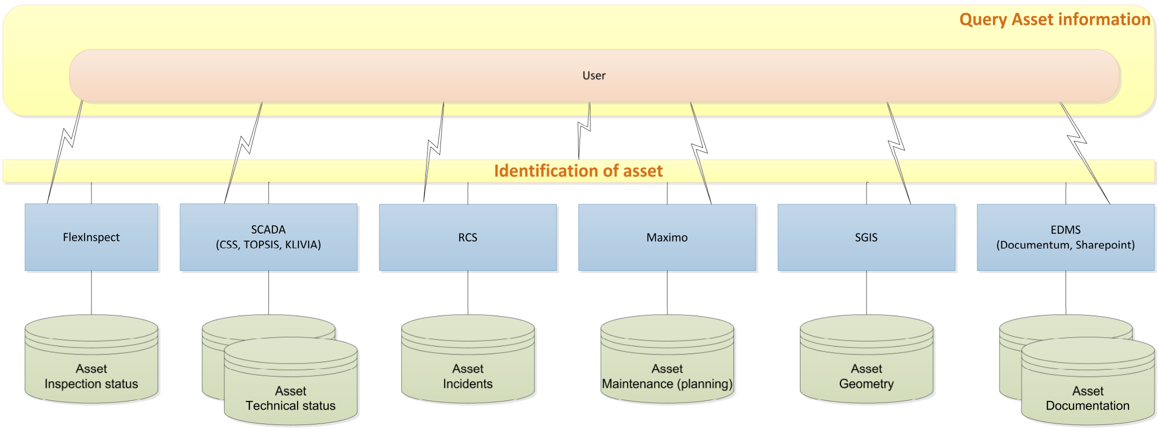


*Figure 3. Example of how a system architecture can look like. (Source: Schiphol)*

To understand the problems of interoperability it is important to know that a system is seen as one or more interacting elements (Naudet, Latour, Guedria, & Chen, 2010, after: Von Bertalanffy, 1968). As such, an element can be a single package of software as well as a set of (software) applications functioning as a whole. Other elements within a system can be hardware components, persons, policies and services (Naudet, Latour, Guedria, & Chen, 2010). The blue print for how the elements within a system need to work together is called architecture (Chen, Doumeingts, & Vernadat, 2008), see figure 3 for an example. The easiest way to compare two systems with each other, is to compare their architectures. The chance that two single systems within two different organizations are alike, are very small (Crook & Kumar, 1998, p. 76; Angeles, Corritore, Basu, & Nath, 2001, p. 338). However, when the individual elements from two systems are compared, chances will be higher that equal or alike subsystems can be found, which improves the chance for a successful data exchange.

Since the majority of systems are different, the communication and the level of understanding of one another's messages will be different too. The levels of interoperability between two separate systems range from incapable of communication to seamless communication. And although Jardim-Goncalves and Grillo (2010) claim that the latter *"remains elusive"*, it is the ultimate goal to reach (Peachavanish, Karimi, Akinci, & Boukamp, 2006, p. 73). I think that seamless communication is not that far away, because formerly isolated worlds (GIS and AEC) are starting to look at each other and started adapting each other's technologies (Van Oosterom, Stoter, & Jansen, 2005).

Within a system, it is also important how subsystems are integrated. Vernadat (2010, p. 140) distinguishes three levels for system integration, i.e. "*loosely coupled*", "*tightly coupled*" and "*fully integrated*" (see figure 4, respectively image 2, 3 and 4). The difference between the three levels can be found in the way the partial subsystems still can be identified as an individual subsystem. Loosely coupled systems function on their own, whilst it will not be possible to distinguish between subsystems in fully integrated systems (Chen, Doumeingts, & Vernadat, 2008). Tightly coupled systems are a hybrid, where subsystems are fully integrated, but still distinguishable. It can be expected that the creation of a fully integrated system will cause more interoperability issues than creating a loosely coupled system.

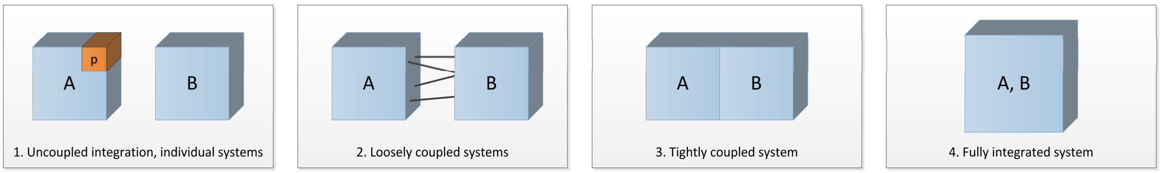


*Figure 4. An overview of the different system integration levels. (After: theory: (Vernadat, 2010); image: (Succar, 2009)) Note: the orange part in the first image represents a plugin.*

Another approach can be the development of a parallel system (Chen, Doumeingts, & Vernadat, 2008). Having two identical copies of (sub)systems should not cause any interoperability issues at all, however such a solution requires intensive organizational co-operation. Before such a step would be taken details have to be looked at also, because even a different version of the same software can be a cause of interoperability issues.

In my opinion it can be stated that interoperability issues in a data exchange can occur at all levels of parameters, characteristics, elements and properties. Knowing that, it is to be expected that a combination of solutions need to be applied to overcome these interoperability issues, although this may lead to additional problems (Farrés, 1992, p. 19).

## 2.5 Standards

Standards have not really been mentioned before, but should (in theory) be the key solution for data exchange. However, the differences in the properties of data have been a source for standardization needs for decades (Goldstein, Kemmerer, & Parks, 1998; Peachavanish, Karimi, Akinci, & Boukamp, 2006) and not one universal solution has been found yet. The problem is that there are some many different software packages, and even more formats and encodings exist, that it is hard, if not impossible, to come to a single solution. At the same time, the fact that these differences exist, is also the reason why standards are needed to overcome the differences.

Standards focus on a wide variety of solutions, e.g. geometry, data (exchange) formats, ontology descriptions, frameworks for data exchange, etc. However, there is not one single organization that focusses on these standards. For example, the Open Geospatial Consortium (OGC) and the Technical Committee 211 of ISO focus on handling spatial data, W3C establishes standards for internet related exchange and buildingSMART, together with ISO, creates standards for 3D modelling and semantics in the AEC industry. An optimal solution will require the cooperation of the different standardization organizations.

Often it is possible to distinct between proprietary and open standards. And although the use of open standards is widely promoted, especially in the public sector, proprietary standards still predominate. Knowing that most standards focus on a specific characteristic of data, makes it understandable that a working solution in data exchange should come from a combination of multiple standards (Farrés, 1992),. However, as stated before, combining multiple solutions, or in this case standards, can lead to additional problems (Farrés, 1992, p. 19). An example of how multiple standards can cooperate is given in figure 5.

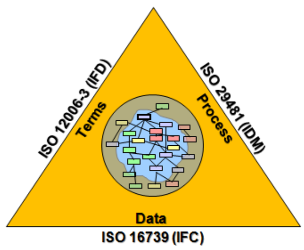


*Figure 5. Multiple standards working together (Source: buildingSMART (2008))*

A large group of standardization solutions looks at the development of exchange formats, which have led to open standards such as IGES and STEP in the 1970's and 1980's and XML, IFC and CityGML in the last two decades. These exchange standards were needed for two reasons: 1.) There are too many differences between individual formats to execute direct conversions (Brodeur, Bédard, & Moulin, 2005); and 2.) GIS data formats have never been designed to transfer update information (Badard & Richard, 2001, p. 19). Whilst exchange formats aim at a decrease of information loss in a data exchange, I think they add a significant risk of an increase of information loss, because an extra conversion has to be executed when such a format is used (see figure 6). Actually most of these exchange formats are not only a file format, but most also contain a data model with semantic meaning.

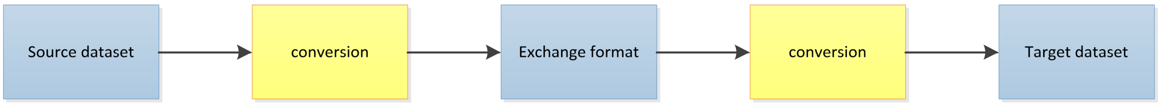


*Figure 6. Data exchange process including the use of an exchange standard.*

Open standards also offer a lot of possibilities but I can say from my personal experience that they are insufficiently supported by software vendors, e.g. IFC and (City)GML. Until this changes, open standards will possibly support a workable solution, but will not offer the complete solution that is needed. In my personal opinion software vendors should stop developing their own proprietary data formats and start working on a single CAD and GIS format that is easy exchangeable. Software vendors can then distinguish by the functionality their software offers, the user friendliness and the performance of their software.

Another solution, based on open standards, combines RDF (Resource Description Framework), URI's (Universal Resource Identifiers) and OWL (Web Ontology Language) (Curry, O'Donnell, Corry, Hasan, Keane, & O'Riain, In press). This way of working is also called "*linked data*" because objects can be linked to other concepts since their definition is clear in all aspects. One of the disadvantages of this approach is that it is designed for cloud data services and it can be questioned whether it is applicable within an organizational setting such as Schiphol, where security of information and data is a great cause. Secondly this method focusses on the exchange in a sense that it adds a layer between source and target datasets and does not offer a solution in terms of direct conversion.

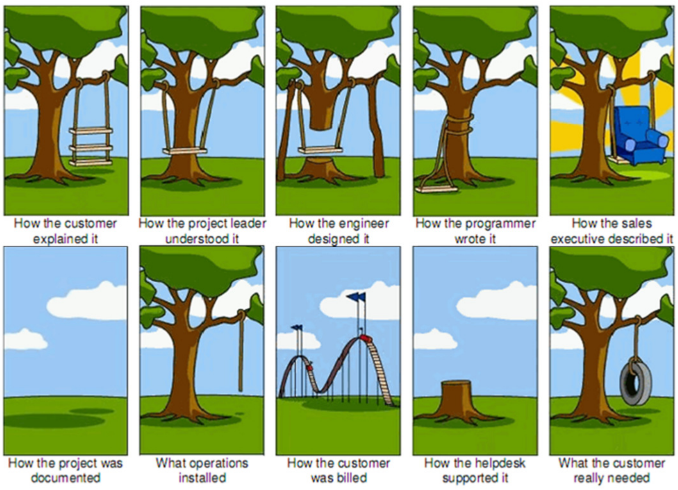


*Figure 7. Famous cartoon on different interpretations of the same concept, linked data has the potential to resolve this problem. (Source: Unknown)*

A possible application of linked data in the Netherlands is the development of a Library of Concepts, that has the potential to become a standard by itself. This library gives a "*generic and re-usable definition*", i.e. semantic, of objects and uses this description throughout the full life cycle of that object. The library is built up based on existing standards and a concept version is already available. The Library of Concepts is compatible with the most relevant standards within the Netherlands and Europe, being INSPIRE, IMGeo, NLCS and NEN2767, but also takes into account worldwide standards like IFC and the buildingSMART Data Dictionary (bsDD). It is expected that a first final version will be realized within two years (BIR, 2012). The biggest advantage of this library is that, if it is applied, information can be easily transferred between the different life cycle stages by its semantic meaning. However, this does not necessarily solve the issues of converting geometry.

Allthough the use of (open) standards in practice differs from the ideas in the scientific world, it is without a doubt that standards are needed to overcome current issues between the worlds of AEC and GIS. Therefor it will be necessary to use existing standards and work from that point forward to new standards (Van Oosterom, 2013) to overcome existing barriers.

## 2.6 Data usage

Before any solutions for (possible) interoperability issues can be offered, I am convinced that it is necessary to look at the question: "How is the data(set) going to be used?". That is because the use of a dataset influences the need for interoperable solutions. Although user requirements have been mentioned multiple times in literature as an important aspect to take into account when data is used or exchanged (Umar & Teichroew, 1990, p. 149; Reeve & Petch, 1999; Rajabifard, Feeney, & Williamsen, 2002, after: Rogers, 1993), the way a dataset will be used has not been described as such yet.

I propose three different ways of data usage, i.e. as-is, integrated or converted. With both as-is and integrated data use, a particular dataset can be used the way it is received, independently of how the data is received. The difference between these two ways of data use can be found in the way data is used within an application. As-is data is used within the same system environment as it was created, being its native software. When as-is data is used within an another system environment, without the need to convert it, the data use is integrated. If any aspect, being an element, property or characteristic, of a dataset needs to be altered before it can be used, it is called converted data use.

### 2.6.1 As-is data use

As-is data use is the most beneficial use of a dataset, because nothing has to be changed and the data can be used directly. As-is data can be used for all kind of different activities, such as map making (when the data has a geographical component), reporting, editing, analysis, etc. The advantage of as-is data use is the fact that the data is used within its original system environment, enabling all the functionality that the original environment offers.

Updating an existing database with a dataset that contains data in the same data model, i.e. data interchange, is an explicit example of as-is data use. Since target and source dataset share the same data model, it is easy to locate the changes and to update the target dataset.

### 2.6.2 Integrated data use

The concept of integration is often referred to as being seamless conversion (Van Berlo & De Laat, 2011, p. 213; Wu & Hsieh, 2007, p. 1085) or as "*semi-automated* conversion" (Peachavanish, Karimi, Akinci, & Boukamp, 2006, p. 72). Both explanations are understandable but in my opinion not correct, simply because of the use of the word "conversion". Integration should be explained as the use of a dataset in its original format, encoding and composition, in a different system environment than it was created in, e.g. the use of a dwg-file (AutoCAD drawing) within ArcGIS. Because the system environment differs from its original environment it is possible that interoperability issues arise. It is possible that data is displayed in another way or that certain information will not be visible or interpreted differently by a foreign system. Also, most examples of integrated data use only support the activity of reading data and not editing it, but there are exceptions, e.g. multiple GIS datasets can be edited and stored with AutoCAD Map 3D. Integrated data use can be useful to compare datasets from different sources within one application. Often a plugin is required to make it possible to use foreign datasets within a system, but this is not always the case.

These examples are really about integrated data use and differ from integrated systems as described earlier (see paragraph 2.4). Therefor I suggest to add another category of system integration, being uncoupled integration (the first image in figure 4). With uncoupled integration data is used over more than one application but without an actual integration of the applications.

The major advantage of integrated data use is that datasets can be used in their proprietary formats, but within a foreign system environment. In this case it is not necessary to convert data and therewith the risk of information loss is eliminated or at least limited to a minimum. A disadvantage can be that within the foreign system environment not the same (read: probably less) tooling and functionality is available. However, since the data is in its original encoding and composition it still can be used in its native environment, eliminating this issue.

### 2.6.3 Converted data use

If it is not possible to use a dataset as it was received, it needs to be converted. When a dataset is converted, there is always a risk of losing information, because changes need to be made to the dataset. These changes can include any of the characteristics (see figure 1) of the source dataset. To determine these changes in a dataset, it is of up most important to understand both the source and target dataset and their data models. Two examples of possible challenges are shown in figure 8 and table 3. The first example shows geometrical challenges that are likely to be overcome. However situations where a source object has a lower dimensional level than the target object, e.g. a point that has to become a polygon, are of a different order and need additional information.

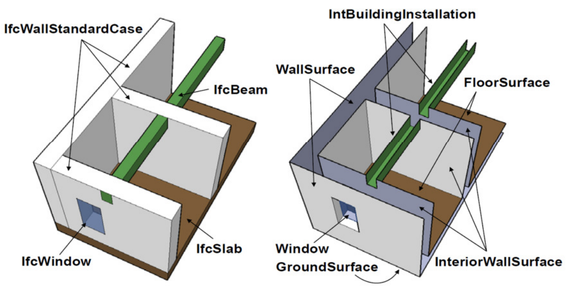


*Figure 8. Different (geometrical) representations between IFC (left) and CityGML (right) used for the same objects (Nagel, Stadler, & Kolbe, 2009, p. 50).*

| | Source | | Target |
|---|---|---|---|
| 1. | Entity | vs. | Entity |
| 2. | Attribute | | Attribute |
| 3. | Entity | | Attribute |
| 4. | Attribute | | Entity |
| 5. | Completely different representations | | |

*Table 3. Classification of schematic heterogeneity. After: Bishr (1998)*

Table 3, the second example, shows schematic challenges. The situation described in the first and second row of this table will probably cause limited to no problems. The other three examples in the table however, are expected to cause serious issues in the conversion, because source and target characteristics do not match. Considering all the possible issues, makes it easy to understand that the costs for data conversion must not be underestimated, as they can increase quite fast (Umar & Teichroew, 1990, p. 150).

Depending on experience, differences in characteristics between source and target datasets, available resources and other factors of influence, a choice has to be made on how a conversion is going to take place. There are different (technical) solutions to choose from (table 4) and there are also different strategies for conversion (table 5). Both, solutions as well as strategies, can be chosen independently from each other.

Looking at the conversion solutions, it is easy to say that the manual transformation is least favoured of all proposed solutions, since manual transformations are time consuming and do not guarantee that errors are excluded (Peachavanish, Karimi, Akinci, & Boukamp, 2006, p. 71). It can even be expected that manual transformations increase the risk of error-making. Another problem is that different users might make different choices when converting data, which makes the conversion inconsistent. From that perspective automated conversions are favoured above manual transformations. The expected advantages include faster execution and a lower amount of errors. But most of all, automated conversions offer the possibility of re-use. This means that a conversion between two datasets only has to be created once and can be re-used every time the same situation comes back again.

| Conversion solutions |
|---|
| Manual transformations |
| Transformation with programming language |
| (R)DBMS proprietary language, e.g. SQL |
| Use of ETL scripts or software |

*Table 4. Overview of different technical solutions for conversion (after: Peachavanish et al (2006), Carreira et al (2007))*

The second and the third solution, respectively using a programming language and the proprietary language of an application, are somewhat alike. Both use the software that is also used for the dataset itself. The difference is that a transformation with a programming language means that additional functionality is created within the application by programming in a language such as C, .NET, JAVA or Python and that the second situation uses the proprietary language of the (database) application itself, e.g. SQL (Carreira, Galhardas, Lopes, & Pereira, 2007).

The last solution uses a separate set of software that is known as ETL (Extract, Transform and Load). The principal of this type of software is that it reads a certain dataset – often tens to hundreds of different file formats can be read –, converts it into its own proprietary format, works through a number of user generated transformations and then writes (i.e. loads) the data into the desired format and encoding. The proprietary format of the ETL software is often designed as a kind of 'super type', being able to support all the different characteristics datasets can have. Examples of this kind of software are FME and GeoKettle/Spatialytics ETL. There is a large number of other ETL software applications, but most of them do not support spatial data. A disadvantage of the use of ETL tools is that the user is dependent on the formats and encodings that are supported within that specific ETL tool.

| Conversion strategies |
|---|
| Mapping |
| Alignment |
| Transformation |
| Fusion |

*Table 5. Strategies that can be chosen for conversion (after: Izza (2009))*

Table 5 offers four different strategies for executing a conversion. These strategies refer to the approach to solve ontology heterogeneities as proposed by Izza (2009) and are based on earlier work of Klein (2001) and Kalfoglou and Schorlemmer (2003). In my opinion these strategies can be applied to data exchange as a whole and not only for ontology. The strategies are explained hereunder:

- Mapping:
  With the mapping strategy alike concepts are linked to each other, but not physically connected. This strategy helps understanding the differences and similarities between two different datasets and can be a first step for the other three strategies, especially for those objects that cannot be paired.
- Alignment:
  The alignment strategy compares two different datasets and alters them in such a way that both datasets can handle the same objects as the other dataset. So to say, they fill the gaps that are present in the other dataset. This approach is suitable when a seamless data exchange is needed between two partners, or with related datasets such as a 1:10k and a 1:50k topographic map.
- Transformation:
  When two datasets are not alike and the target dataset cannot be changed, the source dataset needs to be transformed. These transformations can affect all characteristics of the data. A transformation alters a copy of the source dataset, in such a way that it suits the data model of the target dataset.
- Fusion:
  When two or more datasets are turned into one new dataset, it is called fusion. Fusion can be of use in standardization efforts as well as in creating new datasets for merging organizations. To get physically to the new dataset a transformation might be needed.

Although the first two strategies do not need conversions themselves, they are important to look at when data cannot be used as-is or integrated. Two base principles in ontology (Bishr, 1998, pp. 305, 307) should be kept in mind when comparing multiple datasets, in particular when the datasets are being used over multiple domains, e.g. design, construct and maintenance:

- Objects can refer to the same real-world phenomena with different representations; and
- The same representations can refer to different real-world phenomena.

Another way to approach data conversion is by looking at behaviour and functions (Naudet, Latour, Guedria, & Chen, 2010). No matter what approach is chosen, it is important to understand the true meaning of an object within its source and target dataset to find the most suitable mapping or transformation for each type of objects. Based on the different conversion strategies and data use possibilities I created a selection chart to find the most suitable conversion strategy for a particular situation (see figure 9). The chart helps to select the most appropriate conversion strategy for a specific case. Although it is called a conversion strategy, not all strategies ask for a conversion of the data. Therefor the term 'data exchange strategy' will be used from here on instead.

The strategy at the top has not been mentioned before as a strategy, but this type of data use can be seen as such. Also, it is possible to further extend the selection chart for the '(fusion with) conversion' strategy with the different characteristics of a dataset, but that would only make the selection chart superfluous complex at this point. However it is something to take into account when a chosen strategy is worked out.

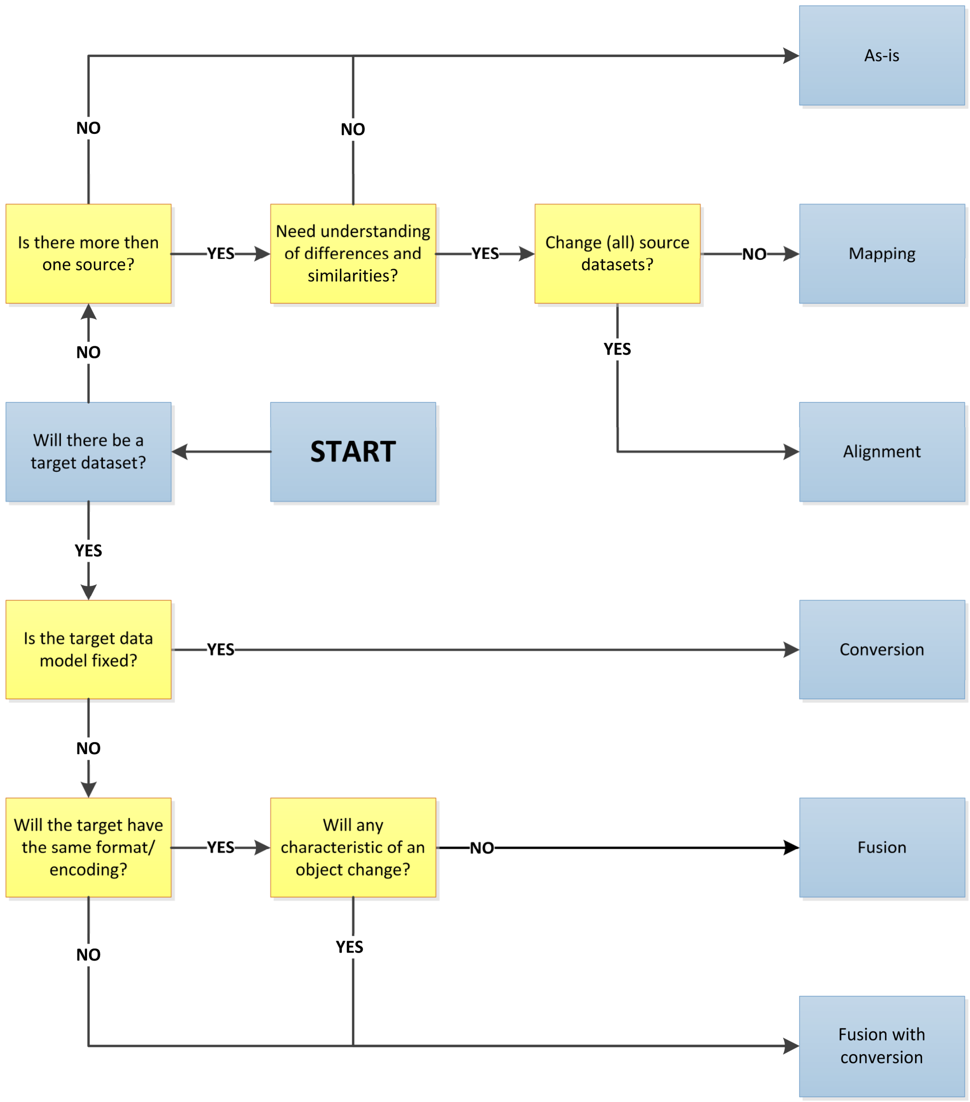


*Figure 9. Selection chart to find the most suitable data exchange strategy.*

At the start of the selection chart the user has to choose whether a target dataset will be created or is already present. The basis for this choice lies in the fact that it is possible to only use source datasets, without creating new datasets. When this is the case, it is necessary to know whether there is only one source dataset or that there are multiple data sources. If there is only one source, there is nothing to compare and the data can be used as-is. If there are multiple source datasets, they can be compared. If a comparison is made without the aim of changing one or more of the source datasets, it is possible to create a (virtual) mapping of the differences and similarities. If it is the aim to change one, multiple or all datasets, it is also possible to align the datasets. In that case the relevant datasets will be adjusted so they can handle each other's data. Again, if there is no need to understand the differences and similarities, the datasets can be used as-is.

If a target dataset is present or a target dataset will be created, another trail has to be passed. A fixed target dataset, in other words a data model that cannot be changed, will result in a conversion. Within this conversion the characteristics of the source dataset will be changed in such a way that they meet the requirements of the target dataset. This strategy was earlier explained as transformation, but the term conversion is more generally used for this kind of activity and a transformation mostly points at a transformation of coordinates and that is just one of the many parameters that can be changed. If the target dataset is not fixed, it is possible to merge two source datasets into a new dataset. In that case fusion is the right strategy. The situation can occur that the new data model does not fully meet the requirements of the input data, e.g. different kinds of attributes or geometries are supported, in that case a combination has to be made between fusion and conversion.

## 2.7 Data exchange interaction

The previous paragraphs described issues with data exchange, but there is more to data exchange than just systems and data. Reeve and Petch (1999) claim that the people within the organization are at least as important as the organization itself. The success rate of a data exchange depends on whether or not social components (i.e. people within and between organizations) have been taken into account (Umar & Teichroew, 1990, p. 149; Reeve & Petch, 1999; Rajabifard, Feeney, & Williamsen, 2002, after: Rogers, 1993). In addition policies, standards and access network, being summarized as dynamic technological components (Angeles, Corritore, Basu, & Nath, 2001; Rajabifard, Feeney, & Williamsen, 2002, pp. 13-14), add another group of components that also should be considered important in data exchange. These dynamical technological components make it possible for systems to communicate and so to exchange data.

Since an exchange happens between a sender and a receiver, having the components organization, people, system, software and data at either side, interactions take place between each set of components (Farrés, 1992, p. 19; Crook & Kumar, 1998, p. 76) or at each level of components. The interactions on the technological level also use components themselves. When I combine these components and their interactions, I come to a framework for data exchange interaction, as displayed in figure 10. The proposed framework shows the mutual relationships in a hierarchical order. It is not to be said that this hierarchical order also applies to the interaction levels themselves, but it seems logical since a lower interaction level cannot exist without the presence of a higher one. The four interaction levels in figure 10 will be explained in the following paragraphs.

The used colours within the framework are also applied within other images through this report. Green and purple are used for data, blue is applied to software and systems, yellow represents processes and the orange and brownish colours are respectively used for people and organizations.

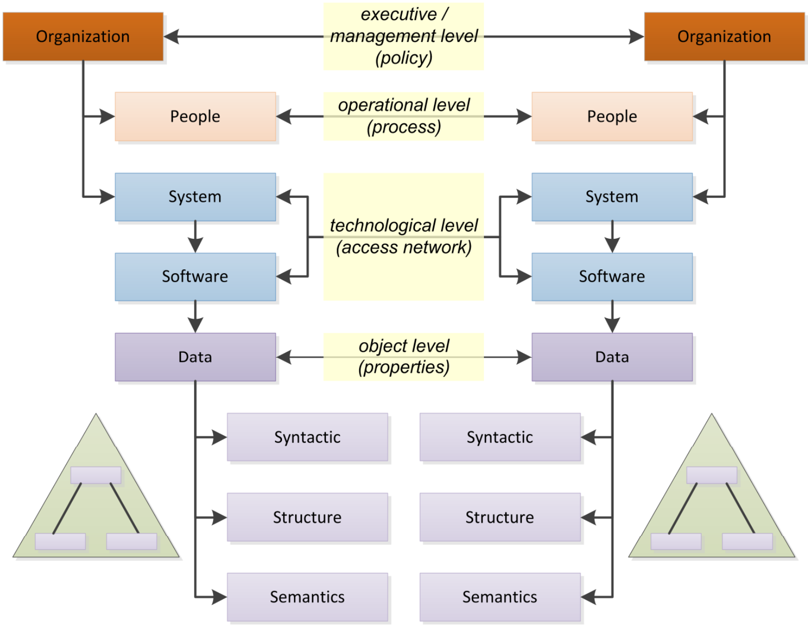


*Figure 10. Framework for data exchange interaction.*

### 2.7.1 Executive and management level

In their book Reeve and Petch (1999) distinguish three levels within organizations, i.e. operational, research & management and executive. The last two levels, research & management and executive, are responsible for setting the goals and core values of the organization and subsequent the policies that can be distracted from those goals.

The contents and the methods used for data exchange are largely depending on the organizations' motive for exchange (Clarke, 1983; Kirby, 1993; Du, Lai, Cheung, & Cui, 2012). Since the motives of an organization are related to the goals and core values and indirectly also to the organizations' policies and strategies, this level of interaction is one of the keys to the success of a data exchange.

The internal values that are not the only aspects that are responsible for the success for data exchange. The mutual relationship between organizations is also of great importance. If a data exchange takes place from a partnering point-of-view, both organizations should share the same values and use data exchange to become more effective and to save costs (Baldwin, Thorpe, & Carter, 1999; Angeles, Corritore, Basu, & Nath, 2001, p. 338). The situation is different when a data exchange takes place within a client – contractor relationship. In most cases both organizations will have different views on the necessity and the contents of the data exchange. Since their views on the exchange of data are different, the chances of success will be much smaller. Together with satisfaction on the outcome of a data exchange, the improvement of inter-organizational relationships is described as the most important success factor in data exchange (Nedovic-Budic & Pinto, 2001, p. 295) from an organizational perspective. This improvement can be achieved by a dedication to common goals and an understanding of each other's individual expectations and values. On the opposite of that are organizations that focus on power and do not have a (natural) trust in their partner or client (Crook & Kumar, 1998, p. 76).

Other relevant issues on the executive and management level are legal issues and the anxiety for the misuse of data (Tenopir, Van der Hoeven, Palmer, Malone, & Metzer, 2011). However this topic lies outside the scope of this research.

### 2.7.2 Operational level

The operational level deals with the people who work with the data themselves and who are said to be responsible for both the data and the actual exchange. This is the level that clearly benefits most from a successful data exchange (Angeles, Corritore, Basu, & Nath, 2001).

Where policies are the key component at the executive and management level, processes are the key component at the operational level. The aim of data exchange is often to streamline these (business) processes. Control of these processes and the ability to manage the necessary changes are seen as critical success factors for a successful data exchange (Benjamin, de Long, & Scott Morton, 1990; Farrés, 1992; Angeles, Corritore, Basu, & Nath, 2001).

There are two major issues within the operational level (Angeles, Corritore, Basu, & Nath, 2001):

- Lack of support by the management level.
- Personnel with different business orientations.

The need for top management support seems obvious, i.e. if the management fails to see the added value or cost savings, that can be achieved by exchanging data, they will not (financially) support the changes needed. Another problem arises when personnel in charge of the data exchange have different interests. Instead of working together they will be working against each other and fail in getting to a successful data exchange. An aspect that was not described earlier is that the people that work on the actual exchange have to apply the same terminology in order to understand each other.

### 2.7.3 Technological level

The technological level connects systems, that include software as an element. The most important component at the technological level is the 'access network', but also the other technical components, such as policies and standards, should be taken into account (Rajabifard, Feeney, & Williamsen, 2002). The policies at this level differ from the policies at the executive & management level in that sense that these policies refer to IT related policies whilst the policies at the executive and management level refer to organizational policies.

Important is also the dynamic character of this technological level and especially the access network (Angeles, Corritore, Basu, & Nath, 2001, p. 339; Rajabifard, Feeney, & Williamsen, 2002). With current technological capabilities the exchange of data does not only take places between organizations, but also within organizations. Current technological opportunities have the ability to create the access to networks that is needed to work online with cell phones, tablets and pen computers. These opportunities allow a broader application of data exchange, especially within organizations. The earlier mentioned communication means are a part of this *access network*.

Another development of the last decade, that underlines the dynamic character of the technological level, is the possibility to receive real-time updates (Badard & Richard, 2001). Where in the past indirect communication was the only possibility, nowadays direct communication offers the possibilities to shift from on-demand to real-time information streams. This development has become possible because data connections are increasing in capacity. Where a decade ago 14kb/s download and 4kb/s upload was the standard, speeds up to 100mb/s for both down- and uploading data are nowadays becoming the standard. I expect that this increase in direct communication means has also led to an increase of (inter-organizational) data exchange.

### 2.7.4 Object level

At the bottom level data itself can be found, with all of its characteristics as described earlier. This is the level where, so to say, the *magic happens*. Most aspects of data exchange at this level have been outlined earlier in this chapter, but some specific aspects on data structure are explained hereunder in more detail.

As was explained already, the syntactic properties apply constraints towards the structural possibilities of a data model. Not all file types support the same attribute types or the same geometrical primitives. Having differences in these characteristics between two file types will potentially lead to a loss of data.

There is a large variety in attribute types, examples of the most common types include the types 'text', 'integer' and 'double'. However, an analysis of the 'integer' type shows that it can be split up in 'short integer' and 'large integer', where different terms are also applied. The 'text' type can also be called 'character' and the attribute type 'date' knows many different ways of storing the information. Not alone differences that include (or do not include) time, but also the notation can be different. These are all aspects that should be analysed and taken into account when data is exchanged over multiple file formats.

The support of different geometrical primitives is a different story. Most applications support the simple 0D to 2D geometrical primitives. Although 1D and 2D can already have different options for using composite objects, for example objects that contain arcs. Different support of arcs can lead to unexpected results when a dataset is exchanged. Hereunder (figure 11) three of the most basic 3D primitives are shown. Most CAD software can work with this kind of objects without any problems, however most GIS applications do not, or hardly, support these primitives. Complex primitives are even a different story, because within CAD systems different ways of support are used to edit and maintain these features. This is something to think about when data (with a 3D component) is exchanged, because objects might get a different shape after an exchange (or conversion) to another file format.

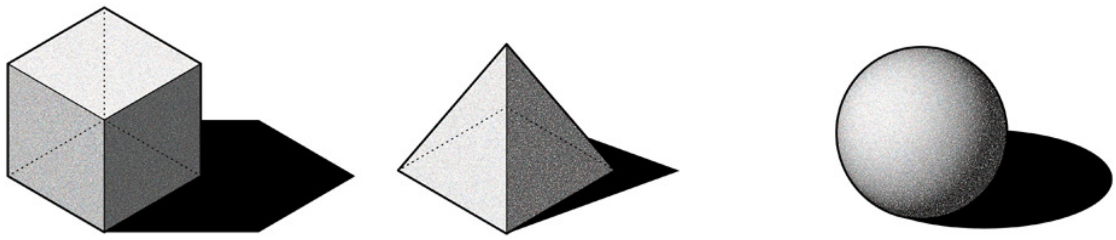

*Figure 11. Examples of different 3D geometries, each having its own specific properties. (Source: (Pazik, 2012))*

Related to that is the aspect of scale or Level of Detail (LoD), as it is also referred to. The use of certain software is often related to the aim of certain tasks. These task often apply data on a different scale, because more or less detail is needed to work with the data. For example CAD software is mostly used to display much details of one object, whilst GIS software is used to present many objects containing a higher level of abstraction (Van Oosterom, Stoter, & Jansen, 2005, p. 12). These differences should be kept in mind when data is used over different applications with different aims.

## 2.8 Conclusion

Data exchange is dependent on many variables, that can be classified according to the interaction levels in the framework for data exchange that I proposed. The framework for data exchange interaction provides the most important levels on which agreement is needed for a successful data exchange between a sender and a receiver. On each level there are separate variables that influence the exchange, such as syntactic, structure and semantics on the data level, communication means and system integration on the level of systems and software and inter-/intra-organizational relationships on the level of organizations.

Some standards can be supportive for data exchange, while others add a risk of information loss. Most important is that it needs to be realized that exchanging data is not only a matter of technical issues, but organizational issues and social issues should be taken into account as well.

# 3 Building Information Modelling

"*Buildings of our current digital era are said to be more complex by information structure than buildings of industrial modernism … This gives us more requirements and sets new needs to manage all the building related information of our time*" (Pentillä, 2006, p. 405). In short this is todays challenge and it is said that BIM is the answer.

| B | I | M |
|---|---|---|
| Building (noun) | | Model |
| Building (verb) | Information | Modelling |
| Builders' | | Management |

*Table 6. Multiple explanations of the acronym BIM*

BIM is an acronym and goes under different explanations as can be seen in table 6. The only constant factor seems to be the "I" for information. Pentillä (2006, p. 405) was expecting that BIM would become a popular development within the construction industry and he was right. A Dutch explanation of the acronym (Bijzonder Irritant Modewoord) can be translated as "Particularly Irritating Buzz-word", which indicates that a lot of people seem to be busy with BIM. Succar (2009, p. 358) thinks that the growing interest in BIM is the result of the recognition that BIM can add value to the building process when it is compared to traditional building methods.

*Figure 12. The Tower of Babel by Pieter Breughel the Elder (1563), a biblical story where people no longer understood each other during the construction of the tower.*

As in any new field, the backside of the popularity is that people no longer talk about the same subject (Benjamin, de Long, & Scott Morton, 1990, p. 20); everybody has its own ideas of the true meaning of the acronym BIM. In that sense I think that at this moment BIM can be compared to the Tower of Babel, people think they are talking about the same, but in the end they mean something completely different (and thus do not understand each other). A short inquiry by Moor (2011) confirms this assumption. He asked different people to give a definition of BIM within 50 words, what resulted in twenty-three different definitions. A review of scientific literature shows a similar picture, although the definitions are much more alike, as can be seen in the citing's hereunder:

*"BIM is the ''process'' of generating and managing building information in an interoperable and reusable way"* (Lee, Sacks, & Eastman, 2006, p. 758)

"*BIM is a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle.*" (Pentillä, 2006, p. 403)

"*BIM is the 3D modelling system with data management, data sharing and data exchange during the lifecycle of the building.*" (Vanlande, Nicolle, & Cruz, 2008, p. 71)

"*Building Information Modelling (BIM) is an IT enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project lifecycle in the form of a data repository.*" (Gu & London, 2010)

"*A digital representation of physical and functional characteristics of a facility.*" (NIBS, 2012)

"*BIM is regarded as having two distinct meanings: either to identify a particular category of engineering software, or to denote a process view of the industry*" (Watson, 2011, p. 574)

The indistinctness about BIM also becomes clear by the question Watson asks (Watson, 2011, p. 574): "*Does the model refer to the underlying schema or to the instantiated model of a specific building, and is the term modelling intended as a noun or a verb?*"

A possible explanation for the large number of different definitions can be found in the increasing number of organizations implementing BIM (Succar, 2009) which led to an increasing number of views on the topic.

Within this chapter attention is paid towards these different views on BIM, the history of BIM and a possible parallel between BIM and a GIS principle. From this point forward the terms 'asset' and 'object' are being used instead of the term 'building', as being a noun, since BIM is not only about buildings, but can also be applied to e.g. bridges and roads. Actually BIM is applicable for any object that can be built. Off course it is also possible to apply BIM to the 'maintenance' of natural objects.

## 3.1 Views on BIM

Scientific literature does not always align with practice as can be seen from the example of Moor (2011) and the citing's from literature in the previous paragraph. Looking at popular magazines, weblogs and conferences it becomes clear that people in the AEC industry have other explanations of BIM than scientific literature (Succar, 2009, p. 358). Often these non-scientific explanations focus on the activities of the person asked. In the following paragraphs different views on BIM are exposed and some important aspects of these views will be explained in more detail.

### 3.1.1 Data

The central word in the acronym BIM is information. Since information is data within a context, BIM is all about data and its context. The context is given in by the model the data is stored in. The data itself, on the other hand, is a different story. The views of BIM as being data is described hereunder.

BIM as being data, can refer to a model describing an object (Eastman, Teicholz, Sacks, & Liston, 2011) containing a virtual representation of (a part of) that object (Björk & Pentillä, 1989, p. 176; Watson, 2011, p. 573). Since BIM is not only about buildings, but can represent any asset, the model should be seen as "*the total of information about an asset*" (Cerovsek, 2011, p. 226). An example of a BIM model not being a building, e.g. a railroad bridge over a river, can be seen in figure 13.

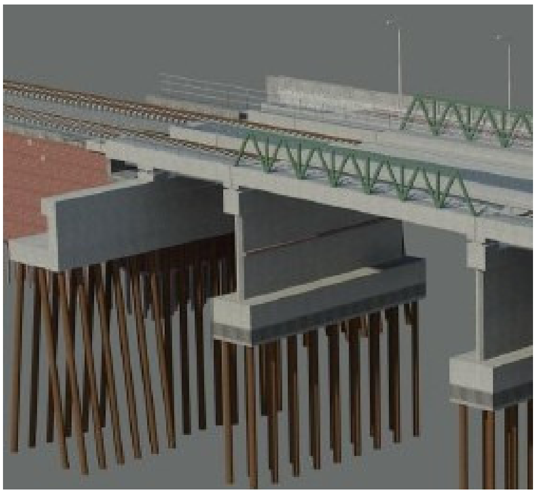

*Figure 13. Example of a BIM model that is not a building (© Heijmans, 2010).*

To be able to work with BIM models it is relevant to make the models consistent in all their aspects (Watson, 2011, p. 574). A model describes how the data is structured and what data must be stored in that specific model (Björk & Pentillä, 1989, p. 176), i.e. the context, to get relevant information out of it. The activity of creating such a model is called modelling (Eastman, Teicholz, Sacks, & Liston, 2011). Some people see the activity of modelling as being the true meaning of BIM.

Another view of BIM as being data is looking at the (file) format and the encoding, either being open formats and/or proprietary formats. In terms of BIM and data, there is one main open standard, being IFC (i.e. Industry Foundation Class; a short description is given hereunder). There are more open standards, such as CIS/2 for steelwork, but IFC is mostly used (Watson, 2011, p. 574).

Although the use of open standards is widely promoted, from experience I can say that proprietary formats are used more commonly in the AEC industry, which is confirmed by colleagues and account managers from software vendors. This can be explained by the fact that companies use a specific group of software, often from one vendor. Secondly, I have noticed that people within companies working with BIM software often do not even know about open standards. For companies, from the perspective of interoperability, it is also easier to use native data formats than to use open standards, because open standards need all kind of data conversions, with the risk of data loss, while different software packages from the same vendor can often 'talk' to each other and 'understand' their own data formats. According to the previous chapter, issues can arise when these organizations want to exchange their data with other organizations that use other software. It is possible that they will have to turn to (open) standards to be able to successfully exchange their data.

***IFC***

IFC is an ISO standard (ISO 16739) and contains a data model[2]. It is part of a framework that also contains an ISO standard containing a dictionary (International Framework for Dictionaries; ISO 12006-3) and an ISO standard for process management (Information Delivery Manual; ISO 29481) (buildingSMART, 2008).

The data model is developed for buildings and over time additional functionality was added with so-called property sets (Psets). The data model can be stored as *physical STEP file* or as XML. An example of how these codes can look like is respectively given in figure 14 and figure 15. Additional attribute information can be added to IFC, but therefor it is necessary to define your own Pset.

The data model describes different elements and allows them to be used differently in hierarchy. This means that it might not be clear up front how a window is placed in a wall within the model. This can cause problems if someone modelled data differently than another expects.

An IFC file stores the geometrical information relatively to a parent object. This makes it easy to change objects, but

```
#1916= IFCBUILDINGSTOREY('1smz0v6l10Nxym5PBdZkqX',#13,'-1. Keller',$,$,#1913,$,'-1. Keller',.ELEMENT.,-2.9);

#13= IFCOWNERHISTORY(#12,#5,$,.ADDED.,$,$,$,1295253721);
#1913= IFCLOCALPLACEMENT(#1893,#1910);
```

*Figure 14. An example of a line of code from an IFC file in STEP encoding, including two lines of code referred to.*

```
<IfcBuildingStorey id="i3453">
 <GlobalId>1smz0v6l10Nxym5PBdZkqX</GlobalId>
 <OwnerHistory>
 <IfcOwnerHistory xsi:nil="true" ref="i1550"/>
 </OwnerHistory>
 <Name>-1. Keller</Name>
 <ObjectPlacement>
 <IfcLocalPlacement xsi:nil="true" ref="i3450"/>
 </ObjectPlacement>
 <LongName>-1. Keller</LongName>
 <CompositionType>element</CompositionType>
 <Elevation>-2.9</Elevation>
</IfcBuildingStorey>

<IfcOwnerHistory id="i1550">
 <OwningUser>
 <IfcPersonAndOrganization xsi:nil="true" ref="i1549"/>
 </OwningUser>
 <OwningApplication>
 <IfcApplication xsi:nil="true" ref="i1542"/>
 </OwningApplication>
 <ChangeAction>added</ChangeAction>
 <CreationDate>1295253869</CreationDate>
</IfcOwnerHistory>

<IfcLocalPlacement id="i3450">
 <PlacementRelTo>
 <IfcLocalPlacement xsi:nil="true" ref="i3430"/>
 </PlacementRelTo>
 <RelativePlacement>
 <IfcAxis2Placement3D xsi:nil="true" ref="i3447"/>
 </RelativePlacement>
</IfcLocalPlacement>
```

*Figure 15. An example of a code block from an IFC file in XML encoding, including two blocks of code referred to. This example shows the same objects as the example in figure 14.*

[2] The full resource for the current IFC data model and its area of application can be found online: http://www.buildingsmart-tech.org/ifc/IFC2x3/TC1/html/index.htm

makes it harder to quickly locate an object in its real world location. However it is possible to contain the location in the IFC file in the WGS84 reference system. Attributes such as height and thickness are often included, but IFC does not work parametric. As a result the attributes can differ from the geometric values of an object.

When one is depending on multiple suppliers of data, which is often the case for public clients, it is preferable to receive data in a consequent manner. In that case open standards, such as IFC, seem to be a logical choice. Not only because most software packages are able to export to such an open standard, but mainly because governments are not allowed to prescribe a specific commercial software (OSOR Editorial team, 2011). This means that it is very important for a client to write a good set of technical specifications, containing a description on what should be delivered and how it should be delivered.

BIM can be applied to 2D models, but a majority sees BIM as being a 3D design of an asset. Where traditionally all AEC design projects were done in 2D, which delivered easy to read drawings for most people, the last view years design takes place in a 3D environment more and more. Although representations in 3D are harder to read by themselves than a single traditional 2D drawing (Howard & Björk, 2008, p. 272), a 3D model gives a better overview than the combination of multiple 2D drawings that are needed to give the same overview of a certain situation.

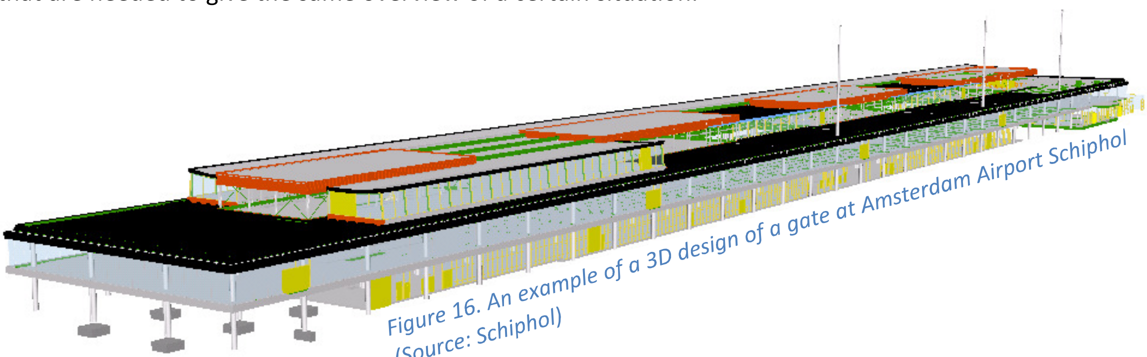

Figure 16. An example of a 3D design of a gate at Amsterdam Airport Schiphol (Source: Schiphol)

Another aspect of the 3D design is that entities have the potential to become object-oriented (Succar, 2009), no longer being individual geographical representations that are not related, but objects with relations and additional information, as can be concluded from the previous paragraphs. If they were just individual lines, it is obvious that a 3D design alone cannot be called BIM (Eastman, Teicholz, Sacks, & Liston, 2011, p. 19), in such a case it could even be compared with a traditional 2D CAD drawing without any intelligence. However with the added information and the mutual relationships, all can be seen from another perspective. The next step in 3D design is the use of parametric objects, where the attributes of the object describe how the object is built up and its representation changes when its attributes are changed (Succar, 2009, p. 364; Cavieres, Gentry, & Al-Haddad, 2011, p. 717). Nowadays some people state that BIM can only be applied if the model contains 3D data, because otherwise it is not possible to analyse the mutual relations of objects in a reliable way.

One aspect of BIM data that has not been mentioned, are the levels of detail (LoD), which can be seen as a representative of the data characteristic 'scale'. The LoDs are "*descriptions of the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision*" (AIA, 2008). During a design phase, the different steps will become more and more detailed, until finally a situation is created that can almost be seen as a 1:1 copy of what will become reality. Within BIM five levels of detail are distinguished, from 100 to 500, each increasing with another 100, as can be seen in table 7. A LoD of 100 is schematically (with e.g. a scale of 1:100) where a LoD of 500 contains the *highest level of*

| LoD | Description |
|---|---|
| 100 | Conceptual |
| 200 | Approximate geometry |
| 300 | Precise geometry |
| 400 | Fabrication |
| 500 | As-built |

*Table 7. Overview of the different LoDs and their description. (Source: AIA (2008))*

*representational precision*. It is important to understand these differences, including their application throughout the asset life cycle, as will also be shown in the V-model in one of the next sections. It is not necessary to apply the same LoD to all the objects in a design, on the contrary, finding a good balance in the different needs for LoD helps creating the design. The description of the LoD should be a part of the data model description that a client should set up. It is interesting to see that a GIS data exchange model, i.e. CityGML, also makes use of different Levels of Detail, however the implementation of these levels differs from the LoD classification that is used with BIM projects. Figure 17 gives an overview of the Levels of Detail that can be found in CityGML. Although it is possible to apply 2D modelling in a BIM project, it can be expected that mostly 3D modelling is applied, because from the third dimension on, BIM becomes the most beneficial. When this is compared with the LoD's of CityGML, it is to be expected that BIM projects, independently from their design stage, will cover at least LoD3 and in most cases LoD4 of CityGML.

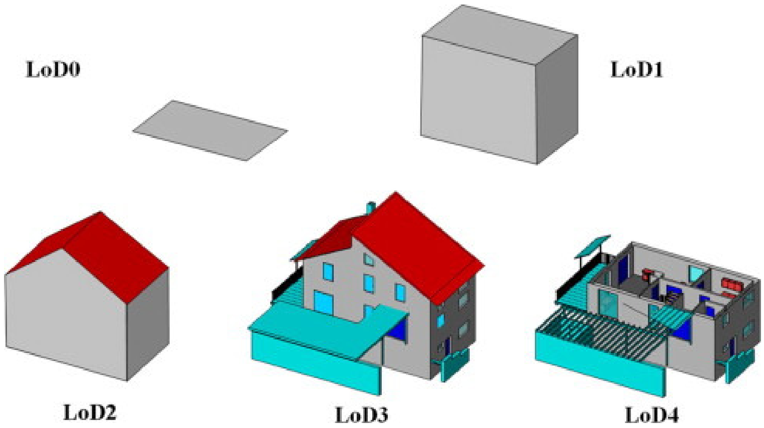

*Figure 17. Overview of the different Levels of Detail of CityGML. (Source: Gröger and Plümer (2012))*

The traditional division in one, two and three dimensions is commonly known and the addition of time as a fourth dimension is also widely accepted. Within BIM additional dimensions are added, such as cost as a fifth dimension or Systems Engineering as a sixth dimension. In my opinion it is not fair to speak of dimensions, but should be spoken about domains or themes, as was also suggested by Van Oosterom and Stoter (2010, p. 313), who claim: *"… However nD modelling focuses mainly on integrating multiple thematic, and not multidimensional, concepts"*. This is, because it is not about e.g. dimensions such as time and space, but mainly on a broader application of BIM in terms of connecting calculation software, maintenance programs, suppliers ( software) and electronic document management systems (EDMS).

### 3.1.2 Technology

Although technology as such is not looked at as a specific view, technology is an essential part of BIM and different parts of technology are seen as separate views on BIM. Technology creates the link between peoples and data (Rajabifard, Feeney, & Williamsen, 2002, p. 14). In that sense, technology is about the components that are needed to connect (relevant) stakeholders with their information.

The most obvious technology view is software. BIM software is, in my opinion unjustified, seen as a special class of software, going far beyond the traditional AEC software. The biggest difference is that so-called BIM software is object-oriented instead of layer oriented like regular AEC software. Object-oriented information can hold information that is related to the object itself, which is not the case with layer-oriented software. However one cannot really speak about specific BIM software; in fact the combination of linked software systems, where at least one system holds a geometrical model, makes it that someone applies BIM. The data from the different software packages is than linked based on a unique identifier, i.e. a loosely coupled system.

Hardware is not seen as a separate view, but without it, BIM is not possible. The (3D) modelling software asks a lot of current hardware capabilities. And not only computers (both desktops and laptops) are needed, but also good servers to link and share the data.

Standards and policies have an important, but mainly supportive, role in sharing and accessing data and using the required equipment to be able to execute the activity of BIM. These standards and policies are IT related and lay outside the scope of this research.

Arrangements, containing procedures between stakeholders, may be the most important in the case of BIM. Within these arrangements the different stakeholders agree on how to deal with data, file formats, exchange, versions, application of standards and policies, storage and responsibilities. These arrangements, or cooperation protocols, are made on the process level of the framework for data exchange, but apply to all lower levels.

### 3.1.3 Asset life cycle

In the traditional AEC (Architecture, Engineering and Construction) industry, one cannot speak of a life cycle as is shown in figure 18. The process actually is straight forward and does not have a loop, as can be seen in figure 19. The process is not shown straight forward, but as a 'V'. The top of the 'V' represents a low level of detail, where the bottom of the 'V' represents a high level of detail.

Traditionally, each step of the asset life cycle is seen as a separate project. For each project (i.e. asset life cycle phase) the process of collecting data, modelling, etc. is applied again, where the kind of project (e.g. construction or maintenance project) does not matter. For each project the data is being recollected or is even being reconstructed based on information from different sources. Seldom existing data is being reused. However, from a BIM point of view the data needs to be re-used during the full life of an asset (Pentillä, 2006, p. 405; Gu & London, 2010; Watson, 2011). This means that a model will be created for an asset at the start of a project, that this model grows during the different phases of the life cycle and that it will be kept up to date until the asset is demolished. The data belonging to an asset undergoes a large number of activities, such as generating, storing, managing, exchanging and sharing asset information during its life cycle (Vanlande, Nicolle, & Cruz, 2008, p. 71).

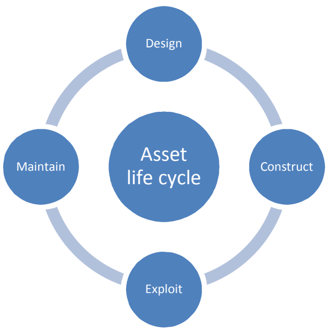


*Figure 18. Asset or building life cycle*

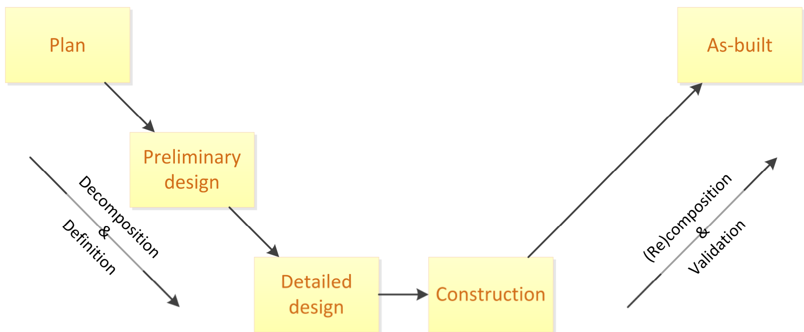


*Figure 19. Traditional AEC-industry process. After Forsberg & Mooz (1991)*

### 3.1.4 Collaboration

Collaboration can be seen as a synonym for BIM, not that it covers all the aspects of BIM, but it is one of the major factors. For the AEC industry BIM is one of the first serious attempts in which the different design departments work together in the same model, sharing their information.

And it does not stop there. In the past all the steps of the asset life cycle where different worlds and people were not working together. In the more advanced developed BIM projects all relevant stakeholders are involved from the first ideas: the owner, the user, the builder, the designer and the maintainer. This does not only lead to a lowering of failure costs, but also gives more opportunities for innovation, mostly thanks to the newly offered possibilities of early decision-making (Cavieres, Gentry, & Al-Haddad, 2011, p. 716), but also because models can easily be modified and recalculated; steps that were too costly in the past due to a lack of the resources time and money.

### 3.1.5 Definition

The previous paragraphs described different views on BIM. Within these views different aspects of BIM come forward. Based on these views I propose the following definition of BIM:

*BIM is a PROCESS in which relevant ACTORS COLLABORATE on creating, analysing and managing MULTIPLE DIMENSION DATA within a DYNAMIC MODEL representing one or more ASSETS throughout its/their LIFE*

The views on BIM clearly show that BIM is a process that goes on and on within the asset life cycle. The process is executed by a group of actors with different backgrounds and each (group of) actors brings in their own specialty.

The BIM process can be broken down in different activities of which creating, analysing and managing (the data) are the most important. These activities are applied to multiple dimension data. The total number of dimensions can differ per project, although at least two dimensions are obligatory and at least three dimensions are recommended.

The data needs to be stored in a model. The model itself is flexible and information can be added or removed, depending on the life cycle phase. Most important is the re-use of data throughout the life cycle of an asset.

The activities building and maintaining are clearly not a part of the definition, neither are they a part of BIM. In my opinion it is the other way around, BIM can be seen as a methodology for building and maintaining.

## 3.2 History

The acronym BIM was introduced in 2002 by Autodesk, one of the leading software vendors in the AEC industry. Although the term seemed new, it was already used by Van Nederveen and Tolman (1992), who described a method to look at a single model through different "aspect" views, but still having one 'truth'. The concept of BIM itself dates back to at least 1989. An article by Björk and Pentillä (1989, p. 176) describes a vision on how "*product models offer a promising method for structuring data describing a building in the databases which will be used in the computer integrated construction process of the next century*". Before 2002 the common terminology for BIM was 'Building Product Modelling' or 'Product Data Modelling' (Eastman, Teicholz, Sacks, & Liston, 2011; Howard & Björk, 2008, p. 272), which explains the term 'product models' in the citing of Björk and Pentillä.

In 2004 a publication of "The Construction Users Roundtable" (CURT, 2004) showed a graph, presenting the true value of BIM. This graph is nowadays known as the MacLeamy curve (see figure 20). The graphs shows the relation between time, represented by the different design stages (on the X-axis), and effort/effect (on the Y-axis). The graph directly showed what needed to change in the AEC industry, and BIM was seen as the instrument to make this change possible. The possibility of this shift in the moment where design choices are made was already described by Hsu and Liu

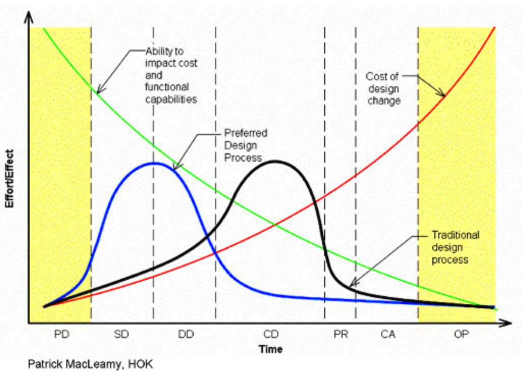


*Figure 20. Image of the MacLeamy curve (CURT, 2004).*

(2000, p. 849) in the editorial of a special edition of the Computer-aided Design (volume 32, issue 14) about conceptual design, proving that technology had reached a point where this shift was possible.

It still took a lot of time before BIM became more popular. The complexity of the solutions to apply this new way of working were to blame for this (Howard & Björk, 2008, p. 271). Despite the fact that failure costs were estimated on € 4 billion per year (for the Netherlands) (USP-MC, 2010), it is only in the last few years that BIM is becoming mainstream, at least within the Netherlands. However, there still is a large difference in experience with BIM between engineers and builders on one side and (public) clients and suppliers on the other, especially engineers show much more experience than other stakeholders (Van Berlo, Dijkmans, Hendriks, Spekkink, & Pel, 2012).

Since 2008 most research focuses on the development of a framework for BIM maturity (Succar, 2009; Cerovsek, 2011; Singh, Gu, & Wang, 2011; Jung & Joo, 2011) and on the development of working with additional dimensions and domains (Hu, Zhang, & Deng, 2008; Popov, Juocevicius, Migilinskas, Ustinovichius, & Mikalauskas, 2010). One of the other important developments deals with 'Integrated Project Delivery' (IPD) (Succar, 2009, p. 362) to allow a better data exchange over the different phases in life cycle. At the moment BIM is mostly used in the design and construct phases, but still has to find its way to the operations and maintenance.

Next to the research towards IPD, research is also conducted towards the exchange between IFC and CityGML. This research is particularly interesting, because CityGML is, like IFC, an open standard and also supports 3D geometries. The biggest problem between IFC and CityGML is the different ways 3D geometries are being approached, as can be seen in figure 8 on page 12 of this research.

## 3.3 BIM, an SDI?

Spatial Data Infrastructures (SDIs) are a way to share data and are well known within the world of Geographical Information Systems (GISs). Looking at explanations of BIM, I believe that BIM and SDIs share a common goal, i.e. "*to provide an environment in which all stakeholders can cooperate with each other in a cost-efficient and cost-effective way to better achieve their targets*" (Rajabifard, Feeney, & Williamsen, 2002, p. 13). When I compared the nature and relations of an SDI according to Rajabifard et al (2002) and the explanation of BIM as is given earlier in in this chapter, I could only conclude that is truly the case, as can be seen in figure 21.

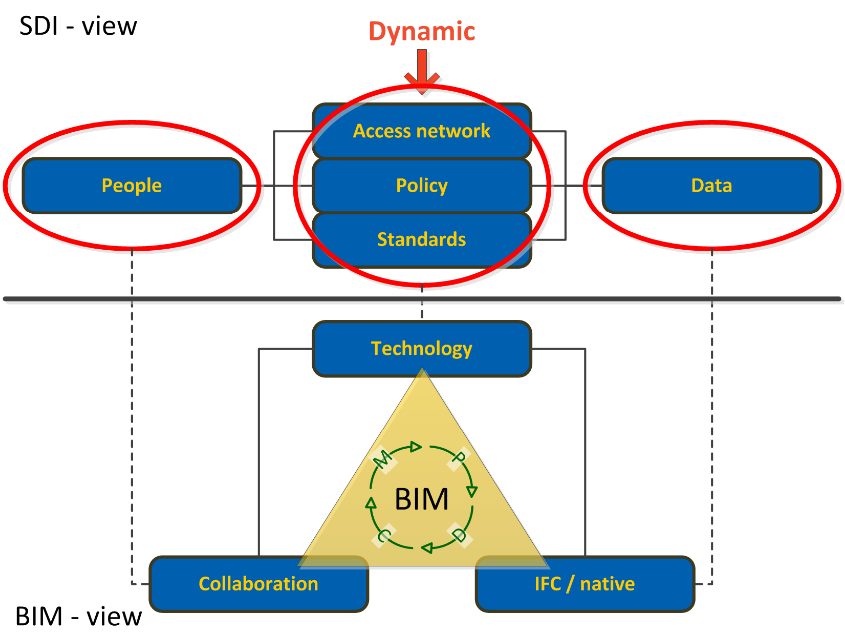


*Figure 21. A comparison between the SDI model of Rajabifard et al (2002) and a BIM counterfeit. The letters in the arrows around 'BIM' represent the steps in the life cycle (i.e. Plan, Design, Construct, Maintain)*

Rajabifard et al (2002, p. 11) state that an "*SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community*." In that sense a comparison between BIM and SDI is comparing apples and oranges, however in essence both share the same goal only within a different environment. The environment of BIM focusses mainly on collaboration within design and construction (and maintenance), whilst the environment of SDIs focusses on sharing referenced geographical information in a wide range of themes.

# 4 Schiphol GIS

Until a few years ago the asset information of Amsterdam Airport Schiphol was stored in four systems which covered 77 information themes and contained more than 100.000 AutoCAD drawings. Each theme provided specific information on a certain topic. The themes were divided over different departments and there was limited coordination between the departments what led to a) a fragmentation of information, b) a large number of inconsistencies and c) differences in representations. The drawings were accessible for approximately 800 employees via a web viewer, but had to be looked at one-by-one. It was not possible to make overlays of multiple drawings.

Since a few years this situation is changing. A central department, i.e. Asset Information Management (AIM), is now responsible for most of the asset information at Schiphol. The original departments are still responsible for the assets themselves and for the information they want to have stored within the information system. However, AIM maintains the information systems and the architecture that comes with them. Figure 22 shows how the system architecture at Schiphol currently looks like, including the expected developments within the next two years. The systems are loosely coupled, which allows the connections between the applications without the need for all kind of complex developments.

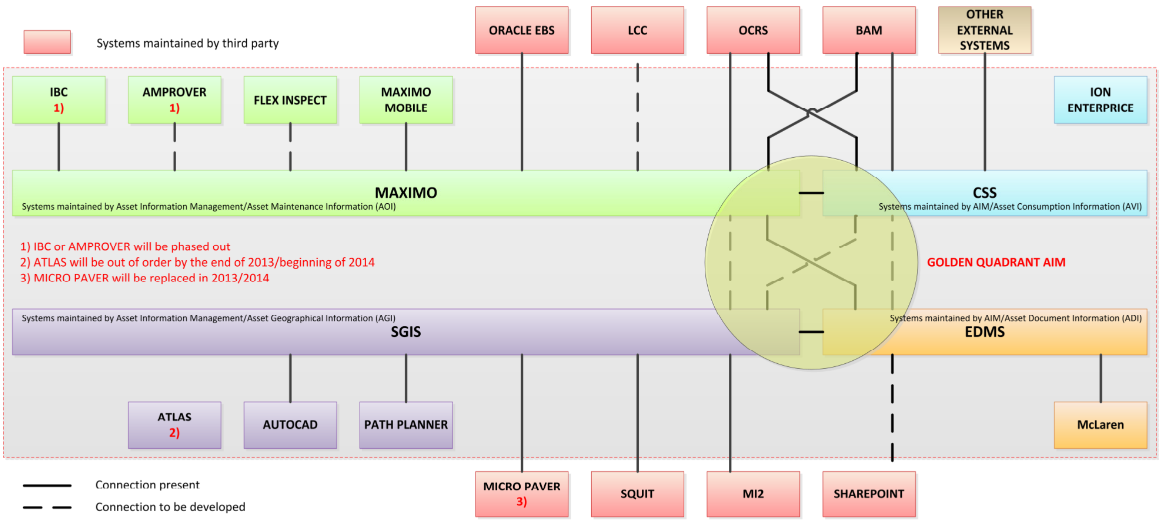


*Figure 22. The system landscape of the department Asset Information Management, including the responsible sections for each set of information systems. The connections in the yellow circle provide the so-called 'golden quadrant of AIM', giving access to almost all available asset information. (Source: Schiphol, AIM)*

The four former systems have been replaced by a single Geographical Information System (GIS), i.e. ArcGIS by Esri, and a data model has been developed with the name SGIS (Schiphol GIS). The replacement of the four systems was the start of a new policy that focusses on a decrease of different systems, a limitation of customized development and the promotion of the use of standard "off-the-shelf" software. If standard software does not meet the requirements, it is first considered whether it is possible to adapt the organization and if that is not possible, the last option is to allow the development of customized software. It is this policy that led to the decision to quit using ArcGIS FM UT, a special application for utilities, and to use the standard geometric networks provided in standard ArcGIS instead. The data model is still under development, but should be finished somewhere in 2014. Although the data model has not been finished as a whole, parts of it are already finished and have already replaced a large number of themes. The official release of SGIS for has taken place on February 1st, 2013. Beside the 800+ users from the former systems, an additional 1700 employees of Schiphol, main-contractors and internal suppliers can also access the data, because it has become available as a standard Schiphol application.

The fact that the SGIS still is under development, also means that there are other (GIS) systems active that contain relevant information. Most of these applications will be replaced by SGIS at a later stage. Some applications cannot be replaced, because they offer specific functionality that is not included in ArcGIS. Adding this functionality via development would cost too much and is not allowed in current policies. Thus the choice was made to allow these standard applications to exist, with the restriction that the information must be made available via the SGIS portal. With this strategy there is only one truth that can only be accessed via one channel. At Schiphol this concept is called 'One view for all'. Figure 23 gives an overview of the currently available themes in the SGIS consult portal. All SGIS themes have been developed for specific target groups and can be divided in two classes i.e. public and closed. The public themes are available for all 2500 users, whilst the closed themes can only be accessed with specific rights that are applied to an user account. There is also a separate portal available for editing.

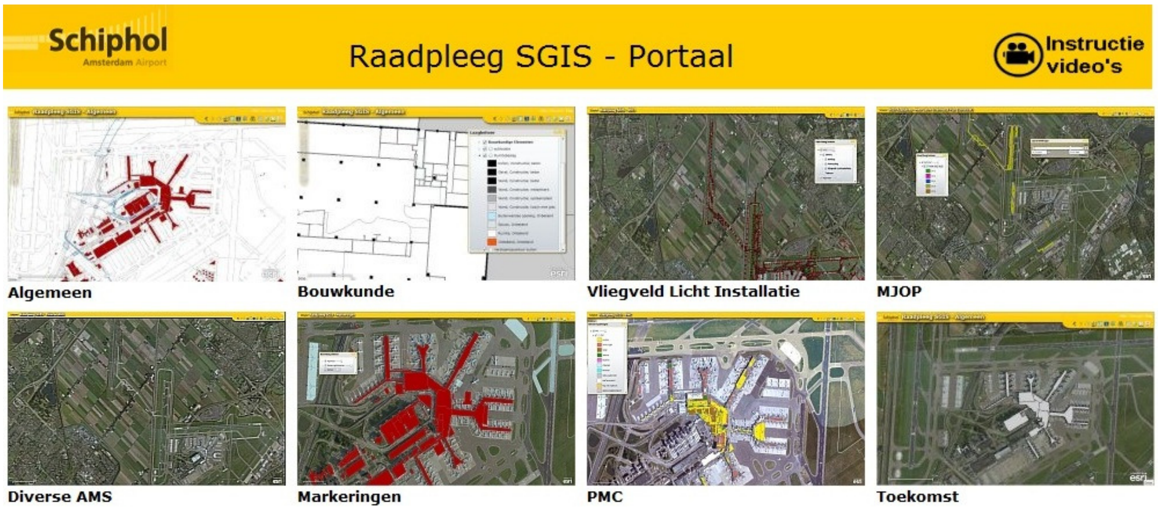


*Figure 23. A screen dump that contains an overview of available themes in the SGIS portal, dd. January 2013.*

SGIS is more than just a data model, it consists also of a portal that provides access to other information systems. The original idea was to create a portal where relevant stakeholders, not only the previously mentioned 800 but also the other stakeholders, could search for an asset and gain access to those systems that contain information about that specific asset. However as soon as the test version of the SGIS portal was launched, people started using it as a starting point in their search for asset information (see figure 24). Now the GIS portal contacts the asset portal to find out whether information for a specific asset is available in other systems and offers a link to the information in those systems. Examples of systems that are already linked, or will be linked within a short time, are (see also figure 22):

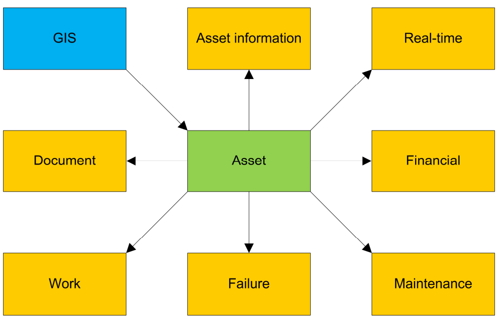


*Figure 24. Information searches for assets no longer start at a central point, (green class) but start at the GIS portal (blue class) and continue from there. After: (Wasserman, 2011)*

- EDMS (Electronic document management system)
- Maximo (Maintenance application)
- FlexInspect (Inspection status application)
- Real-time status information

Other systems will be linked in a later stage. Future development focusses on the possibility to unlock all data with a geographical component via the SGIS portal, either based on location or by relating information to an existing object. The term "GIS-enabling" is used for this activity. The total setup can be seen as a corporate SDI, providing all the available information via a central access point. It is clearly not the aim to turn SGIS into an asset management application, other software is available for that purpose.

## 4.1 Data exchange

Within section 2.7 a framework for data exchange interaction is proposed. This framework can be applied towards both inter- and intra-organizational relationships. Because of the size of Schiphol as an organization, but also due to the large variety of activities and asset types, both types of relationships are present.

Within the internal organization, there are five departments Schiphol GIS has to deal with. Four of these departments are responsible for operations and maintenance, i.e. Terminal Real Estate, Utility Services, Airfield Maintenance Services and Schiphol Real Estate. The first three are responsible for the airport itself. Schiphol Real Estate is responsible for the properties that are owned by Amsterdam Airport Schiphol within and around Schiphol, that are leased to commercial companies, e.g. shops, cafes and restaurants. The fifth department that deals with SGIS is PLUS, who are responsible for executing the projects at the airport, mainly being design and construction projects.

The four departments that deal with operations and maintenance are responsible for the information they want to get out of SGIS and the other available systems. The remark made by Vollebregt and Vos (2012) that SGIS does not contain enough detail, is something that needs to be discussed between that department, in this case most probably TRE, and the department responsible for maintaining SGIS, being AIM/AGI. The departments are responsible for the quality of the data in terms of completeness and correctness. AIM is responsible for the validity of the data conform the technical demands for SGIS.

Because the SGIS portal contains the only truth within Schiphol, there will be no issues in data exchange within the internal organization. The issues that are present, because of former systems that are being replaced, only need to be solved one time and will not occur in the future. Currently mobile solutions are also being developed that directly connect to SGIS via an editable web feature service. SGIS is available 24/7 and the moment an edit is approved, it becomes available in the viewer.

Schiphol has chosen to become a directive organization and wants to outsource the activities of conducting operations and maintenance. Therefor Schiphol has chosen to work from partner relationships instead of using the classical client-contractor relationship. The advantage of partnering is that both organizations share common goals and have a common interest in realizing efficiency benefits. The activities for operations and maintenance have been split into a dozen parcels that were put out to contract at the start of 2012. The aim of Schiphol is to maintain a durable relationship with the contractors that won the parcels. These contractors are called main-contractors and can also be seen as preferred suppliers (of services and smart solutions). Schiphol also has a partnership relation with the organizations that are responsible for the design of new projects. These partners are not called main-contractors, but are called ‘consultants’ and are seen as ‘internal suppliers’. For the construction projects the traditional ‘client-contractor’ relationship is used.

Because of the partnership approach, the employees of Schiphol, the main-contractors and consultants have a good understanding of each other’s expectations. There is a great will to cooperate and to achieve the same goals, being an efficient asset life cycle process at Amsterdam Airport Schiphol, in order to support the ambition of being Europe’s preferred airport.

It is not expected by Schiphol that all main-contractors and consultants have a similar system setup as is the case at Schiphol. Therefor Schiphol has decided to create an environment in which changes can be updated to the as-is situation in SGIS, EDMS, Maximo and other relevant systems via a predefined workflow. Due to quality issues in the original CAD drawings, regarding the wrong use of layers, block definitions and conversion problems, Schiphol no longer wants that changed situations are added to SGIS via conversions. The changes must be redrawn manually in SGIS and be checked during the editing process. The SGIS edit environment for the main-contractors is not yet operational, but that situation will change within a few months. By the end of the year all main-contractors should be working with SGIS. The edit environment will become available via a direct network connection through a Citrix connection from any PC with an internet connection. It also allows direct access to local drives, which makes it possible to easily copy data from the local PC drives to the Schiphol edit environment.

Each department has setup a specification of the information that must be delivered during a project. Contents, method and time aspects are described within these delivery specifications. The main-contractor is responsible for delivering the information, the responsible department will check the contents of the changes and the completeness, and AIM checks whether the data is correctly updated. The main-contractor is expected to check his revision with an automated tool that checks the data for validity.

## 4.2 Data model

The last interaction level in data exchange framework is the object level. Within Schiphol it is not necessary to exchange data, because everybody works with the same system. Main-contractors are obliged to update SGIS and other systems when they made changes to the assets of Schiphol. To be able to add these changes to SGIS, it is important to have knowledge of both the source and the target data model. It can be expected that the source data model differs per main-contractor and might differ per project. Also Schiphol does not want data to be converted to the SGIS model, therefor only a description will be given of the SGIS data model.

The original (logical) data model was based on a number of relevant Dutch standards, as can be seen in figure 25, that are also linked to international standards. During a research for the redevelopment of the data model, it appeared that most attribute fields, that were prescribed by the NEN3610 (NEN, 2005; NEN, 2011) and the applied sector models, were not used. Therefor these fields have been removed, mostly involving the geo object from the NEN3610, and some missing attributes were added. A reason for not filling these attributes can be found in the fact that they serve a purpose that is related to exchange files. However, SGIS is a dataset that contains an as-is situation and will only be maintained at Schiphol. From that perspective those attributes are superfluous. The other two standards were maintained and deal with a classification for objects throughout the design, built and management process of construction projects (NL-SfB or Elements method 2005) (TU Delft, Unknown) and with the calculation of the useful area of terrains and floors or parts of it (NEN2580).

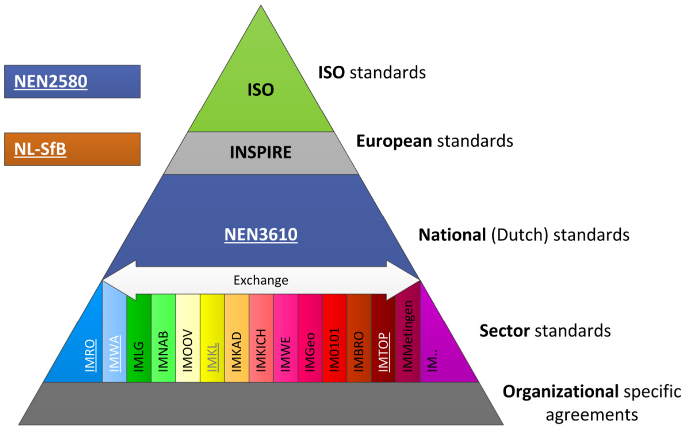


*Figure 25. The relation between international standards. The standards with underlined and white/grey coloured text are used for the original design of SGIS. The NEN2580 and NL-SfB are originally not a part of this image. (After: GeoNovum)*

It is interesting to see that some of the themes within SGIS contain data from sources that are Dutch key registrations already, or will be within a few years. Examples are large scale topography, buildings and the cadastral registration. These datasets are not linked to the web services they originate from, but are updated on a regular basis. This situation emerged from the past, when these datasets were not offered as web services. There are two other reasons why Schiphol wants to own these datasets. The first reason is that Schiphol wants to keep track of history and the second reason is that Schiphol does not want to be dependent on web services in case of calamities. A web service can drop out at such a moment and the data will not be available than. Personally I can understand this policy, however you can also call it hypocrite, because their own main-contractors and internal suppliers are no longer allowed to keep copies of the Schiphol dataset and at the same time Schiphol is keeping copies of other datasets that are continuously available. The argument of keeping of history can also be doubted, since a history should always be available at the source of a certain data supplier.

The SGIS data model is unique, because of the large number of themes it will cover, by now over 77. The themes cover different sectors, like infrastructural objects, roads and buildings, including all related sectors like installations. Hereunder, in table 8, an impression is given of a number of themes that already are present in the SGIS data model or will be within the near future. The diversity of the data also has consequences for the editing process. Therefor special workflows have been created, that only provide the necessary themes and the feature classes that belong to those themes, again these themes have been developed for specific target groups. Actually the same has been done for the consulting portal, because the overload of information would otherwise create images that cannot be understood anymore and will only distract from the topic a certain theme is about.

| | | |
|---|---|---|
| Air fuel supply | Clocks | Sewer |
| Cadastral registration | Aerial photography | Security |
| Fire security | Furniture | Sprinkler installation |
| Camera systems | Evacuation systems | Routing |
| Climate | Platform equipment | Airfield Light installation |

*Table 8. Impression of some of the available themes within Schiphol GIS.*

The themes show a large overlap with design topics. This also counts for the data model of SGIS. It shows more resemblance with the classifications and terms that are used in design and construct, e.g. IFC or STABU, than those that are used in maintenance, such as the breakdown structure of the NEN2767. Due to this similarity, it is expected that it will be easier to exchange data on the level of entities and attributes. Otherwise complicated schemas need to be developed to match entities to attributes and vice versa. If that would have been the case, a potential risk arises where the geometry also would have differed. A difference with the design and construct phase is the allocation of the objects. In the design and construct phases a local system is used in most cases that has a zero-point somewhere on the D-pier of Schiphol, is north oriented and is often drawn in millimetres. The SGIS data on the other hand is located in the Dutch spatial reference system Rijksdriehoekstelsel (RD) and uses meters as spatial units. Luckily the last is also north oriented, but it's zero-point is near Paris. The advantage of the use of a single coordinate system, whether it is local or referenced, is that it will not be necessary to apply a geo referencing activity to a dataset, thereby risking a distortion of the geometry. Figure 26 presents an top view of the topography of SGIS, including the location of the zero-point.

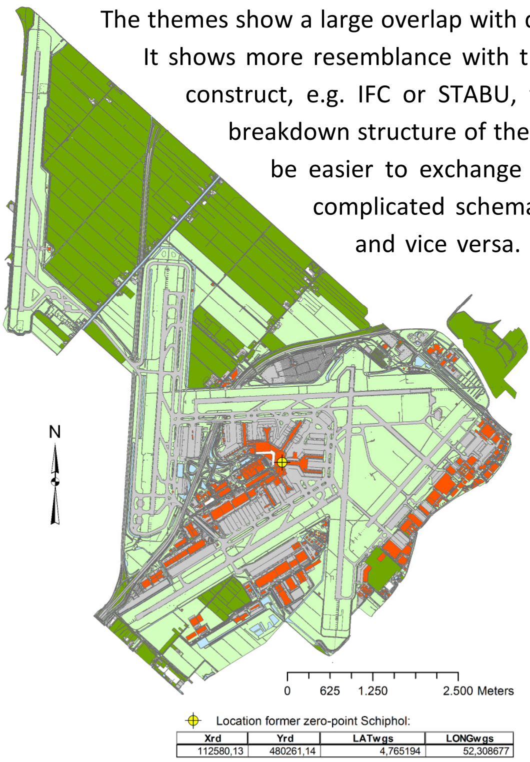


*Figure 26. An overview of the topography of SGIS and the location of the zero-point used in the design and construct phase.*

Each theme also has its own demands in geometry and dimensions. At the moment the SGIS data model is oriented towards the building floors. Within the SGIS portal it is possible to switch between these different floors, where applicable. Most of the data is drawn in 2(½)D, because that is sufficient for this type of data organization. For the in-building installations a different choice was made, they are drawn as 3D installations, but still only by using 0D and 1D primitives that contain a Z-value. That is, the lines and point objects, resembling the cables, pipes and their connectors have 3D coordinates, but they are still lines or points. The floors will be put to height soon and an additional feature class containing glass will be added soon as a 3D feature class too. Only a small group of the other feature classes that use a polygon representation also contain Z-values along the edges. Topography is an example of such a theme. Within all themes the possibility is offered to store height information as an attribute, but experience showed that this attribute is filled poorly (yet). Within the feature class the heights will be stored relative towards the Dutch vertical coordinate reference system, i.e. NAP, however within the views the relative heights towards the floor surface will be shown.

There are also experiences with 3D visualizations at Schiphol, where the benefits proved themselves. For a tender concerning glass cleaning, a 3D model was generated of the terminal. The model was created by a company Cebra and could be accessed via the VirtuoCity[3] environment they created. The advantage of this model was that the contractors had a much better overview of the different situations at Schiphol and were better able to make their bids. The received bids that year were substantially lower than bids from earlier tenders. It is expected that the fact that the extra height information, the 3D model offered, and the more detailed quantity information caused the lower bids. At the same time, the development costs were recovered, because additional use of the model was made for route and perception analysis in relation to way finding.

All information in SGIS is stored in an Oracle Spatial database. Within the database a group of tables is stored for each feature class. These tables include an add/delete table that keeps track of history. Also two different views are defined, one for GIS (Consult view, RVW) and one for AEC files (CAD view, CVW). All tables are linked to the main, or 'mother', feature class. The geometry within the feature class is stored in the native Esri type ST_Geometry. The advantage of this type is that it works seamless with ArcGIS. On the other hand you are limited in the use of certain geometries, because for 3D primitives only multi-patches are supported by ST_Geometry, where native Oracle geometry (SDO_Geometry) also allows real 3D primitives such as NURBS.

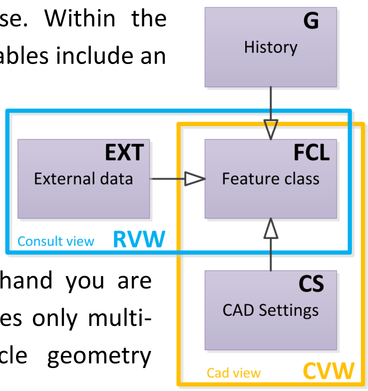

*Figure 27. Overview of tables for a single feature class*

It is obvious that a high level of detail is integrated in the SGIS data model. It is not that every design detail is also contained in SGIS, but the complete building interior is contained in SGIS as are the complete installations (both inside and outside of buildings). However something like wall structure is not contained in SGIS, but there was no reason to do so for 2D representations.

## 4.3 BIM

The subject of BIM is relatively new to Schiphol. Only recently Schiphol started to develop a policy towards BIM and that has not finished yet. The real start of BIM 'thinking' at Schiphol was made after the research that was conducted by Vollebregt and Vos (2012). And although their solution seems to be radical and not realistic to implement, it got people started to think about the adoption of BIM as a mean to get more influence on the design and construction process. However the main reason for interest in BIM is the possibility of cost reduction during design and construction, as well as the possibilities for a fluent information flow through the life cycle.

[3] More information via http://www.cebra.nl/

It is without a doubt that Schiphol has a role in BIM. As an asset owner Schiphol wants to benefit from the positive effects that the BIM methodology can bring. Schiphol is already collaborating intensively on all phases of the asset life cycle. The view on BIM of Schiphol differs from my view on BIM and is explained hereunder. The new areas of exploration for Schiphol include integral cooperation that is supported by a three dimensional model. With these activities Schiphol is hoping to achieve a higher quality of development, realisation and maintenance of Schiphol buildings for a lower amount of costs. Also BIM should provide a full insight and overview of the (building-related) assets. Also finance and planning must be linked to the 3D model.

Currently Schiphol is preparing a decision by the management of Schiphol for the application of BIM in the way that is described above. The aim is to conduct a feasibility study towards BIM, which will provide insights in those issues that still need to be cleared out for a complete overview of what needs to be done before a BIM implementation can be applied. The relationship between BIM and GIS is seen as a risk and will be included in the feasibility study.

| BIM element | D & C | O & M |
|---|---|---|
| **Process** | Short and dynamic | Long lasting and static |
| **Actors** | Architect, Constructor, Engineer and Owner | Operators, Mechanics and Owner |
| **Dimensions** | 3D, local, mm's | 2 - 3D, RD, m's |
| **Dynamic model (software)** | AEC | GIS |
| **Aim (life cycle)** | Creation | Sustain |

*Table 9. Overview of the differences between the design and construct stages (D&C) and operations and management (O&M) in relation to the elements of BIM for Amsterdam Airport Schiphol*

It is my vision that the BIM methodology is already applied for the operations and maintenance phases of the asset information life cycle. Not only inside buildings, but also outside. I must say that I am disappointed by the fact that Schiphol mainly focusses on buildings for the application of BIM. However, a number of steps still need to be taken before BIM can be fully applied to the whole life cycle at Schiphol. These steps deal with the current differences between the models in the design and construct phase on one side and the operations and maintenance phase on the other. The most obvious differences based on the definition of BIM, as was given in section 3.1.5, are shown in table 9. A more extended description of the encountered problems will be given in the next chapter.

## 4.4 Topography

One of the themes in SGIS is topography. I found the presence of this class is somewhat remarkable, because all SGIS already contains a closed area of objects in the database. A second point of attention is that Schiphol collects its own data by surveying with terrestrial techniques, whilst the data is also collected and maintained within a national dataset. Therefor I decided to take a closer look at the reasons for doing so, thereby also taking into account the relations with the Dutch key registrations.

From before 1988 Schiphol keeps her own copy of topography. In that year a new set was created from aerial photography. This set of features contains the area that covers the full airport and is referred to as 'Schiphol Centrum'. The dataset is maintained by Schiphol, because the current national standard (GBKN) does not provide all the details that are needed for Schiphol. Also Schiphol is a restricted area and not all topographical information must be included in the national datasets for security reasons. The last reason why the GBKN was not used as a base set was because the environment of Schiphol was too dynamic to keep track of all the changes within the necessary time available. The technical specifications for surveying these changes are written in a document (Schiphol, 2012). A separate preferred supplier is responsible for keeping the topography dataset up-to-date in their own system and the topography dataset in SGIS is updated once every three months.

With the upcoming new key registrations in the Netherlands, Schiphol will keep her own dataset of topography. Not so much because of the level of detail is not sufficient, but mostly because of practical reasons. The key registration for large scale topography (BGT) will be kept up-to-date by different public organizations, such as municipalities, provinces, the national road agency and water boards. In the case of Schiphol the municipality of Haarlemmermeer is responsible for keeping the key registration for topography up-to-date. In consultation with Schiphol the agreement is made that Schiphol delivers the topography to the municipality and that the municipality will add the information to the key registration. This way the municipality does not have to access Schiphol for surveying and does not need to know where all the changes are. On the other hand Schiphol can define which information is classified and may not be added to the key registration. Personally I would suggest not to remove the classified information, but to change the attributes so that it gets another, logical, function. It is much easier to see which objects are left out (on purpose) than to find out which objects are not classified correctly. Schiphol will be financially compensated for the efforts. The restricted area resolution also allows Schiphol not to add their cables and tubes to the national databank for cables and tubes.

Schiphol also uses a part of the GBKN dataset that is surrounding Schiphol. This part is referred to as 'Schiphol Grensgebied' (Schiphol Borderland). Some departments within Schiphol have a special interest in this region, for example because Schiphol has some properties there. Schiphol does not maintain any data here, but instead buys a copy of the GBKN dataset for that specific region that is surrounding the 'Centrum' area. In the future the BGT web service can be used for this goal.

I found it remarkable that an agreement was made for the BGT, but not for another key registration, being Addresses and Buildings (BAG). One of the demands in this key registration is an area containing the top view of every building. For a map of the obstacle-free-zone, all roofs are contained in the topography dataset of Schiphol. Schiphol responded positively on my suggestion and will discuss it with the municipality of Haarlemmermeer.

For the BGT and parts of the BAG, it is clear why the available web services will not be used. Schiphol actually will be the supplier of the data and the key registrations will not contain all the correct data that is part of the topography dataset of Schiphol for security reasons.

Another aspect is that the topography dataset is used as a base layer, because the topography can also be extracted from other classes. Changes in the topography dataset are not necessarily worked through in the other classes the resemble the same features, creating different truths again.

## 4.5 Recommendations

As was stated before, SGIS is still under development. Based on earlier input, hereunder I offer some recommendations for the further development of SGIS, based on my findings.

According to the research by Vollebregt and Vos (2012) SGIS does not meet the current requirements of the users. The question needs to be asked who are pointed at by referring to 'the users', since it is not expected that all users are not satisfied with the available information in SGIS. However, it can be recommended to setup a process that evaluates the data model and functionalities of SGIS with both the departments within Schiphol, the main-contractors and the internal suppliers. Based upon these inputs change propositions can be made that can be judged by AIM and the responsible operations and maintenance department within Schiphol. According to the MoSCoW method a planning can be made for the implementation of the necessary changes. Ultimately this will lead to a broader support of SGIS, because people feel that they are involved and heard.

Schiphol wants her internal suppliers, main-contractors and other stakeholders that apply changes to her assets, to redraw these changes in SGIS. I would not recommend this for two reasons: 1) redrawing is a potential source of errors, because objects will be drawn differently or will be forgotten and 2) from the perspective of BIM, you want to re-use your existing data instead of creating a new set of data. I would suggest to create a single standardized conversion and to develop a control tool that is able to check the input data set on its quality. Only if the quality check is sufficient, SGIS can be updated with the converted dataset. The standardized conversion should be based on a set of technical specifications on how a 'BIM' data model should look like.

The development of the Library of Concepts for the Netherlands (CB-NL) can be seen as a relevant development in terms of exchangeability of SGIS. The CB-NL will describe concepts in terms, explicit definitions and intrinsic properties and takes into account relevant standards, such as the NEN2767-4, the NL-SfB and the Information Model Geo-information, i.e. NEN3610. Other relevant international standards the CB-NL will use are IFC and the combination of RDF and OWL (BIR, 2012). For future developments of SGIS it would be advisable to adapt this Library of Concepts. A first draft version is expected to be available by the end of 2014. If Schiphol finds it relevant and is interested, they currently have the possibility to join the next stage in the development of the CB-NL.

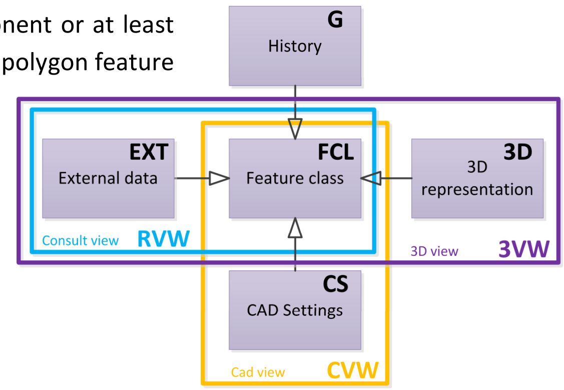


*Figure 28. Possible setup for the addition of 3D multi-patch objects.*

Some of the feature classes in SGIS have a 3D component or at least the option to store the data in the third dimension. All polygon feature classes have the option to store Z-values at the edges of an object. And although it is possible to extrude these objects, if the features have a base height and the height attribute is filled, it still is not a 3D primitive. Another aspect of this way of working is that the objects are visually presented as blocks, while they have different shapes in reality. Therefor I would like to recommend to add a 3D representation to those feature classes where the current representation is insufficient to create a true 3D model. There a two things that need to be considered, 1) how and where is this additional representation going to be stored and 2) does the current data model setup provide sufficient support for the requirements that need to be met. Hereby I refer to the possibilities of ST_Geometry and SDO_Geometry. The native Oracle geometry does support true 3D primitives in her data model. With the help of views, these primitives can be turned to multi-patch features for display in ArcGIS. Otherwise it is only possible to store multi-patch features that can actually be explained as multi-part polygon classes. The first consideration refers to technical issues related to the storage of multiple geometries in a single feature class. Within Oracle Spatial, it is possible to store more than one geometry (column) in the database. ArcGIS however, can only work with a single geometry (column) in a feature class. It will be necessary to research whether both geometrical representations can be stored in the 'mother' feature class and that a choice can be made which representation needs to be added to a view, or that it is needed to create an extra feature class that will store either the 2D or the 3D representation. In the last case I would advise to store the representation that resembles reality the most (probably the 3D representation) with the 'mother' feature class and to create an additional class for the other representation. With this way of working the full 'reality' is stored in one class. It would be an even better solution not to create an additional class for the storage of the 2D representation, but to extract it in a view from the 'mother' feature class, but I am not sure whether that is possible with the current options in Oracle.

The current dataset is projected in the Dutch Rijksdriehoekstelsel (RD). Often the design for new development and renovation is drawn in a local system. In the past there was a zero-point that was used as a local system. It can be advised to reuse this zero-point or to define a new zero-point especially for this kind of projects. If data is delivered for an update of SGIS, it will be easier to re-locate it, because the same local systems is then used for all projects, which makes it easier to geo-reference these projects. It was explained by Nico Wasserman, manager of the AGI department, that the request for the projection of SGIS data in RD came from the internal suppliers. If that is the case and all internal suppliers will work from RD, such an addition is not necessary, but in any other case I would suggest to use a standardized zero-point. If it is necessary to keep a zero-point, I would suggest to replace the former zero-point to a location where all coordinates in the local system will become positive. The current location shows negative coordinates in approximately six-seventh of the area of Schiphol.

If Schiphol wants to keep using copies of the key registrations and other data that is available via web services, instead of using those (web) service directly, I suggest to design an overnight batch process that creates an extract of the area-of-interest. This way the most recent data is always available, without a dependence on the web service. I would also suggest not to store the history of datasets, as long as they are not critical for daily processes. History can be asked for when it is needed at the supplier of the data. If Schiphol keeps on storing copies of other datasets, they should consider that they are actually doing themselves what they do not want their internal suppliers and main-contractors to do.

An analysis needs to be made between SGIS and the topography feature classes. At the moment these datasets fully overlap and changes are only updated in the topography class. I would advise to first analyse which feature classes in SGIS contain the same data as the topography classes and secondly to analyse how these two datasets can be integrated in each other. This will result in a change of contract with the preferred supplier, who will then have to edit the geometry of SGIS, but at the same time the data will again show a single truth. If a topography base map must be available, I suggest to create a new view of the feature classes already available in SGIS that show, if necessary via an automated generalization, a simplification of the SGIS data.

## 4.6 Conclusion

Although the SGIS data model is still under development and that the golden quadrant of AIM (see figure 22) has not been fully realized yet, it is clear that this system will function as a Central Information System as was proposed by Vollebregt and Vos (2012). It will not be possible for main-contractors to create new designs in SGIS or to follow a construction process, but the system was never designed for those activities in the first place, as 3D AEC modelling software never was designed to maintain as-is datasets. In fact it can be stated that the golden quadrant of AIM is an application of BIM for the operations and maintenance phases in the life cycle.

There are some recommendations for the SGIS data model that will help linking SGIS to design and construction drawings and vice-versa. With these changes SGIS is equipped for the future and has a strong basis for a wide variety of spatial analysis, simulations and decision support at Amsterdam Airport Schiphol.

# 5 Asset Information Life Cycle

The asset life cycle as such has been described shortly earlier in this report (see paragraph 3.1.3). This chapter will continue from there and elaborates on the possible issues that can be encountered within and between the different stages of the asset information life cycle. Before the problems in the asset information life cycle are described, first a small description is given on how the 3D models, that are used for the prototyping in this research, were acquired.

## 5.1 Use case

At the start of this thesis research the opportunity was provided to join a design project at Schiphol that was called CSNS (Central Security Non Schengen). The project, currently named 'One XS' (pronounced as 'one access'), deals with a different way of handling the security checks of incoming passengers from non-Schengen countries[4]. Therefor existing piers must be expanded and a new building has to be created.

The design team for this project, that was put together from different internal supplies, suggested to design a part of the project as a BIM project, i.e. the expansion of the G-pier, the G-corridor and the new GH-building. The internal suppliers contained an architectural firm, i.e. Benthem Crouwel, and four engineering firms, i.e. DHV, NACO, Deerns and Royal Haskoning. Each (group of) engineering firm had its own responsibilities:

- DHV for designing the construction.
- Benthem Crouwel and NACO for the architectural design and were design coordinators.
- Deerns and Royal Haskoning for the design of the installations.

On demand of Schiphol the design team wrote a cooperation protocol that contained all the relevant agreements between the mutual suppliers on the use of software (versions), sharing data, making backups, etc. Within the cooperation protocol also a definition was given of the 'BIM' objectives the design team wanted to achieve and the information they wanted to be able to extract from the model. Since this was one of the first BIM projects for all parties involved, the 'BIM' objectives were set relatively low. The objectives were to create a 3D model and the ability to extract 2D drawings and quantities from the model. Additional information that was added to the model contained naming for zones.

The design team started to create a 3D model of the G-pier based on her own data. Benthem Crouwel and NACO kept their own set of drawings of the parts they designed in the past for Schiphol and used those for the creation of the 3D model. After the current situation, as far as necessary, was created the design continued from there.

During the preliminary design the design team had the idea to create a 3D model, but to deliver 2D drawings as a final product. When I asked why the 3D model was not used as a deliverable, after all one of the most important aims of BIM is the re-use of data, they answered that they did not want to be held responsible for any design errors in the 3D model. Finally the design team was willing to use the preliminary 3D design as input for subsequent (design) stages and to deliver it as an informative product together with the 2D drawings that had an official status. This change of view was a first step in maintaining data throughout the asset life cycle at Schiphol (and my first BIM success at Schiphol).

[4] The Schengen countries are a group of countries within Europe that together provide a borderless zone with a minimum of internal border controls. Everybody from outside this region needs to pass security before it is allowed to enter the Schengen zone.

The design team had chosen to work with the most recent version of Revit[5] at that time, being Revit 2012, as their 3D modelling software. The design of the installations was only partly done within Revit, because the engineers claimed that the software did not meet their requirements (yet). For the design of the installations classic AutoCAD was used instead, but at a few locations the engineers worked out the installations in Revit for the purpose of 'clash detection'. Clash detection actually is an analysis towards unwanted intersections of objects in the third dimension. The classification of the objects within the models followed the standard classification that is offered by Revit.

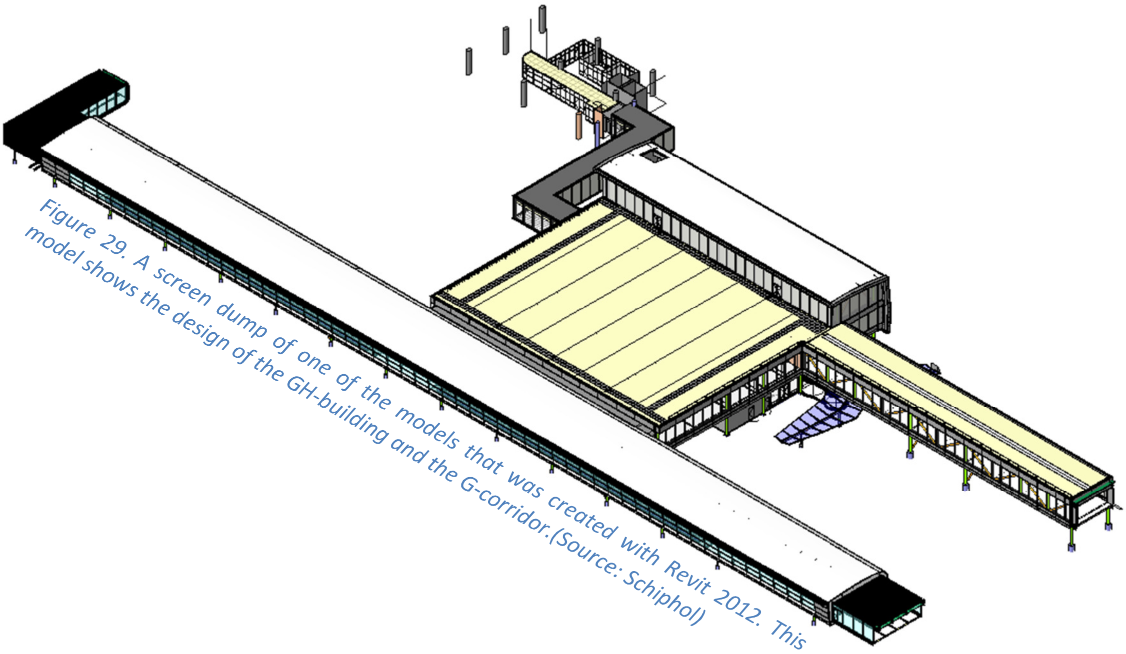

*Figure 29. A screen dump of one of the models that was created with Revit 2012. This model shows the design of the GH-building and the G-corridor.(Source: Schiphol)*

The datasets containing the new design of the G-pier, G-corridor and the GH-building for the One XS project, the final design version in Revit 2012 format, as well as a checkout from SGIS are used for researching possible solutions for the challenges encountered, see next paragraph, within the asset (information) life cycle.

## 5.2 Life cycle views

In my opinion, there are three different ways to look at the asset life cycle:

- From the perspective of an asset.
- From the perspective of the process.
- From the perspective of a complex of assets.

*Figure 30. An example of the dynamics of an asset. The location and type of the luminaires can change during the design and construction phase, but afterwards only the lights will be replaced when they broken.*

The first perspective on the asset the life cycle describes the point-of-view of a single asset. From that view the asset life cycle can be divided into two parts. The first part deals with the (plan,) design and construct phases. This part, when seen in time, is relatively short but very dynamic where it deals with the information storage and the creation of the asset. Whereas the second part contains the operate and maintain phases, which are long lasting and static by nature (Van Oosterom & Stoter, 2010). In most cases little changes are

[5] Revit is the AEC 3D modelling suit from Autodesk

made to the asset information during the operations and maintenance phase. The cause for that can be found in the fact that the physical state of an asset hardly changes during operations and maintenance, see explanation with figure 30. It is expected that the geometry of an asset does not change during the operations and maintenance phase and that some attribute information will be changed at most.

The process view, the second view on the asset life cycle, focusses on the time element of the life cycle. Like an individual asset, operations and maintenance are long lasting activities, but instead of approaching them as a one-time occurring event, they should be approached as an on-going process (Van Oosterom, Stoter, & Jansen, 2005). Plan, design and construction are a series of activities that occur when a (group of) asset(s) is created or as parallel processes when they need to be revised during operation and maintenance. Figure 31 gives on overview of how I think the asset information life cycle looks in reality.

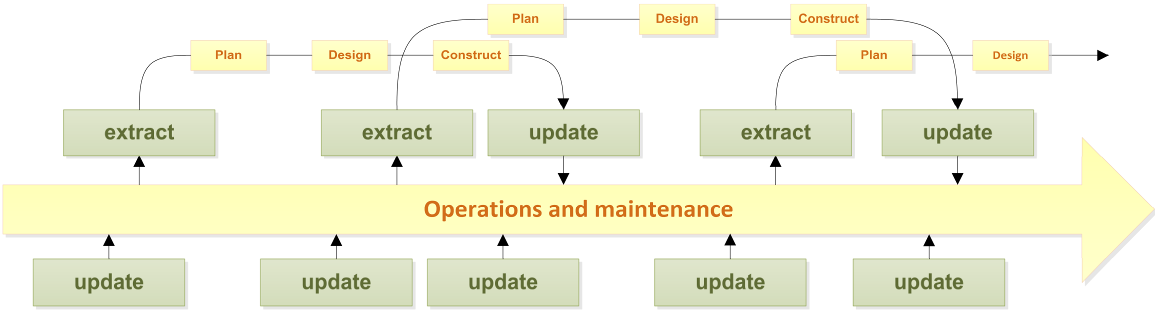


*Figure 31. The information process for operation and maintenance.*

The figure does not only show that plan-design-construct processes run parallel with the operations and maintenance phase, but also that multiple plan-design-construct processes can occur at the same time. It also shows that updates are added to the as-is dataset due to changes caused by regular maintenance and related activities. Additionally the process shows that individual assets seem to be static by nature, but that the total process creates a dynamic situation for the full as-is dataset.

The last view approaches the asset life cycle from the perspective of a complex of assets, where a combination of the previous two views can be seen. Just like the single assets, the life cycle phases can be distinguished in two groups with their temporal characteristics, i.e. design and construct as one group, taking a relatively short time and having a dynamic character, and operations and maintenance as a long lasting group with a static character. However, like the process view the design and construct phases occur as parallel processes during operation and maintenance and bringing the dynamic nature of all assets as a single collection to the front.

It is remarkable that in all three views on the asset life cycle the same distinction is made between the design and construct phases on one side and the operations and maintenance phases on the other side. From that, it can be expected that possible issues with data exchange will occur at those locations where these phases will follow each other up.

## 5.3 Problems

The problems for completing the asset information life cycle that are encountered in this chapter and the previous chapters can be separated in four main categories that follow the asset information life cycle and the framework for data exchange:

- Life Cycle Perspective.
- Organizations and People
- Systems and Software.
- Data and Objects.

Each category contains its own problems, but the problems are also interrelated. The different problems that are encountered will be explained per category.

### 5.3.1 Life Cycle Perspective

The first problem is related to the fact that the life cycle too often is approached from the view of a single asset, where it should be approached from the perspective of a complex of assets. The real problem is that (data exchange) issues are solved on an ad hoc basis. To be able to successfully manage the assets, it is important to realize that possible issues within the asset life cycle will not occur once, but that they have a repeating character.

Another problem with the asset life cycle is that when it is approached from the perspective of a single asset many people forget that it continues after operations and maintenance. From the perspective of a complex of assets, this means that a parallel process will start.

From that perspective the asset life cycle can be compared with a cycle that is now known as the Deming cycle (see figure 32) that aims at continuous process improvement (Wikipedia, 2013). During an inspection (an operations activity) it becomes clear (*check*) that a group of assets does not function. Therefor action (*act*) needs to be undertaken and can either include maintenance or revision. This activity needs to be planned (*plan*) and executed (*do*). When applied to the asset life cycle, maintenance is just the next step in the cycle. Revision however, would start a new design and construct process. In the last case the as-is information available from operations and maintenance, but also from previous design and construction phases, must serve as an input for the new (plan-)design-construct phase. These phases have demands for the contents of the information. Currently it is often not clear what information is needed in these phases. Related to that, it is also not clear what level of detail corresponds to the information need.

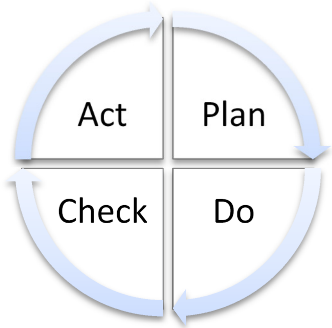


*Figure 32. The Deming circle, a method used for standardization and continuous improvement.(After: Wikipedia (2013)*

### 5.3.2 Organizations and People

There are two aspects of organizations and people within the data exchange framework that can be responsible for problems in data exchange. The first problem deals with the motive of an organization to commit a data exchange. This motive can be related to the goals and aims of an organization. From my personal experience I can say that especially in organizations that work on a project base, it is the intention to finish a project with the least amount of effort and a maximal benefit. The delivery of as-built information in these cases often is seen as a burden.

I have seen that this behaviour is reflected in the way employees of such an organization behave towards their clients. They are not willing to put an extra effort in a project to deliver as-built information whether it is a contractual demand or not. Often this behaviour is caused by the fact that they do not see the importance of such a delivery and they do not take into account that a poor information supply after a project can, and probably will, cause issues in a subsequent project for the same asset. I find it also interesting to see that the same organizations are not happy with the limited information supply in a tender, whilst they are (partly) responsible for the lack of information in the first place.

### 5.3.3 Systems and Software

There is a clear distinction in use of software during the asset life cycle, see figure 33. During the design and construct activities mostly AEC software is used where GIS software is used during operation and maintenance. As I explained in the chapter on data exchange, the type of software used affects the possibilities for information exchange. I specifically mention information in this case and not data, because the data in this kind of processes already has a context.

The necessity for the use of different software systems in the life cycle can be found in the origin of the software, i.e. AEC software was developed for design and construction, where GIS is used for decision support and spatial analysis (Pu & Zlatanova, 2006). The aim of both types of software suits the need within the life cycle phases they are applied. Since the syntactic and structure of both application types have not been designed for mutual information exchange, a potential thread arises for completing the asset information life cycle. Also within one life cycle the data has to be exchanged twice, once from AEC to GIS software (after construction) and once from GIS to AEC software (at the start of a design project). Because the nature of the data use in both phases is different, it is my expectation that it currently will not work to think of one solution for both situations. This is confirmed by an analysis of Pu and Zlatanova (2006, pp. 9.61-9.62), who point out two major issues that must be resolved, before AEC and GIS software can work from the same data:

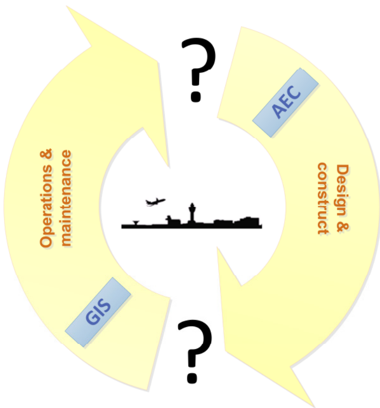

*Figure 33. Software use within the asset life cycle*

- Different support of types of geometrical primitives.
- 3D topology is (partly) lacking in both systems (AEC and GIS).

Most probably separate solutions have to be worked out between both parts of the asset information life cycle.

### 5.3.4 Data and Objects

For years, the main-contractors and internal suppliers at Amsterdam Airport Schiphol maintained their own sets of drawings that described the as-is situation of the airport. This meant that even a larger number of ‘truths’ were being maintained than was already the case within Schiphol. There are two possible reasons for these organizations to keep their own datasets:

- The data at Schiphol did not match reality. As a result main-contractors and internal suppliers used their drawings to create their copy of reality.
- A better vision on the ‘truth’ then your client creates a dependency, which will potentially lead to additional projects in the future.

With SGIS, Schiphol wants to show one truth for everybody, including the main-contractors and internal suppliers. Now these stakeholders must be convinced to start using SGIS as the one-and-only truth. It can be doubted whether the situation at Schiphol stands on its own. I think that it can be expected that there are many more asset management organizations having this same problem. This is not only a problem because of the multiple truths that are created (and which one is correct?), but mostly because of the wasted resources due to double work.

For large projects an increase can be seen in the application of the BIM methodology during the design and construct stages. In the majority of these cases this also means a transformation of geometry in the design models from 2D to 3D. It is obvious that this switch has a major impact on the exchange of data over the different life cycle phases. As long as the data stays within the same software environment when it passes on to the subsequent life cycle phase, I do not expect that there will be many problems with the data exchange.

A potential issue with 3D geometry in the exchange of data was already shown in figure 8 on page 12. Because of the geometrical differences in the current data models of IFC and SGIS, it is hard to convert the geometry in the right manner. This is because SGIS can only support multi-patch features at this moment, while IFC is supporting 3D solid objects. Each type of software uses a different technique to build and store 3D geometries. Different ways to build up and store a solid object can exist within a single software package. It can be expected that the differences between separate software packages are even bigger (Van Oosterom, Stoter, & Jansen, 2005). Examples of different solid types are SweptSolid, CSG and B-Rep (Wu & Hsieh, 2007, p. 1086). The differences can be found in the way these solid objects are described. An analysis of the different type of solid objects is outside the scope of this thesis research.

There are also examples of software packages that are not capable of handling solid objects. Some cannot handle 3D geometries at all and other packages use different techniques to represent 3D geometries, such as the earlier mentioned multi-patches. When solid objects are compared with multi-patch objects, some potential problematic issues come to front. Multi-patch objects are, for example, not necessarily closed, a constrain that is demanded for solid objects. Another issue with multi-patch objects is that it is not possible to calculate their volume, for example because some applications, like FME, do not accept a multi-patch object as being a 3D primitive.

In current GIS data models for asset management, objects are mostly stored in 2D. I think that for the purpose of asset management this is sufficient, as long as height differences are limited. When I look at SGIS for example, the data model is oriented on building levels. In most situations this will do, maybe a maintenance crew needs a ladder to reach for some assets, but it will provide a sufficient overview. However, a large hall, like the entrance of Schiphol, will benefit from a 3D view, because it gives a more realistic view for a certain situation.

If you want to use a 3D geometrical object, you also need to think about whether a top view offers the appropriate image. Often the footprint of such a project is wanted, which makes it necessary to store multiple representations of the same object, for example a 2(½)D and a 3D representation. It is needed to analyse the possibilities to store multiple representations of the same object. And if you want to store multiple representations, it is also important to look at the most appropriate way to extract them from your design model.

The last aspect for data and objects that can cause troubles during a data exchange involves the level of detail. Differences in the level of detail between two phases in the asset life cycle phase can be a cause for information loss, especially if an LoD in the first stage contains more detail than in the subsequent stage. It is than the question whether the details from the previous need to be preserved and if so, how they need to be preserved.

# 6 Solutions

Within this chapter I offer different solutions for the previously described problems. The suggested solutions follow the same order as the problem descriptions in the previous chapter. After that I will filter from the proposed solutions, so that a solution can be proposed that suits the current situation at Amsterdam Airport Schiphol best. In some cases I will first describe additional, Schiphol specific, information that will impact my choice of solutions before I apply a filter towards the proposed solutions. Finally a description is given of the prototyping I was able to apply.

## 6.1 Life Cycle Perspective

### *Parallel processes*

It is my opinion that from the perspective of a complex of assets, the asset life cycle must be approached as a process. The reason there for is that certain processes re-occur. This does not necessarily have to be a problem as such, but it should be taken into account when solutions for the exchange of data are proposed. These solutions must be sustainable and not ad hoc. Sustainable solutions are developed in such a way that they can be re-used if an identical situation will come up again. The development of the solutions is expected to be more time consuming than an ad hoc solution, but the benefits will be gained on longer terms when the solution is re-used multiple times.

There is an additional reason for Schiphol to find a sustainable solution for parallel processing. To start with, there are at around 1.000 projects per year at Schiphol, varying from replacing light bulbs to the creation of new buildings. Secondly, Schiphol wants to add the future situation to SGIS. This does not only allow them to look back, based on the history tables on the server, but also to look into the future. As a result SGIS not only has to be updated after the construction phase, but also after each design phase. It can be possible to only add the result of the planning stage, but Schiphol wants to show the design developments from the individual design stages. This means that after each phase in design and construction, SGIS needs to be updated. Figure 34 shows how such a process will look like for a single project.

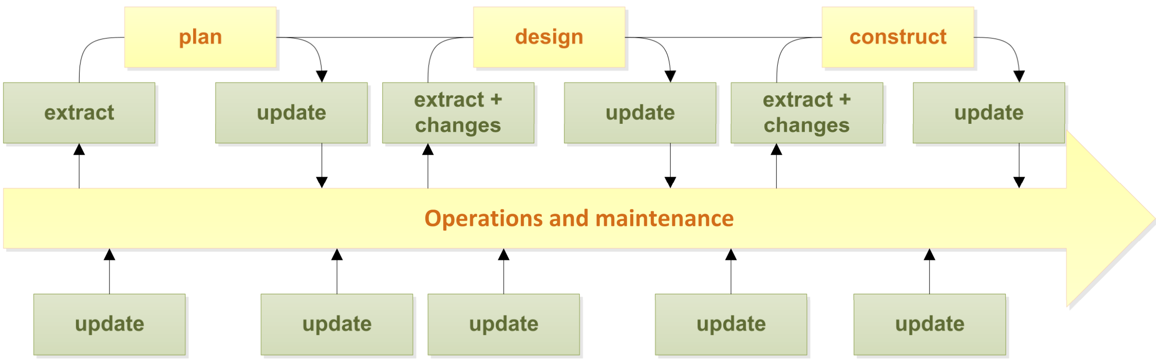


*Figure 34. A close up of parallel processing between operations and maintenance on one side and a design and construct process on the other with updates after each individual life cycle phase.*

The information density increases in this situation because the design and construction team not only present updates to SGIS, but also receive updates on the changes made in the current situation. This was not the case in the old process and will potentially lead to a (c)leaner building process. On the other hand SGIS will be able to show future situations, which allows the responsible operations and maintenance departments to adjust their maintenance and inspection strategies at an earlier stage. This process has the potential for lowering the maintenance costs.

The problem of 'parallel processing' does not need a solution as such, but delivers a condition for future problems. This condition is that a solution must be sustainable, in other words it must applicable for re-use. This counts for Schiphol, but also for other asset management organizations.

An additional functionality that can help the design team, is to create an information feed, that notifies if changes are made to the as-is data, where they are creating a new design for. Currently a feature class is available in SGIS that contains all project locations. At the moment only projects in the construction phase are present in this feature class. Depending on the project phase and the applied changes to the as-is data, a message can be sent to a project manager that something has changed, including a description of the change. The project manager can make an impact analysis of the change and decide whether the change will or will not affect the design. By adding the planned projects and projects that are already in the design phase, it will create an additional insight in the planned activities at Schiphol. This offers the potential to combine planned projects, instead of executing them shortly after each other. The real stakeholders, the travellers, will experience less nuisance of projects and potentially costs can be saved.

### *Information demands*

Knowing that the life cycle is continuous and does not stop is not a problem as such. Not knowing what information is needed in the next phase(s) because you think you are the end of the line is a problem in my opinion.

No matter where one is in the life cycle, I think that an information delivery specification should be available for every next step in the life cycle. This specification must be shared with those responsible for the previous phase. Thereby I mean that the information delivery specification is not only known by those how have defined it, but also by those who will be delivering the information.

At Amsterdam Airport Schiphol each department has a document that describes the information needs and demands for projects. For each project a selection is made of the demands that are applicable for that project. This means that it is clear what information is needed for operations and maintenance. On the other hand Schiphol does not know what the information demands of the architect, constructor and the engineers are. In the past copies of all the relevant drawings were asked by the design teams and currently they have access to the available drawings of Schiphol. The design teams take the drawings they need, without any knowledge at Schiphol of the true information need of her partners in the design team.

I think that for Schiphol it would help to ask the partners that are responsible for creating the design to setup an information delivery specification. This specification can be used to check the current as-is dataset for the availability of this information and to think of a solution for how missing information can be added. It might even be possible that the information demands after the construction phase have to be changed so that all the necessary information can come around.

## 6.2 Organizations and People

From the problem description for the data exchange interaction levels organization and people two possible problems can be extracted:

1. The inter-organizational relation.
2. The attitude and behaviour of people within projects.

The two described problems are related to each other and need an integral approach to be solved. There is a clear distinction between client-contractor relationships and partnerships between clients and contractors. This difference is often related with the thin line between suspicion and trust. Client-contractor relationships are often project based and focus on results. Partnerships also focus on results, but from a joint perspective with equal responsibilities, where a contractor in a client-contractor relationship is held accountable for the results.

In my daily practice I have seen that in case of client-contractor relationships it helps to start a dialogue early in the process on the mutual expectations in the process. Especially where it deals with the delivery of as-built documentation, it is important to become acquainted with motives of both parties. Having the expectations cleared out early in the process, will help in getting a higher quality as-built product.

It is even better to have a partnership relation between a client and a contractor, but in the daily reality of projects, that is often not possible. The advantage of a partnership is that client and contractor already have a common goal and a mutual motive. A contractor will better understand the need for a high quality as-built documentation, because he will benefit from that information at a later stage.

I do not foresee many problems in this area for Schiphol. The department of AIM created a portal with workflows that allows the main-contractors to update a subset of the full SGIS, where they can add the changes they made. However Schiphol, the client in this case, needs to take into account that the contractor might have little to no experience in the conversion of data nor have experience with GIS software. Since Schiphol is willing to support her contractors, she will offer them courses in how to update SGIS. At the moment the process is still under development and the main-contractors and internal suppliers still deliver traditional AutoCAD drawings for as-built. It is expected that by the end of 2013 all main-contractors work according the new workflow. The backside of this approach is that the main-contractors are responsible for executing the data exchange from their own system to Schiphol GIS and it can be questioned whether they are ready for to take that step. Based upon the outcomes of this research, Schiphol is willing to support the main-contractors in executing the data exchange by offering additional services, a step that is a direct consequence of the partnership. How this support is going to look like will be dependent on the implementation of the suggested solutions.

## 6.3 Systems and Software

The solutions on the level of systems and software will not be as easy as on the level of organization and people. Before suggesting solutions for the transitions between the different asset information life cycle phases, I first would like to focus on overall solutions.

Before I start to propose solutions, it is important to realize that the design processes between buildings, civil structures and infrastructure differ in software use and that consequently also the data models and (file) formats are different. Within the next paragraphs I will distinct between AEC 3D modelling software, that aims at the design of buildings, including architecture, construction and in-building installations, and AEC software, that focusses on the more ‘regular’ CAD software. As a consequence it is possible that multiple solutions have to be worked out to get all the relevant data into the “as-is” (and “to-be”) database.

### *Overall solutions*

The most wishful situation would be a solution where data does not have to be exchanged, but can be read and written, or shared, from a central source, based on the same geometric primitives, as was also suggested by Pu and Zlatanova (2006, p. 9.62). Therefor a spatial (R)DBMS is the only solution. To be able to use such a solution, a lot has to change especially in the handling of data in both AEC (3D modelling) and GIS software packages. This solution does not want to create one database for all the information in a project, it aims at having a central database for storing geometries and attribute information that can be linked with other databases, or feature classes, that contain domain specific information. Figure 35 gives an example of how I propose such a setup within a project environment. Other databases can be linked based on (global) unique identifiers.

The most important change that is needed to apply this solution is to align the different types of 3D geometries that currently exist in both types of software (AEC and GIS). An additional effort on the side of AEC software can be done to also align the different design sections (architecture, installations and construction) at the same time. Different studies have been conducted towards the types of (3D) geometries that possibly can be used (Zlatanova, Rahman, & Pilouk, 2002; Pu & Zlatanova, 2006; Wu & Hsieh, 2007). Within AEC software, especially the 3D modelling software that is used within projects where BIM is applied, a lot is possible with 3D primitives. However, these objects still have to find their way to the world of GIS software. Secondly these geometry types also have to be added to the current (native) geometries that can be stored in spatial databases, such as Oracle Spatial or Microsoft SQL Spatial. To make this solution feasible, both AEC and GIS vendors have to come up with a common object-oriented model of geometric primitives for all dimensions that is natively supported by their software. Additionally the model should also be supported by the vendors and developers of the spatial databases. Especially the last also need to support functionality for the 3D primitives, because otherwise they are not of much use other than visualization. Looking at regular CAD software, it might be needed to develop a second model that is layer-oriented instead of object-oriented. Software vendors are than challenged to distinct their software from each other by functionality, user-friendliness and performance. I my opinion the market should force these vendors to work together to such a model. Pu (2005) has already succeeded in implementing NURBS as user defined data types, which should mean that it cannot be long before these primitives are natively supported and the issues should be resolved between AEC and GIS vendors, of which the GIS vendors will need to change the most.

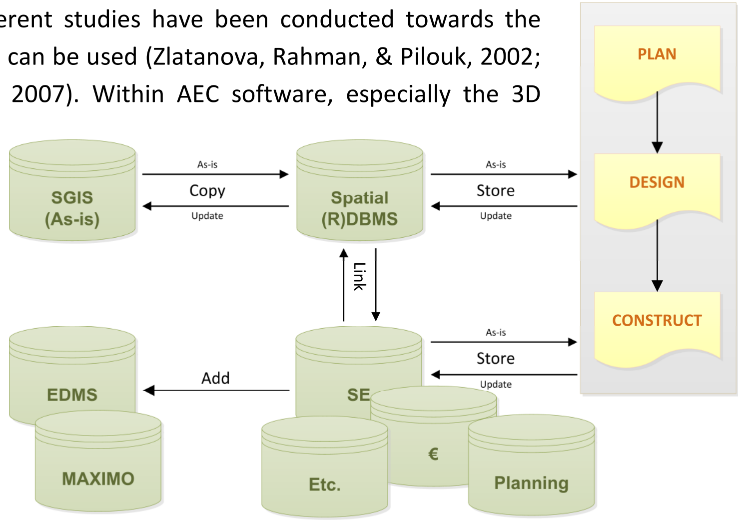


*Figure 35. A conceptual solution for the potential problems in transitions between the different stages of the asset information life cycle.*

This solution might also solve the problem of the loss of detailed information. During the design and construction phases detailed information is generated that is not relevant for maintenance. By working from the same database it is possible to keep this data stored and to re-use it in a later stage for e.g. a revision project. If the data is present in feature classes that are in used for operations and maintenance, views can be used to keep the data out from the visually presented as-is datasets. It should be taken into consideration that these details often deal with constructive and architectural information that will probably not change over time, until the structure of an asset will be changed.

Another solution would be to consider the use of the same software for the spatial objects throughout the asset life cycle. The use of a single software application does not need data conversion and can keep all information that was added. However, in most cases the asset management organizations are not the ones who make the design and construct the new assets, although they will order those activities. Commercial organizations have the possibility to demand the use of a certain software type, but that is not possible for public organizations (OSOR Editorial team, 2011). As a result, the chances are realistic that the design and as-built information will still come from different software than the own system, which will inevitably lead to a conversion of data. Secondly, as stated before, software is developed for certain activities and, as far as I know, there is currently no software available that can manage all activities of the asset life cycle. This would result in custom application design and that is just the development that Schiphol tries to avoid.

When I look at the situation of Schiphol, both options would be interesting. When you take into account the second option, in combination with the current layout for mutation processing, it could be a possibility for Schiphol to go for a single system and to make it available for the contractors. This way the clause for not prescribing certain software can be avoided. However, since current software is not able to cover the full asset life cycle for all activities, this is not seen as a realistic solution yet. The first solution is a conceptual solution and at this moment it will not be possible to apply this. If it is possible to apply the suggested solution, than the spatial (R)DBMS will contain a copy of the SGIS dataset that by itself will stay in the production environment, as was proposed by Vollebregt and Vos (2012), containing a, as they call it, 'Release-BIM' and a 'Project-BIM'. The other additional databases can possibly add relevant data to the other systems that are maintained by AIM. Looking at the current situation it must be concluded that both suggested options are not yet feasible, but could be considered in the (near) feature.

### *Differentiated solutions*

Since the overall solutions are not yet realistic to implement, I also want to look at different solutions, that are more realistic to apply. At first I will look at the exchange from the (design and) construction phase to the operate and maintain phase and after that I will offer solutions for the exchange of data from (operations and) maintenance to the plan and design phase. Herby I assume that data exchanges within the process of design and construction will not cause problems, because of a consequent application of the same software systems within these phases. I make this distinction, because there is an essential difference between both transitions. The first transition needs the as-built information to update the as-is situation so it resembles the real world at that time. This means that objects have to be changed within, removed from and added to the existing to database. The second transition, on the other hand, needs the as-is situation as a base layer to create a new design on, so there is no need to change the existing dataset. It needs to be taken into account that during the design phase, people can benefit from having the true objects within the base layer, to make it easier to make change them (if necessary) for a new situation.

When I look at the situation where data needs to be exchanged between the construction and the operations phase and I apply the selection chart (figure 9, page 14) to define the most suitable strategy, I come to the conversion strategy (see figure 36). My starting point is that an as-is dataset for operations and maintenance is already present, which also implies that the data model of the target dataset is fixed. As a result the source data resulting from the construction phase needs to be converted into the as-is dataset. If the data model and the file format would have been the same, it would not have been necessary to apply the selection chart, because data can then be used as-is.

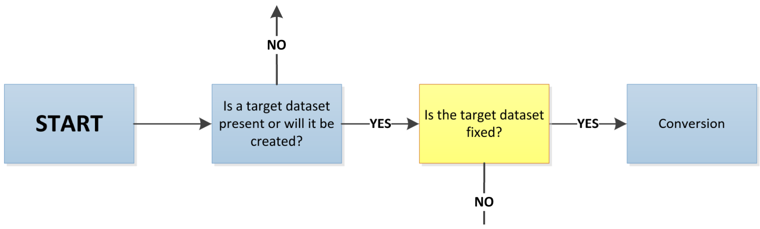


*Figure 36. Strategy choice for data exchange between the construction and the operations phase.*

With current technology it does not seem to be possible to directly import 3D models from software that is used in 'BIM projects', like Autodesk Revit and Bentley Architecture, into other software packages. This means that the models have to be exported by its native application in another (exchange) format before the models can be used, what includes an extra risk of information loss. The logical choice would be to export the models to IFC, the most common open standard in the design and construction industry that is also supported by these AEC 3D modelling software packages. IFC is an open standard that can be read by many applications and that will make it not too hard to get the information converted to other (file) formats and/or data models.

Before 1800 production took place by copying physical models of an object (Goldstein, Kemmerer, & Parks, 1998, p. 3), like still is being done with keys, see figure 37. This methodology inspired me to think of another way of 'conversion'. Just read a 3D model and create a replica by reshaping an empty solid box. The big difference with existing conversion techniques is that they try to adjust objects within the source model, so they can be used in the target model. The advantage of this method would be that 3D objects will be recreated from scratch like a sculptor tries to get a shape out of a raw piece of stone or wood. A disadvantage of this method is that all (semantic) information, that is present in the model, will get lost and that the remaining geometry lacks all context.

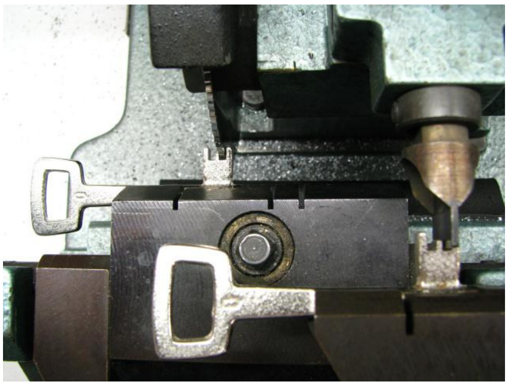

*Figure 37. Is it possible to use the principle of a key copy machine for the conversion of 3D models?*

Of the two solutions I suggested for the conversion of the 3D model to SGIS, only one is feasible and ready to implement in my opinion. I propose to change the SGIS data model, based on the recommendations in chapter 4, in such a way that the use of 3D geometries is supported. In my opinion the preferred solution will use SDO_Geometry for the storage of 3D objects, where ST_Geometries can be used to create views for ArcGIS. Also a standard conversion model needs to be created, for example with FME, and a technical specification will be needed that describes how the IFC file should look like in terms of classifications, attributes and property sets.

The second situation a data exchange is needed, according to the software use in the asset life cycle, is between the maintenance and plan/design phases. I think that two different strategies can be applied here, being conversion and as-is. Conversion is as obvious as it was in the first situation between construction and operations. The target data model delivers a problem, since the data model will be dependent on the 3D modelling software that is used. A possible solution to overcome this issue is to use IFC as an exchange format. Again the position of IFC as open standard that is widely supported offers opportunities. I specifically propose the use of IFC, and not e.g. CityGML, because of its relation with the building process and the fact that the current data model of SGIS resembles IFC much more than, for example, CityGML does.

A possibility could be to export the GIS model to IFC, but such a conversion tool is not yet available and should be developed than. The quickest way therefor would be to consult an ETL provider, like FME or Spatialytics, to develop a writer for IFC. I think that the current data approach of SGIS, being building floor oriented, can be of help for the creation of an IFC dataset. Because it is possible to relate the objects in SGIS as a parent-child relationship (all objects on a certain building floor are related to that floor), just like IFC does, it might be possible to construct an IFC file from the objects in SGIS. However, this is purely theoretical and will need testing to be proved.

Since not much changes are expected in the geometry during the operations and maintenance phase, it might be an option to use the delivered IFC files from the construction phase as a starting point for a new design phase. Additionally information about the changed geometries needs to be added for full information. The next solution could be used to deliver that information.

A simple solution that also can be applied already is an export to the regular file format of the software vendor, e.g. DWG or DGN. The backside of this solution is that the solid, for as far as it was still present, gets lost just like the additional information that was contained in the dataset. It stays possible to add the geometries, that will become faces when it is not possible to export to solid geometry, to a structure of layers so that it stays clear what the semantic meaning of an object is.

The second strategy that can be used is as-is data use. This strategy is possible because the target data model will generate a new situation based on existing information. This implies that a conversion can be left behind and that a dataset can be used as-is, only to present the current situation. The problem with this situation is that only a limited number of file types can be read by the AEC 3D modelling software that is used in projects where BIM is applied. In my opinion this can be solved by using general techniques for adding data.

The first solution I want to refer to are web feature services that allow to load 3D objects in a software application. Again a problem arises, because the AEC 3D modelling software aimed at architecture and construction does not support the use of web services. For non-building projects this approach is expected to be more successful, because other types of design software, like regular CAD software, are used there.

Autodesk developed a solution they called "Feature Data Object" Access Technology (FDO). This technology is used by Autodesk to give access to GIS files within their own GIS solution 'AutoCAD Map 3D'. The FDO technology has recently become an open source project under the flag of OSGeo. Extending this technology to the AEC 3D modelling software would also allow access to GIS files and is expected to be quite easy for the software vendors, but first needs to be implemented before it can be used.

Before any solution for the exchange of data from maintenance to design is suggested, Schiphol should first start with asking the designers and constructers for their information demands. A specification on what they exactly need, can help Schiphol in providing the right information. The positive effect will be that it will be easier to create the design, because it is known what information is available, when it is available and how it is made available, just like Schiphol asks in her information delivery specifications for as-built information.

With the current technological possibilities it is my proposition that Schiphol re-uses the earlier delivered IFC files so that they can be used as a base layer for the new design. Additional drawings will be added with the changes between the delivery of the IFC file and the start of the new design. It would have had my preference to directly export from SGIS to IFC, but there for an additional IFC writer has to be developed by FME[6]. At the start of my thesis research they have informed me that they are willing to develop such a writer if it is a necessity for certain business processes. In my opinion this offers possibilities for Schiphol, because standard software is being used and at the same time they have the opportunity to deliver the optimal information for the design phase.

## 6.4 Data and Objects

Since data and objects are a result of the software used and the data model applied, it is expected that the biggest issues in data exchange will occur at this interaction level of the framework for data exchange. The problem description and the offered solutions make together that the following topics need solutions:

- Loss of detail.
- Differences in available geometric representations.
- The use of multiple geometric representations.
- Extraction of the desired representation from a 3D object.
- Overcoming semantic differences.

As becomes clear from the list above, no solutions will be offered for the problem of the duplicate dataset. I made this choice because it is expected that this problem will be resolved by itself with the introduction of SGIS. Off course SGIS still has to prove itself, but the expectations are positive, especially when the proposed recommendations and solutions are implemented.

### *Loss of detail*

A bigger overall problem is the loss of detail. Especially for construction and architecture design these details can be essential. In most cases these details are already lost at the first data exchange from

[6] Schiphol already uses FME for the conversion of the old CAD drawings to SGIS

construction to operations. To overcome this hurdle, it is an option to maintain the original design and the corresponding detail drawings and to store them in a document management system. This way the details will be available but do not hinder the daily users for operations and maintenance. The backside of this solution is that it is expected to use much storage room, but I my opinion that is not an excuse with current technical possibilities for storage.

The offered solution is directly applicable at Schiphol, who use an EDMS (Electronic Document Management System) to store additional information that cannot be stored in one of the other applications that are used by AIM, reports are a good example of such documents.

I would also like to introduce two other solutions that can be applied when all data is stored in a central spatial (R)DBMS. The first solution is the application of different views, that leave out the superfluous details for a specific life cycle phase, and the second solution is the application of 'automated generalization'. Both solutions can already be applied within SGIS, allowing for the use of the original data, but without being overwhelmed by unnecessary details.

A last solution is actually proposed by Van Oosterom and Stoter (2010), but is in its initial development stage. This solution stores scale as being a dimension of an object, which will allow consistency across all space, time and scale dimensions. However this is still theory and has not been applied yet, but offers quite some possibilities for data handling throughout the life cycle with its differencing demands in each phase.

### *Differences in available geometric representations*

One of the bigger problems is the differences in the (3D) geometric representations used by the different software within the asset life cycle. In my opinion there is only one way to overcome this problem, as I described with the overall solution for systems and software, i.e. the development of a common geometry model that will be natively supported by both AEC (3D modelling) and GIS software as well as by spatial databases.

Another (temporal) strategy might be to align the geometries, which will allow at least a conversion of the geometry with a limited loss of information. This strategy can be used until better solutions become available.

In the current situation the 3D geometries from the IFC files will be transferred to multi-patch objects. As already is explained, multi-patch objects are not true 3D geometries and are especially useful for visualization. At the moment that is sufficient for Schiphol, for the longer term it might not be, when analysis are conducted in the third dimension, such as volume calculations. When the SDO_Geometry will be used, it will already be possible to conduct some 3D analysis, with the functionality of Oracle Spatial. However, I think that it can be expected that a better support, in terms of geometric primitives and functionality, for 3D solids within ArcGIS will be developed within the next couple of years.

### *The use of multiple geometry representations*

With the current technological possibilities it is not strange that people want to have the option to store different representations of the same object. There are software applications that allow different views of the same object, for example its footprint and a three dimensional representation. Current GIS software does not allow that functionality. A top-view always is available, but does not necessarily equals the footprint of the same object. A separate 3D view is also available in most cases, however some software needs additional applications and licenses to be able to see the 3D view, e.g. ArcGIS Desktop cannot display data in the third dimension, therefor ArcScene is needed which needs additional licensing. For these situations it offers added value to store multiple representations of the same object, in this example a 2D polygon, possibly with Z-values around the edges, and a solid or multi-patch representation, depending on the possibilities of the software.

Some spatial databases do not allow the storage of two spatial representation in the same feature class, which would be the preferred situation. In such a case the addition of an extra feature class that only holds the second representation and has the same (global) unique identifier as its original object as an attribute can be a solution to this problem.

Since the first option is not possible within the current setup of SGIS, I will keep with my original suggestion to switch to SDO_Geometry in the 'mother' feature class and an additional representation. Views with ST_Geometry can then be used .for the display of either to 2D or the 3D representation.

### *Extraction of the desired representation from a 3D object*

During the standard import of an IFC file to another data model, only the original geometry will be converted. If it is necessary to extract another geometrical shape from the original feature, additional actions have to be taken.

An analysis of the IFC data model shows that it should be quite easy to extract the footprint of a 3D object. In principle an IFC object is described relatively towards its parent objects. If I take a wall from a room on the second floor as an example. The wall starts at a height of 0 meters and goes up an X distance. The wall starts at the Cartesian coordinate X,Y relatively to the room and goes X meters in a particular direction. The room is located at the Cartesian coordinate X,Y relatively to the floor and is high X meters and stretches X meters along one axis and X meters along the other axis. The floor is located X meter above the ground level, etc., etc.

I am not sure whether the extraction of the footprint will be as easy as described, but practice will have to prove that. In any other case it should be possible to analyze the individual faces of the 3D geometry and to select the lowest most horizontal object from the available faces.

Although an 'off-the-shelf' solution is not available, I do not expect that this problem will cause many issues and that it will be possible to extract the footprint of the 3D geometry for any purpose. Any other 2D representation will need an clip between a 2(½)D object and the 3D object. The resulting object within both the polygon and the 3D object is than the 2D representation.

### *Overcoming semantic differences*

In my opinion the best way to overcome semantic differences between two datasets is the use of a register of all possible objects, including an overview of the attributes stored with that object and the possible values for those attributes. It makes no difference whether this register is stored as *linked data* or that a register is published as a document. It is important to know what is meant with a certain term in both geometry as well as in attributes.

Looking at the asset life cycle and the BIM developments within the Netherlands, I would suggest to adept the Library of Concepts as soon as it comes available and to oblige contractors to use the same definitions in the design and construction phases.

I want to advise Schiphol to adept the Library of Concepts as soon as it becomes available. Until that time I would suggest to create an IFC specification and to add to that an object overview including properties of the individual objects that need to be a part of the IFC data model. Because Schiphol does not want to prescribe any software, it is not possible to create a product library of which the design objects need to be chosen. Instead I think that a description of the allowed objects would do. The delivered IFC file can then be checked on validity based on this description. By describing the objects from the perspective of Schiphol, it is very well possible to incorporate the properties that are stored within SGIS. This way a win-

win situation is created, because the designers know what objects they are allowed to use and the conversions from and to SGIS are expected to run efficient.

## 6.5 Prototyping

Since the dataset that was provided to me only contained models in Revit, I was not able to test with similar software from other vendors, simply because I did not have the time for that and also because I did not have a dataset in another file format available.

What I try to do in this stage, is to export data from Revit and to get it into the SGIS model. I expect to use FME as an ETL tool to convert the data that is coming from Revit and bring it into SGIS. I will also try to read exported data back into Revit, without the loss of information.

### *Export from Revit*

Revit is a 3D modelling application by Autodesk, that is used to design new buildings. In the 2012 version, the version that I used for testing and the version that is used for the One XS project, has three varieties, i.e. Architecture, Structure and MEP (Mechanical, Electrical and Plumbing Engineering). In principal the applications do the same, only different tooling is available. In the 2013 version of Revit there is no longer a distinction between these varieties, all tooling is available from one application.

A model in Revit can only be stored in its native format, that is when you want to be able to edit your data. It is also possible to add (link) data from other files, but these must be in Revit, CAD, DWF or Point cloud format. For the export of data more options are offered, see figure 38. To export information for re-use in other applications only three options:

- CAD formats (DWG, DXF and DGN)
- IFC
- ODBC Database

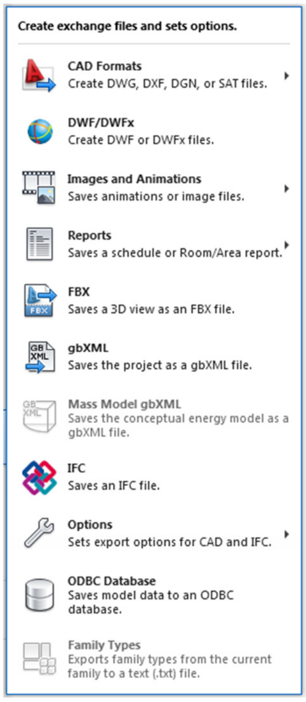


*Figure 38. Export options from Revit (Source: Autodesk Revit)*

For the CAD formats and the IFC format it is possible to assign a mapping for the objects that are available in Revit. For the current exports I used the standard settings. Changing the settings can have a positive effect on your export was proven by De Riet (2012; 2013), but I did not have enough time to experiment with that.

The export to IFC and DWG (a CAD format) did not show any problems during export. The result in CAD however only shows the geometries and all additional (attribute) information is lost, although the geometries are classified to different layers. The IFC export did seem to contain all information, but that is hard to check, taking into account the large amount of information that is available.

I did not succeed in exporting a Revit model via an ODBC connection to Microsoft Access or to Microsoft Excel. The cause for this problem was that Revit is a 64-bit application, where Microsoft Office is a 32-bit application. An additional driver is available that would allow to export the data to a 32-bit Microsoft Access database, however with the resources I had available I was not able to re-install Microsoft Office. I also did not have a computer setup that would be able to write to a database server. Meaning that I had to let go of this option.

### *Conversion with FME*

Before I started to map the IFC data to the SGIS data model, I first tried to run a plain conversion from IFC to a file geodatabase (FGDB) in Esri. Therefor I selected all IFC files as a source and used a single target FGDB. Further I used all the standard settings to see what the output would be. This conversion did not seem to cause too many problems, although two spatial objects were too complex to be exported. It is my expectation that there were errors present in these geometries, because by its type I could see that the objects should have contained not too complex geometries. A second problem that came to front was the use of the same attribute names in the same class, but with a different caption use (see figure 39). FME is very strict when it comes to captions, whilst ArcGIS only looks at the name. Where FME thinks that 'Height' and 'height' are two different attributes, ArcGIS sees them as the same. When FME tries to create a new column of one type, when the other is already present this causes problems, i.e. loss of information, in the conversion. This kind of problems can be avoided if a prescribed data model is used and the IFC file is (automatically) checked before it is exported.

```
Encountered two field names ('Materiaal' and 'materiaal')
in table 'PSet_Revit_Type_Materials_and_Finishes' which
differ only in case.
An error occurred while attempting to create the table
'PSet_Revit_Type_Materials_and_Finishes'. The error
number from ArcObjects is: '-2147220649'. An attempt was
made to insert a duplicate field name.
A fatal error has occurred. Check the logfile above for
details
```

*Figure 39. FME error with identical field names.*

The output of this export was analysed in ArcGIS. It became clear that some information was missing to link the information in the Property sets. As can be seen in figure 40, a string containing a '#'-character and a number, are used to reference to other instances in the STEP file. This reference is the only way to link the different instances in the IFC to each other. It appeared that not all instance information came over during the conversion.

```
#1916= IFCBUILDINGSTOREY('1smz0v6110Nxym5PBdZkqX',#13,'-
1. Keller',$,$,#1913,$,'-1. Keller',.ELEMENT.,-2.9);

#13= IFCOWNERHISTORY(#12,#5,$,.ADDED.,$,$,$,1295253721);
#1913= IFCLOCALPLACEMENT(#1893,#1910);
```

*Figure 40. Fragment of an IFC file in STEP encoding.*

Based on the experiences from the plain conversion with standard settings and the additional analysis in ArcGIS some changes are made to the conversion model:

- Removal of 'too complex' objects based on id.
- Additional underscore in duplicate field names (see figure 41).
- Adding schema attribute 'ifc_instance_name'

With these additions it becomes possible to relate the feature classes to the different Property sets that contain additional information on the building elements.

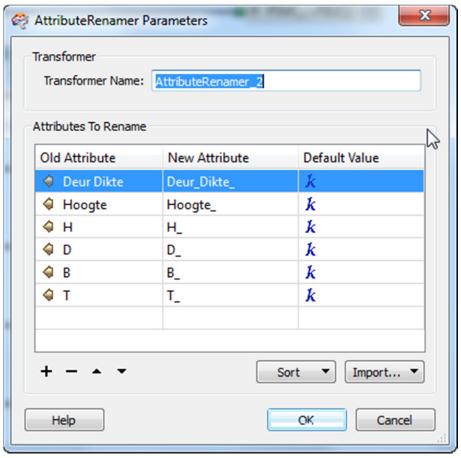


*Figure 41. Change duplicate field names*

After the conversion it also became clear that the geometric objects are presented in a local coordinate system that uses millimetres as spatial units. I found it remarkable that the project location, that is included in the Revit file, was not included in the IFC file. Maybe this has to do with certain settings in Revit that should be adjusted before an export is executed, although I would expect that such information automatically is included. It is important to move the objects to its correct location and to apply a scale factor so that the objects will be presented in the Dutch Rijksdriehoeksstelsel. After the conversion, based in the standard zero-point, it appeared that the converted IFC dataset still did not match the geometry of SGIS. I also verified the data on an aerial image and that at about showed the same deviations. The IFC file needed to be moved approximately -1,98m in X-, 0,10m in Y- and -2,80m in Z-direction. The geometries still do not fully match, but are much more alike. Possibly also a rotation factor should be included, but due to a lack of time, I have not been able to go deeper into this subject and for the purpose of testing it does not make a difference.

The next step is to connect the attributes from the different property sets with the building elements. Central in the connection of this information is the set of relationship tables that begin with *IfcRel** that links the building elements. I have not physically executed this step, but with the help of a FeatureMerger transformer this action is very well possible. Some of the attributes refer to multiple objects within a single field. For these attributes it is possible to create a single instance in the table for each attribute, as can be seen in figure 42.

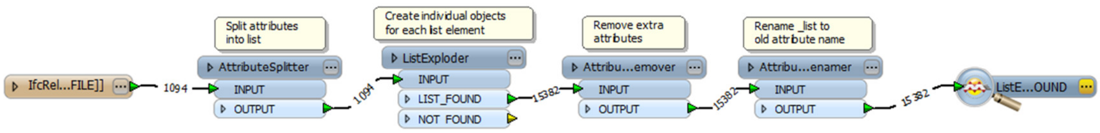


*Figure 42. FME process steps to create individual instances for references to multiple objects in one field.*

Although the first impression was that the schemas of IFC and SGIS would match on the level of entity and attribute, a further investigation showed that some IFC entities must become attributes in a SGIS feature class. This export delivered 31 feature classes that hold a geometry, of which twenty-two are different IFC types. The other nine feature classes are IFC types that contain multiple representations. Also not all instances should be exported to SGIS. In the example in figure 43 two different representations for the same door are shown. It is clear that the lines, that indicate to which side the doors open, should not be contained in the export, although a simple 2½D representation can be extracted by removing all the vertices in between the start and the end point of the line. To see what can be used and what not, first insight is needed in the objects that are exported. The currently exported features from the IFC file are either a line or a multi-patch object (in ArcGIS). Since there are no multi-patch classes in SGIS, these should be created first. According to the recommendations, the 'mother' feature class is going to hold two representations, of which one holds the 3D representation. However in my test environment I did not have a server available, so I could not test this option. Due to a lack of time I did not research the actual mapping from IFC to SGIS. I did not do this for two reasons:

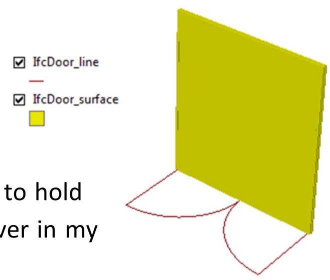


*Figure 43. Two representations for the same door.*

- I have proven that it is possible to get features from an IFC file in a native Esri FGDB.
- The IFC classes and the SGIS objects do not match one-on-one and it will take too much time to fully find out what actually belongs where.

With the current setup I think that it will take at about 2-3 days to fully workout a workbench, based on the test data, including the mapping to SGIS and a comparison of the available attributes.

### *Results in ArcGIS*

During the conversion with FME I used ArcGIS to look into the (geometrical) information that came from the IFC file. After I made some changes to the location of the objects, they seem to be correctly placed towards each other, however I do think that it is necessary to check why (and how) it can be possible that the data is not projected in the right location. I think that with a little bit more time, it is very well possible to get the IFC data in Schiphol GIS.

### *Import in Revit*

I also tried to read the IFC file back into Revit, because De Riet (2012, p. 14) claimed that IFC objects could be imported and after that handled as if they were native Revit objects. The result I got to see, contained a wired model of all objects of the G-pier. From a distance it was no longer possible to distinguish between the different objects. I am not sure whether this was caused by writing the Revit data to the IFC file or during the import to Revit. With the article by De Riet in one hand and the other with the computer it might be interesting to test the different possibilities.

Another aspect I found very remarkable was that a lot of errors were generated. This could point to an IFC file that is not fully correct, or perhaps or to errors in the Revit model. Because of too little knowledge on Revit I was not able to figure this out in such short notice.

### *Conclusion*

From my test case I have not fully succeeded in completing the asset information life cycle. However, I expect that is should be possible, by looking at the articles by De Riet. It is very well possible to transfer IFC data to SGIS, but there for a FME Workbench will have to be created and a mapping has to be made between IFC and SGIS.

# 7 Conclusion and recommendations

## 7.1 Conclusions

This research looked at the possibilities of completing the asset information life cycle in general and suggested solutions that suit the specific situation at Amsterdam Airport Schiphol. Therefor an analysis was made of the aspects that are important in data exchange and an explanation was given of the acronym BIM. The description of the data model SGIS and the portal with the same name were added to make it enable a focus towards the specific situation at Schiphol. Subsequently the focus was put on the asset information life cycle to find out what problems can be encountered in data exchange over the different phases of the life cycle.

The first part of the research focussed on the meaning of data exchange. Data exchange is a transaction of data between a sender and a receiver. The data can be seen as the currency in the transaction and its characteristics (syntactic, structural and semantic) define the meaning of the data, as well as the software that can be used to work with the data. Besides data, there are also other aspects that are of influence on a data exchange, therefor I proposed the framework for data exchange interaction (see figure 44). The interactions happen at each level and can both be intra- or intra-organizational. The four levels of interaction are 'executive/management level', 'operational level', 'technological level' and the 'object level'. Each level of interaction has to be agreed on to make a data exchange successful. The interaction levels of organization and people deal with cooperation and mutual understanding. For the technological level different system integration types have been proposed to support a smooth exchange and for the object level a selection chart was created do find to most suitable strategy to exchange objects.

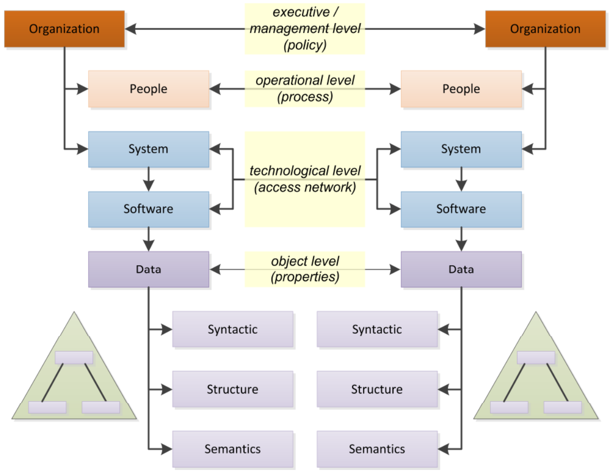

*Figure 44. Framework for data exchange interaction.*

There exist many views on BIM. BIM is an acronym for Building Information Modelling, but its application is much wider than buildings alone. Where many people see the application of BIM alone for design and construction, it can actually be applied to the whole life cycle. The biggest advantages that can be reached with BIM are cost savings due to a more efficient and effective way of working. The most important difference with the current way of working is that decision making happens in an early stage of the design process and that multiple 3D designs are combined in a single model. Based on literature research I came to the following definition:

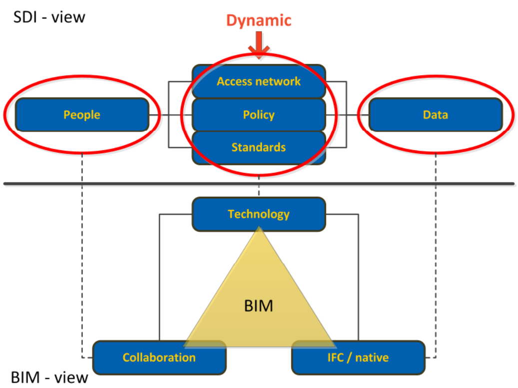

*Figure 45. Comparison between BIM and the GIS concept SDI.*

"BIM is a PROCESS in which relevant ACTORS COLLABORATE on creating, analysing and managing MULTIPLE DIMENSION DATA within a DYNAMIC MODEL representing one or more ASSETS throughout its/their LIFE CYCLE".

I also found out that BIM shows a lot of overlap with the GIS concept 'Spatial Data Infrastructures' (see figure 45), although both have different application domains.

Schiphol GIS is a data model and a portal at Amsterdam Airport Schiphol. The data model contains the geographical representations of the as-is and historical information of almost all assets of Schiphol. Additional information is included in applications that are linked (or will be soon) with SGIS. Although some geographical information is not included in SGIS, because the software used does not offer the functionality needed, all information can be accessed and edited via a single portal that also carries the name 'SGIS'. At the moment SGIS is still under development and it is expected that the data model is finished somewhere in 2014. Together with the other applications that are maintained by the department of Asset Information Management, SGIS forms a Central Information System (CIS). This CIS can be seen as the 'BIM system' that is proposed by Vollebregt and Vos (2012), with that difference that SGIS only covers the operations and maintenance phase and does not include design and construction. However, the software and the data model have not been developed for that task, as the software that is used with design and construction never has been developed to conduct operations and maintenance.

The aim of this research is to complete the asset information life cycle. The term 'complete' implies that something is missing in the current asset information life cycling. The analysis of the problems in the life cycle confirmed this statement. In the current situation it is not possible to re-use information from the start of a project through the full life cycle into a new project and so on. The problems are caused by a division of the life cycle into two different worlds in all aspects of the framework for data exchange and the life cycle itself. The life cycle is approached as being a continuous circle, but instead it is an on-going and static process that is dominated by operations and maintenance. Design and construction are short and dynamic projects that run parallel with the operations and maintenance phase, as can be seen in figure 46.

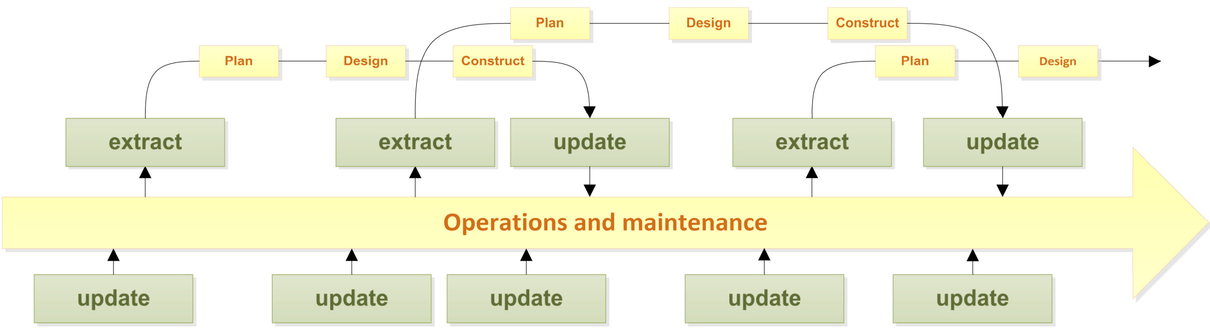


*Figure 46. A different approach of the asset (information) life cycle.*

From the perspective of data exchange, a similar division of the asset life cycle can be seen. In the design and construction phase mostly so-called AEC (3D modelling) software is used, where GIS software is used in the phases operations and maintenance. The differences in the aim of the life cycle phases also work through in the organizations that execute the work and the motive they have. The differences in software affect the possibilities for data usage and cause subsequently problems in the exchange of data due to differences in the characteristics of the data, especially in the differences in support of geometrical primitives.

A set of solutions is offered to overcome the earlier described problems. Some of these problems need a further development at the side of software vendors and in terms of standardization, whilst other solutions are directly applicable. However, it should be mentioned that the solutions that are directly applicable, do not contain the most optimal solutions. The best solution would be to work from a central shared spatial database with a common geometrical model throughout the full asset life cycle. Different software applications can approach the data and use specific views to show the relevant information for the activities that are conducted with that specific software. Software distinguishes by functionality, user friendliness and performance and is implied in the phases where it is developed for. The biggest issue in this solution is the support of a common geometrical model over the different AEC and GIS applications.

The applicable solutions for Schiphol include a conversion from the AEC (3D modelling) software to the open standard IFC for the step from construction to operations. Therefor a technical specification is created that describes the contents of the IFC model, including the use of objects. The IFC file will then be put into SGIS via a automated conversion. This same IFC file will later be used to transfer information from the maintenance phase to the design phase, including an overview of the changes made in SGIS.

It is not yet possible to complete the asset information life cycle in terms of data exchange for the current situation at Amsterdam Airport Schiphol. However with a few changes to the data model of SGIS, it is at least possible to complete the life cycle in terms of geometry. Problems are mainly present at the boundary from maintenance to design. The biggest issue is the transfer of the additional information of the assets. The main problem can be found in the closed nature of the AEC 3D modelling software and the lack of conversion possibilities from GIS to AEC (3D modelling) software.

In my opinion it is also clear why people think that the BIM methodology is mainly used within the design and construct phases of projects and not during operations and maintenance. The building industry was not familiar with this way of working and started a new movement (in their view). However within operations and maintenance GIS is already in use for many years. This means that they already know how it is to work object oriented and also with databases that can be connected to each other. The comparison of BIM and SDI as I made in section 3.3 already showed this overlap. In fact within operations and maintenance the BIM methodology is already in use for many years, but a different kind of software is used to do so.

## 7.2 Recommendations

The recommendations can be split in two categories, being Schiphol specific recommendations and recommendations for the software vendors.

There are two major issues at Amsterdam Airport Schiphol that need to be solved for completing the asset information life cycle. The first one is that Schiphol needs to define a BIM strategy in which they will take a stand in the use and delivery of BIM software and data models and the relation with SGIS. Since Schiphol applies a policy where they want their main-contractors to use their own software, I recommend Schiphol to setup a technical specification that is related with current delivery protocols in which they define that all 3D 'as-built' models must be delivered in the IFC data format, including a definition on the information the IFC model must contain.

Secondly I recommend to change the SGIS data model in such a way that it will support the use of 3D primitives. It is possible to contain multiple representations in the main feature class of an object and to create views that can be handled by the current GIS software at Schiphol. Therefor the geometry type that is currently used for the storage of representations has to be changed from ST_Geometry to SDO_Geometry.

I also want to recommend Schiphol to keep a critical attitude towards the current SGIS model, because it still seems that certain objects are present in multiple feature classes. This way the risk of not having a single source of truth is still present and will lead to problems in the future. Therefor it is also important to do a research towards the information needs in the design and construction phase and to develop a technical specification for the delivery of IFC data, including a FME model that will update SGIS. A part of this investigation should also be how the different levels of details that are needed in the individual life cycle phases can be applied to the SGIS data model, or one of the other systems within the '*golden quadrant of AIM*' in such a way that information does not get lost.

Related to the previous recommendation I would recommend to Schiphol to apply the Library of Concepts to the SGIS model as soon as it becomes available. The available choices need to be documented and added to the previously mentioned technical specification. This way semantic issues in the conversion and sharing of the data will be overcome.

One of the topics I did not look into is how the 3D data spread amongst the users of SGIS. Hereby I point to the application of spatial analysis in the third dimension and the application of tooling for the visualization of this 3D data.

To the software vendors I would like to recommend to develop one single geometrical model that will be applied in both the AEC and the GIS software. This way issues with converting geometry will no longer occur and I cannot imagine that the current differences need to be maintained.

A short term development that would be very welcome to the 3D modelling EAC software is the support for web services and especially for 3D web feature services. This way it will be possible to present other relevant data and to link new objects to existing ones. Additionally it will also provide the opportunity to access information that is linked to the model. The GIS vendors I would like to recommend to work on their support for 3D primitives, because compared to the AEC (3D modelling) software a large step still has to be taken.

This research has not looked at implications of the proposed solutions in terms of planning, finance and legal implications. These implications need to be researched to be able to implement the proposed solutions.

## 7.3 Reflections

When I look back at my thesis research, I must say I am partly happy with the result. At the start of the research, I was planning to do a much more technical research where I would really develop something. An example of such a research is the cited research by Pu (Managing Freeform Curves and Surfaces in a Spatial DBMS, 2005), who developed something, in this case a 3D primitive, and did a lot of testing with it. I was hoping to do something similar, but it turned out otherwise.

This also counts for the contents of what I have written. Where I have a feeling that I really had the possibility to dig out some topics, I stayed on the surface and tried to link everything that is visible within my horizon. This has resulted in a very analytical thesis, that in the eyes of some may miss some depth. On the other side should it be taken into account that it is not easy to oversee so many aspects at the same time.

Although I have come up with some new suggestions in both the literature research and the proposed solutions, most suggestions, in my personal feeling, seem to be obvious and do not add that much to science. However, the confirmation that some of the proposed solutions have also been proposed by others, shows that these solutions are expected to be solid and should be worked out further.

When I look at the solutions that I have proposed, I must distinguish between those that can be directly applied and those that really need further research and development. Most of the solutions that can be applied directly are not the most ideal solutions. For example the conversion of 3D AEC models to SGIS, need an additional step of which I already claimed that this might lead to an additional loss of information. Also the re-use of the model and delivering the additional changes with a limited context is not a solution that makes someone really happy. On the other side, it must be realized that these solutions can be applied directly and that in the meantime the more ‘sustainable’ solutions can be researched further and worked out, so that things become easier and will go more fluently.

The same feeling I have with SGIS. It aims at providing all users at Schiphol the (geographical) information they want. Therefor it supports a lot of themes, over 77, but it is not possible to cover all topics or functionality. Therefor it might be necessary to use different software tools in the life cycle, and maybe in the future someone will conclude that the proposed solution of a central (spatial) database that provides data to different software is not a workable solution under the given circumstances.

What I really learned is to do what you are good at, but I keep hoping that the next time I will go beyond my own borders and dig deep into a specific topic, whereby I come with a new developed (and tested) solution.

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# Appendix

*Appendix A* *People spoken with for information on Schiphol GIS*

*Appendix B* *Data model Schiphol GIS*

# Appendix A

***People spoken with for information on Schiphol GIS***

### *People spoken with for information on Schiphol GIS*

- Nico Wasserman - Owner of SGIS
  Discussed multiple times about the contents of SGIS and how SGIS relates to data that is used in design and construction.

- Peter Kanbier Systems architect
  Peter is the designer of the first logical data model of SGIS. I spoke with him about how the SGIS data model was designed and which reason laid the foundation for the choices that were made.

- Wim Janssen - Designer of the technical data model
  Wim created the technical data model of SGIS. I spoke with him about the setup in different feature classes and views.

- Arjen de Kok - Works on the implementation of SGIS
  I spoke with Arjen about SGIS, why it is setup the way it was, and how it could be related to BIM.

- Laura Stoutjesdijk (no longer in function) - Manager AIM
  Laura explained to me her vision on the development of SGIS and the other departments of AIM.

- Teun Bijlsma -Manager AIM/Asset Maintenance Information
  I spoke with Teun about the relation between SGIS and Maximo.

- Hans Kraaieveld - Manager AIM/Asset Document Information
  Hans and I spoke about the use of EDMS in relation to SGIS and other as-built documentation.

- Iwan de Kok - Manager AIM/Asset Consumption Information
  I spoke with Iwan about the relation between SGIS and the relation with consumption as well as real-time information.

- Boudewijn van Os - Projectleader for SGIS
  We spoke about issues regarding the implementation of SGIS and the troubles that have happened in the past.

- Daan Aarsten - Advisor for the acquisition of topography data
  I spoke with Daan about the way topography data is collected and used and the relationship SGIS has with some key registrations.

- Mohammed El-Morabit - Revision coordinator
  Mohammed and I spoke about encountered problems in the SGIS implementation and the use of GIS principles for SGIS.

- Ed Rutgers - Technical Information coordinator
  I spoke with Ed about his tasks in relation to SGIS.

# Appendix B

***Data model Schiphol GIS***

### *Data model Schiphol GIS*

Hereunder an overview is given of the different themes that are currently contained in SGIS, including the feature classes belonging to those themes. There was insufficient time to create a UML diagram of SGIS, therefor this overview is added. The feature classed have a naming in Dutch and are mostly ordered that way and not per related theme.

#### Grounding

- SGIS.AARD_NETWERK_FDS
  - SGIS.AARD_ELEMENT_FCL
  - SGIS.AARD_KABEL_FCL
  - SGIS.AARD_NETWERK_NET
  - SGIS.AARD_NETWERK_NET_Junctions
- SGIS.AARD_E61_ANNO
- SGIS.AARD_E61_BLOCK_FCL
- SGIS.AARD_E61_LIJN_FCL
- SGIS.AARD_E61_PUNT_FCL
- SGIS.AARD_ELEMENT_RVW
- SGIS.AARD_KABEL_RVW
- SGIS.AARD_PLAAT_FCL
- SGIS.AARD_PLAAT_RVW

#### Cadastral registration

- SGIS.AKR_40_05_REL
- SGIS.AKR_70_40_REL
- SGIS.AKRTABEL01
- SGIS.AKRTABEL05
- SGIS.AKRTABEL10
- SGIS.AKRTABEL15
- SGIS.AKRTABEL20
- SGIS.AKRTABEL25
- SGIS.AKRTABEL30
- SGIS.AKRTABEL35
- SGIS.AKRTABEL40
- SGIS.AKRTABEL45
- SGIS.AKRTABEL50
- SGIS.AKRTABEL55
- SGIS.AKRTABEL60
- SGIS.AKRTABEL65
- SGIS.AKRTABEL70
- SGIS.AKRTABEL75
- SGIS.AKRTABEL80
- SGIS.AKRTABEL85
- SGIS.AKRTABEL90
- SGIS.AKRTABEL99

#### BAG

- SGIS.BAG_ADRESLOCATIE
- SGIS.BAG_LIGPLAATS
- SGIS.BAG_OPENBARERUIMTE
- SGIS.BAG_PAND
- SGIS.BAG_STANDPLAATS
- SGIS.BAG_WOONPLAATS

#### Calamity

- SGIS.CAL_AANRIJROUTE_FCL
- SGIS.CAL_AANRIJROUTE_G
- SGIS.CAL_AANRIJROUTE_RVW
- SGIS.CAL_ONTRUIMINGSZONE_FCL
- SGIS.CAL_ONTRUIMINGSZONE_G
- SGIS.CAL_ONTRUIMINGSZONE_RVW

#### Communication

- SGIS.COM_OMROEPZONE_FCL
- SGIS.COM_OMROEPZONE_G
- SGIS.COM_OMROEPZONE_RVW

#### Fire fighting

- SGIS.BRB_ANNO
- SGIS.BRB_BLUSZONE_FCL
- SGIS.BRB_BLUSZONE_G
- SGIS.BRB_BLUSZONE_RVW
- SGIS.BRB_BMCZONE_FCL
- SGIS.BRB_BMCZONE_G
- SGIS.BRB_BMCZONE_RVW
- SGIS.BRB_BRANDBEVEILIGING_EXT
- SGIS.BRB_BRANDBEVEILIGING_EXT_REL
- SGIS.BRB_BRANDBEVEILIGING_FCL
- SGIS.BRB_BRANDBEVEILIGING_G
- SGIS.BRB_BRANDBEVEILIGING_RVW
- SGIS.BRB_BRANDBEVEILIGINGSPLAN_FCL
- SGIS.BRB_BRANDBEVEILIGINGSPLAN_G
- SGIS.BRB_BRANDBEVEILIGINGSPLAN_RVW
- SGIS.BRB_BRANDMELDZONE_FCL
- SGIS.BRB_BRANDMELDZONE_G
- SGIS.BRB_BRANDMELDZONE_RVW
- SGIS.BRB_LEIDING_FCL
- SGIS.BRB_LEIDING_G
- SGIS.BRB_LEIDING_RVW
- SGIS.BRB_SCHEIDING_FCL
- SGIS.BRB_SCHEIDING_G
- SGIS.BRB_SCHEIDING_RVW

#### Antenna

- SGIS.ANT_FDS
  - SGIS.ANT_ANTENNE_FCL
  - SGIS.ANT_DEKKINGSGEBIED_FCL
  - SGIS.ANT_MAST_FCL
  - SGIS.ANT_SIGNAALKABEL_FCL
  - SGIS.ANT_STATION_FCL
- SGIS.ANT_ANTENNE_ANTENNETYPE_REL
- SGIS.ANT_ANTENNE_MAST_REL
- SGIS.ANT_ANTENNE_ONTVANGFREQ_REL
- SGIS.ANT_ANTENNE_RVW
- SGIS.ANT_ANTENNE_STATION_REL
- SGIS.ANT_ANTENNE_ZENDFREQ_REL
- SGIS.ANT_ANTENNETYPE_RVW
- SGIS.ANT_ANTENNETYPE_TAB
- SGIS.ANT_CONTACTPERS_VERGHOUDER_REL
- SGIS.ANT_CONTACTPERSOON_EXT
- SGIS.ANT_DEKKINGSGEBIED_RVW
- SGIS.ANT_MAST_RVW
- SGIS.ANT_ONTVANGFREQUENTIE
- SGIS.ANT_ONTVANGFREQUENTIE_RVW
- SGIS.ANT_SIGNAALKABEL_RVW
- SGIS.ANT_STATION_RVW
- SGIS.ANT_STATION_STATIONTYPE_REL
- SGIS.ANT_STATIONTYPE_RVW
- SGIS.ANT_STATIONTYPE_TAB
- SGIS.ANT_VERGEXTERN_VERGHOUDER_REL
- SGIS.ANT_VERGEXTERN_ZENDFREQ_REL
- SGIS.ANT_VERGINTERN_ANTENNE_REL
- SGIS.ANT_VERGINTERN_MAST_REL
- SGIS.ANT_VERGINTERN_VERGHOUDER_REL
- SGIS.ANT_VERGUNNINGEXTERN_EXT
- SGIS.ANT_VERGUNNINGHOUDER_EXT
- SGIS.ANT_VERGUNNINGINTERN_EXT
- SGIS.ANT_ZENDFREQUENTIE
- SGIS.ANT_ZENDFREQUENTIE_RVW

## Camera

- SGIS.CCTV_FDS
  - SGIS.CCTV_CAMERA_FCL
  - SGIS.CCTV_MATRIX_FCL
  - SGIS.CCTV_MODULE_MATRIX_FCL
  - SGIS.CCTV_SIGNAALKABEL_FCL
  - SGIS.GMI_CAMERA_FCL
  - SGIS.GMI_MODULE_SWITCH_FCL
  - SGIS.GMI_SIGNAALKABEL_FCL
  - SGIS.GMI_SWITCH_FCL
  - SGIS.MAST_FCL
- SGIS.CCTV_CAMERA_RVW
- SGIS.CCTV_MARTIX_MODULE_REL
- SGIS.CCTV_MAST_RVW
- SGIS.CCTV_MATRIX_RVW
- SGIS.CCTV_MODULE_MATRIX_RVW
- SGIS.CCTV_SIGNAALKABEL_MODULE_REL
- SGIS.CCTV_SIGNAALKABEL_RVW

## Profile

- SGIS.DSN_DOORSNEDE_TEKENING_FCL
- SGIS.DSN_TEKENING_ANNO
- SGIS.DSN_TEKENING_LINE_FCL
- SGIS.DSN_TEKENING_POLYGON_FCL
- SGIS.DSN_TRACEVLAG_FCL

## Inventory

- SGIS.GBI_INVENTARIS_FCL
- SGIS.GBI_INVENTARIS_G
- SGIS.GBI_INVENTARIS_RVW
- SGIS.GBI_INVENTARIS_VLAKKEN_EXT
- SGIS.GBI_INVENTARIS_VLAKKEN_EXT_REL
- SGIS.GBI_INVENTARIS_VLAKKEN_FCL
- SGIS.GBI_INVENTARIS_VLAKKEN_G
- SGIS.GBI_INVENTARIS_VLAKKEN_RVW

## General

- SGIS.GEN_ANNO
- SGIS.GEN_HULPLIJN_FCL
- SGIS.GEN_HULPLIJN_G
- SGIS.GEN_HULPLIJN_RVW
- SGIS.GEN_PLOTVAK_FCL
- SGIS.GEN_PLOTVAK_G
- SGIS.GEN_PLOTVAK_RVW
- SGIS.GEN_PUNT_FCL
- SGIS.GEN_PUNT_RVW
- SGIS.GEN_SNAP_GRID_FCL
- SGIS.GEN_SNAP_GRID_RVW
- SGIS.GEN_VLAK_FCL
- SGIS.GEN_VLAK_RVW

## Frost alarm installation

- SGIS.GMI_CAMERA_MAST_REL
- SGIS.GMI_CAMERA_MODULE_REL
- SGIS.GMI_CAMERA_RVW
- SGIS.GMI_MODULE_SWITCH_RVW
- SGIS.GMI_SIGNAALKABEL_MODULE_REL
- SGIS.GMI_SIGNAALKABEL_RVW
- SGIS.GMI_SWITCH_MODULE_REL
- SGIS.GMI_SWITCH_RVW

## Cadastral Surveying Information

- SGIS.LKI_ADRES_20121010
- SGIS.LKI_BEBOUWING_20121010
- SGIS.LKI_PERCELEN_20121010

## Building

- SGIS.GBW_BWKELEMENT_LIJNEN_ANNO
- SGIS.GBW_BWKELEMENT_LIJNEN_FCL
- SGIS.GBW_BWKELEMENT_LIJNEN_G
- SGIS.GBW_BWKELEMENT_LIJNEN_RVW
- SGIS.GBW_BWKELEMENT_VLAKKEN_FCL
- SGIS.GBW_BWKELEMENT_VLAKKEN_G
- SGIS.GBW_BWKELEMENT_VLAKKEN_RVW
- SGIS.GBW_DEUR_EXT
- SGIS.GBW_DEUR_EXT_REL
- SGIS.GBW_DEUR_FCL
- SGIS.GBW_DEUR_G
- SGIS.GBW_DEUR_RVW
- SGIS.GBW_EVWOPSTELPLAATS_FCL
- SGIS.GBW_EVWOPSTELPLAATS_G
- SGIS.GBW_EVWOPSTELPLAATS_RVW
- SGIS.GBW_GEBOUWEN_EXT
- SGIS.GBW_GEBOUWEN_EXT_REL
- SGIS.GBW_GEBOUWEN_FCL
- SGIS.GBW_GEBOUWEN_G
- SGIS.GBW_GEBOUWEN_RVW
- SGIS.GBW_HULPLIJN_FCL
- SGIS.GBW_HULPLIJN_RVW
- SGIS.GBW_OVERIGELIJNEN_FCL
- SGIS.GBW_OVERIGELIJNEN_G
- SGIS.GBW_OVERIGELIJNEN_RVW
- SGIS.GBW_PLAFOND_FCL
- SGIS.GBW_PLAFOND_G
- SGIS.GBW_PLAFOND_RVW
- SGIS.GBW_PMC_FCL
- SGIS.GBW_PMC_G
- SGIS.GBW_PMC_RVW
- SGIS.GBW_RUIMTE_FCL
- SGIS.GBW_RUIMTE_G
- SGIS.GBW_RUIMTE_RVW
- SGIS.GBW_RUIMTEBESLAG_EXT
- SGIS.GBW_RUIMTEBESLAG_EXT_REL
- SGIS.GBW_RUIMTEBESLAG_FCL
- SGIS.GBW_RUIMTEBESLAG_G
- SGIS.GBW_RUIMTEBESLAG_RVW
- SGIS.GBW_RUIMTENUMMER_UITGIFTE_EXT
- SGIS.GBW_RUIMTENUMMER_UITGIFTE_EXT_REL
- SGIS.GBW_RUIMTENUMMER_UITGIFTE_FCL
- SGIS.GBW_RUIMTENUMMER_UITGIFTE_G
- SGIS.GBW_RUIMTENUMMER_UITGIFTE_RVW

## Building zones

- SGIS.GBZ_CONSTRUCTEURSZONE_EXT
- SGIS.GBZ_CONSTRUCTEURSZONE_EXT_REL
- SGIS.GBZ_CONSTRUCTEURSZONE_FCL
- SGIS.GBZ_CONSTRUCTEURSZONE_G
- SGIS.GBZ_CONSTRUCTEURSZONE_RVW
- SGIS.GBZ_DAKZONE_EXT
- SGIS.GBZ_DAKZONE_EXT_REL
- SGIS.GBZ_DAKZONE_FCL
- SGIS.GBZ_DAKZONE_G
- SGIS.GBZ_DAKZONE_RVW
- SGIS.GBZ_GEVELWASZONE_FCL
- SGIS.GBZ_GEVELWASZONE_G
- SGIS.GBZ_GEVELWASZONE_RVW
- SGIS.GBZ_SCHOONMAAKZONE_EXT
- SGIS.GBZ_SCHOONMAAKZONE_EXT_REL
- SGIS.GBZ_SCHOONMAAKZONE_FCL
- SGIS.GBZ_SCHOONMAAKZONE_G
- SGIS.GBZ_SCHOONMAAKZONE_RVW
- SGIS.GBZ_SUBLOCATIE_FCL
- SGIS.GBZ_SUBLOCATIE_G
- SGIS.GBZ_SUBLOCATIE_RVW
- SGIS.GBZ_VERDIEPINGSCON_BINNEN_FCL
- SGIS.GBZ_VERDIEPINGSCON_BINNEN_G
- SGIS.GBZ_VERDIEPINGSCON_BINNEN_RVW
- SGIS.GBZ_VERDIEPINGSCON_BUITEN_FCL
- SGIS.GBZ_VERDIEPINGSCON_BUITEN_G
- SGIS.GBZ_VERDIEPINGSCON_BUITEN_RVW

## Frost alarm station

- SGIS.GMS_FDS
  - SGIS.GMS_MEETSTATION_FCL
  - SGIS.GMS_MODULE_MEETSTATION_FCL
  - SGIS.GMS_MODULE_WEERHUT_FCL
  - SGIS.GMS_Net
  - SGIS.GMS_Net_Junctions
  - SGIS.GMS_SENSOR_FCL
  - SGIS.GMS_SIGNAALKABEL_FCL
  - SGIS.GMS_WEERHUT_FCL
- SGIS.GMS_MEETSTATION_RVW
- SGIS.GMS_MODULE_MEETSTATION_RVW
- SGIS.GMS_MODULE_WEERHUT_RVW
- SGIS.GMS_MODULEMEETSTATION_MEETSTATION_REL
- SGIS.GMS_MODULEWEERHUT_MODULEMEETSTATION_REL
- SGIS.GMS_MODULEWEERHUT_WEERHUT_REL
- SGIS.GMS_SENSOR_MODULEMEETSTATION_REL
- SGIS.GMS_SENSOR_RVW
- SGIS.GMS_SENSOR_SIGNAALKABEL_REL
- SGIS.GMS_SIGNAALKABEL_MODULEMEETSTATION_REL
- SGIS.GMS_SIGNAALKABEL_MODULEWEERHUT_REL
- SGIS.GMS_SIGNAALKABEL_RVW
- SGIS.GMS_WEERHUT_RVW

## Central clock system

- SGIS.KLK_FDS
  - SGIS.KLK_CENTRALE_FCL
  - SGIS.KLK_KLOK_FCL
  - SGIS.KLK_LASDOOS_FCL
  - SGIS.KLK_MODEM_CENTRALE_FCL
  - SGIS.KLK_MODEM_SUBCENTRALE_FCL
  - SGIS.KLK_MODULE_FCL
  - SGIS.KLK_SIGNAALKABEL_FCL
  - SGIS.KLK_SUBCENTRALE_FCL
  - SGIS.KLK_VERZORGINGSGEBIED_FCL
- SGIS.KLK_CENTRALE_RVW
- SGIS.KLK_KABEL_LUS_REL
- SGIS.KLK_KLOK_LUS_REL
- SGIS.KLK_KLOK_RVW
- SGIS.KLK_KLOK_TYPE_REL
- SGIS.KLK_KLOK_VERZORGINGSGEBIED_REL
- SGIS.KLK_LASDOOS_LUS_REL
- SGIS.KLK_LASDOOS_RVW
- SGIS.KLK_LUS_RVW
- SGIS.KLK_LUS_TAB
- SGIS.KLK_MODEM_CENTRALE_RVW
- SGIS.KLK_MODEM_SUBCENTRALE_RVW
- SGIS.KLK_MODEMCENTRALE_CENTRALE_REL
- SGIS.KLK_MODEMSUBC_MODEMC_REL
- SGIS.KLK_MODULE_LUS_REL
- SGIS.KLK_MODULE_RVW
- SGIS.KLK_MODULE_SUBCENTRALE_REL
- SGIS.KLK_SIGNAALKABEL_RVW
- SGIS.KLK_SUBC_MODEMSUBC_REL
- SGIS.KLK_SUBCENTRALE_RVW
- SGIS.KLK_TYPE_RVW
- SGIS.KLK_TYPE_TAB
- SGIS.KLK_VERZORGINGSGEBIED_RVW

## Furniture

- SGIS.MEU_MEUBILAIR_ANNO

## Main-contractors

- SGIS.MNC_MAINCONTRACTORZONE_EXT
- SGIS.MNC_MAINCONTRACTORZONE_EXT_REL
- SGIS.MNC_MAINCONTRACTORZONE_FCL
- SGIS.MNC_MAINCONTRACTORZONE_G
- SGIS.MNC_MAINCONTRACTORZONE_RVW
- SGIS.MNC_PERCELEN_AIRSIDE_FCL
- SGIS.MNC_PERCELEN_AIRSIDE_G
- SGIS.MNC_PERCELEN_AIRSIDE_RVW

## Climate control

- SGIS.LBH_FDS
  - SGIS.Anno_3539_3541
  - SGIS.Anno_3544_3546
  - SGIS.LBH_ADAPTER_FCL
  - SGIS.LBH_AFTAKKING_FCL
  - SGIS.LBH_BOCHT_FCL
  - SGIS.LBH_KANAALCOMPONENT_FCL
  - SGIS.LBH_KANALEN_FCL
  - SGIS.LBH_KANALEN_FLA
  - SGIS.LBH_KLEP_FCL
  - SGIS.LBH_Net
  - SGIS.LBH_Net_Junctions
  - SGIS.LBH_ROOSTER_ANNO_FLA
  - SGIS.LBH_ROOSTER_CONTOUR_FCL
  - SGIS.LBH_ROOSTER_FCL
  - SGIS.LBH_STIJGZAKPUNTEN_FCL
  - SGIS.LBH_UNIT_CONTOUR_FCL
  - SGIS.LBH_UNIT_FCL
  - SGIS.LBH_VAVBOX_FCL
  - SGIS.LBH_VAVBOX_FLA
- SGIS.LBH_ADAPTER_RVW
- SGIS.LBH_AFTAKKING_RVW
- SGIS.LBH_AIRCOUNIT_FCL
- SGIS.LBH_AIRCOUNIT_RVW
- SGIS.LBH_BOCHT_RVW
- SGIS.LBH_CONTROLE_POINT_RVW
- SGIS.LBH_KANAALCOMPONENT_RVW
- SGIS.LBH_KANALEN_RVW
- SGIS.LBH_KLEP_RVW
- SGIS.LBH_ROOSTER_CONTOUR_RVW
- SGIS.LBH_ROOSTER_REL
- SGIS.LBH_ROOSTER_RVW
- SGIS.LBH_RUIMTEBESLAG_FCL
- SGIS.LBH_RUIMTEBESLAG_RVW
- SGIS.LBH_STIJGZAKPUNTEN_RVW
- SGIS.LBH_UITVAL_LIJNEN_RVW
- SGIS.LBH_UITVAL_POLYGONEN_RVW
- SGIS.LBH_UITVAL_PUNTEN_RVW
- SGIS.LBH_UNIT_CONTOUR_RVW
- SGIS.LBH_UNIT_REL
- SGIS.LBH_UNIT_RVW
- SGIS.LBH_VAVBOX_CONTOUR_FCL
- SGIS.LBH_VAVBOX_CONTOUR_RVW
- SGIS.LBH_VAVBOX_REL
- SGIS.LBH_VAVBOX_RVW

## Environment

- SGIS.MIL_ASBESTZONE_FCL
- SGIS.MIL_ASBESTZONE_G
- SGIS.MIL_ASBESTZONE_GEEN_FCL
- SGIS.MIL_ASBESTZONE_GEEN_G
- SGIS.MIL_ASBESTZONE_GEEN_RVW
- SGIS.MIL_ASBESTZONE_NTG_FCL
- SGIS.MIL_ASBESTZONE_NTG_G
- SGIS.MIL_ASBESTZONE_NTG_RVW
- SGIS.MIL_ASBESTZONE_RVW
- SGIS.MIL_ASBESTZONE_VERDACHT_FCL
- SGIS.MIL_ASBESTZONE_VERDACHT_G
- SGIS.MIL_ASBESTZONE_VERDACHT_RVW

## Plotting

- SGIS.PLOT
- SGIS.PLOTJOB
- SGIS.PLOTJOBPARAMETER
- SGIS.PLOTPARAMETER

## Sanitary

- SGIS.SAN_SANITAIR_FCL
- SGIS.SAN_SANITAIR_G
- SGIS.SAN_SANITAIR_RVW

## Operational equipment

- SGIS.OPI_OPINRICHTING_LIJNEN_FCL
- SGIS.OPI_OPINRICHTING_LIJNEN_G
- SGIS.OPI_OPINRICHTING_LIJNEN_RVW
- SGIS.OPI_OPINRICHTING_PUNTEN_FCL
- SGIS.OPI_OPINRICHTING_PUNTEN_G
- SGIS.OPI_OPINRICHTING_PUNTEN_RVW
- SGIS.OPI_OPINRICHTING_VLAKKEN_FCL
- SGIS.OPI_OPINRICHTING_VLAKKEN_G
- SGIS.OPI_OPINRICHTING_VLAKKEN_RVW

## Evacuation installation

- SGIS.ORI_FDS
  - SGIS.ORI_AANSTURING_FCL
  - SGIS.ORI_BRANDCOMPARTIMENT_FCL
  - SGIS.ORI_LASDOOS_FCL
  - SGIS.ORI_LUSZONE_FCL
  - SGIS.ORI_MODULE_FCL
  - SGIS.ORI_ONTRUIMING_FCL
  - SGIS.ORI_ONTRUIMINGSZONE_FCL
  - SGIS.ORI_SIGNAALKABEL_FCL
  - SGIS.ORI_SUBCENTRALE_FCL
  - SGIS.ORI_ZAKSTIJGPUNT_FCL
- SGIS.ORI_AANSTURING_RVW
- SGIS.ORI_BRANDCOMPARTIMENT_RVW
- SGIS.ORI_LASDOOS_RVW
- SGIS.ORI_LUSZONE_ONTRUIMINGSZONE_REL
- SGIS.ORI_LUSZONE_RVW
- SGIS.ORI_MODULE_RVW
- SGIS.ORI_MODULE_SUBCENTRALE_REL
- SGIS.ORI_ONTRUIMING_LUSZONE_CENTRALE_REL
- SGIS.ORI_ONTRUIMING_RVW
- SGIS.ORI_ONTRUIMINGSZONE_BRANCOMPARTIMENT_CENT
- SGIS.ORI_ONTRUIMINGSZONE_RVW
- SGIS.ORI_SIGNAALKABEL_RVW
- SGIS.ORI_SUBCENTRALE_RVW
- SGIS.ORI_ZAKSTIJGPUNT_RVW

## Low voltage

- SGIS.LSP_NETWERK_FDS
  - SGIS.Anno_36_487
  - SGIS.Anno_40_485
  - SGIS.LSP_AANSLUITPUNT_FCL
  - SGIS.LSP_ARMATUUR_FCL
  - SGIS.LSP_BORD_FCL
  - SGIS.LSP_CONTACT_FCL
  - SGIS.LSP_GROEP_ANNO
  - SGIS.LSP_GROEP_FCL
  - SGIS.LSP_HOOFDSCHAKELAAR_FCL
  - SGIS.LSP_INT_SCHAKELAAR_FCL
  - SGIS.LSP_INT_TRANSFORMATOR_FCL
  - SGIS.LSP_KABEL_ANNO
  - SGIS.LSP_KABEL_FCL
  - SGIS.LSP_LASTSCHEIDER_FCL
  - SGIS.LSP_METER_FCL
  - SGIS.LSP_NETWERK_NET
  - SGIS.LSP_NETWERK_NET_Junctions
  - SGIS.LSP_NOODVOEDING_FCL
  - SGIS.LSP_PATROONHOUDER_FCL
  - SGIS.LSP_RAIL_FCL
  - SGIS.LSP_TRANSFORMATOR_FCL
  - SGIS.LSP_VERBINDINGSELEMENT_FCL
  - SGIS.LSP_VERDEELINRICHTING_PUNT_FCL
  - SGIS.LSP_WANDCONTACTDOOS_FCL
  - SGIS.LSP_WKK_FCL
- SGIS.LSP_AANSLUITPUNT_RVW
- SGIS.LSP_AANSLUITPUNT_RVW2
- SGIS.LSP_ARMATUUR_RVW
- SGIS.LSP_ARMATUUR_RVW2
- SGIS.LSP_ARMATUURTYPE_EXT
- SGIS.LSP_BORD_FCL__ATTACH
- SGIS.LSP_BORD_FCL__ATTACHREL
- SGIS.LSP_BORD_RVW
- SGIS.LSP_CONTACT_RVW
- SGIS.LSP_GROEP_ARMATUUR_REL
- SGIS.LSP_GROEP_ASP_REL
- SGIS.LSP_GROEP_BORD_REL
- SGIS.LSP_GROEP_KAST_REL
- SGIS.LSP_GROEP_RVW
- SGIS.LSP_GROEP_SCH_REL
- SGIS.LSP_GROEP_WCD_REL
- SGIS.LSP_HOOFDSCHAKELAAR_RVW
- SGIS.LSP_INT_SCHAKELAAR_RVW
- SGIS.LSP_INT_TRANSFORMATOR_RVW
- SGIS.LSP_KABEL_RVW
- SGIS.LSP_LAAGSPANNING_HSCH_REL
- SGIS.LSP_LAAGSPANNING_KAST_REL
- SGIS.LSP_LAAGSPANNING_NV_REL
- SGIS.LSP_LAAGSPANNING_RVW
- SGIS.LSP_LAAGSPANNING_SCEN_REL
- SGIS.LSP_LAAGSPANNING_T
- SGIS.LSP_LAAGSPANNING_TRAFO_REL
- SGIS.LSP_LAAGSPANNING_WKK_REL
- SGIS.LSP_LASTSCHEIDER_RVW
- SGIS.LSP_MAST_ARMATUUR_REL
- SGIS.LSP_MAST_FCL
- SGIS.LSP_MAST_RVW
- SGIS.LSP_METER_RVW
- SGIS.LSP_NOODVOEDING_RVW
- SGIS.LSP_NOODVOEDING_SOURCE_REL
- SGIS.LSP_PATROONHOUDER_RVW
- SGIS.LSP_RAIL_RVW
- SGIS.LSP_SCENARIO_SCHAKEL_REL
- SGIS.LSP_SCENARIO_SOURCE_REL
- SGIS.LSP_SCHAKELAAR_FCL
- SGIS.LSP_SCHAKELAAR_RVW
- SGIS.LSP_SCHAKELAAR_RVW2
- SGIS.LSP_SCHAKELAAR_SCHAKEL_REL
- SGIS.LSP_SCHAKELSCENARIO_RVW
- SGIS.LSP_SCHAKELSCENARIO_T
- SGIS.LSP_SCHAKELSTAND_RVW
- SGIS.LSP_SCHAKELSTAND_T
- SGIS.LSP_SOURCEINSTELLING_RVW
- SGIS.LSP_SOURCEINSTELLING_T
- SGIS.LSP_TRAFO_KAST_REL
- SGIS.LSP_TRAFO_SOURCE_REL
- SGIS.LSP_TRANSFORMATOR_RVW
- SGIS.LSP_VERBINDINGSELEMENT_RVW
- SGIS.LSP_VERDEEL_GROEP_REL
- SGIS.LSP_VERDEEL_PUNT_VLAK_REL
- SGIS.LSP_VERDEELINRICHTING_ANNO
- SGIS.LSP_VERDEELINRICHTING_PUNT_RVW
- SGIS.LSP_VERDEELINRICHTING_VLAK_FCL
- SGIS.LSP_VERDEELINRICHTING_VLAK_RVW
- SGIS.LSP_VERLICHTINGSZONE_EXT
- SGIS.LSP_VERLICHTINGSZONE_EXT_REL
- SGIS.LSP_VERLICHTINGSZONE_FCL
- SGIS.LSP_VERLICHTINGSZONE_G
- SGIS.LSP_VERLICHTINGSZONE_RVW
- SGIS.LSP_WANDCONTACTDOOS_RVW
- SGIS.LSP_WANDCONTACTDOOS_RVW2
- SGIS.LSP_WKK_RVW
- SGIS.LSP_WKK_SOURCE_REL

## *(Road) Marking*

- SGIS.MKR_DETAIL_EXT
- SGIS.MKR_DETAIL_EXT_REL
- SGIS.MKR_DETAIL_FCL
- SGIS.MKR_DETAIL_G
- SGIS.MKR_DETAIL_RVW
- SGIS.MKR_LIJNEN_EXT
- SGIS.MKR_LIJNEN_EXT_REL
- SGIS.MKR_LIJNEN_FCL
- SGIS.MKR_LIJNEN_G
- SGIS.MKR_LIJNEN_RVW
- SGIS.MKR_MARKERING_ANNO
- SGIS.MKR_OPSTEL_VLIEGTUIG_RVW
- SGIS.MKR_OPSTEL_VLIEGTUIG_T
- SGIS.MKR_OPSTELPLAATS_RVW
- SGIS.MKR_OPSTELPLAATS_T
- SGIS.MKR_PUNTEN_EXT
- SGIS.MKR_PUNTEN_EXT_REL
- SGIS.MKR_PUNTEN_FCL
- SGIS.MKR_PUNTEN_G
- SGIS.MKR_PUNTEN_RVW
- SGIS.MKR_RVV_LIJNEN_EXT
- SGIS.MKR_RVV_LIJNEN_EXT_REL
- SGIS.MKR_RVV_LIJNEN_FCL
- SGIS.MKR_RVV_LIJNEN_G
- SGIS.MKR_RVV_LIJNEN_RVW
- SGIS.MKR_RVV_PUNTEN_EXT
- SGIS.MKR_RVV_PUNTEN_EXT_REL
- SGIS.MKR_RVV_PUNTEN_FCL
- SGIS.MKR_RVV_PUNTEN_G
- SGIS.MKR_RVV_PUNTEN_RVW
- SGIS.MKR_VLAKKEN_EXT
- SGIS.MKR_VLAKKEN_EXT_REL
- SGIS.MKR_VLAKKEN_FCL
- SGIS.MKR_VLAKKEN_G
- SGIS.MKR_VLAKKEN_RVW
- SGIS.MKR_VOP_VLAKKEN_FCL
- SGIS.MKR_VOP_VLAKKEN_G
- SGIS.MKR_VOP_VLAKKEN_RVW

## *Platform equipment*

- SGIS.PFM_PFMMEUBILAIR_LIJNEN_FCL
- SGIS.PFM_PFMMEUBILAIR_LIJNEN_G
- SGIS.PFM_PFMMEUBILAIR_LIJNEN_RVW
- SGIS.PFM_PFMMEUBILAIR_PUNTEN_FCL
- SGIS.PFM_PFMMEUBILAIR_PUNTEN_G
- SGIS.PFM_PFMMEUBILAIR_PUNTEN_RVW
- SGIS.PFM_PFMMEUBILAIR_VLAKKEN_FCL
- SGIS.PFM_PFMMEUBILAIR_VLAKKEN_G
- SGIS.PFM_PFMMEUBILAIR_VLAKKEN_RVW

## *Security*

- SGIS.SEC_PERIFERIE_EXT
- SGIS.SEC_PERIFERIE_EXT_REL
- SGIS.SEC_PERIFERIE_FCL
- SGIS.SEC_PERIFERIE_G
- SGIS.SEC_PERIFERIE_RVW
- SGIS.SEC_SLEUTEL_FCL
- SGIS.SEC_SLEUTEL_G
- SGIS.SEC_SLEUTEL_RVW
- SGIS.SEC_WAPEN_FCL
- SGIS.SEC_WAPEN_G
- SGIS.SEC_WAPEN_RVW

## *Terrains*

- SGIS.TER_GROENVELD_EXT
- SGIS.TER_GROENVELD_EXT_REL
- SGIS.TER_GROENVELD_FCL
- SGIS.TER_GROENVELD_G
- SGIS.TER_GROENVELD_RVW

## *Broadcast installation*

- SGIS.OMR_AUDIO_FDS
  - SGIS.OMR_AUDIOKABEL_FCL
  - SGIS.OMR_AUDIOLASDOOS_FCL
  - SGIS.OMR_AUDIOMODULE_FCL
  - SGIS.OMR_AUDIOZAKSTIJGPUNT_FCL
  - SGIS.OMR_OMROEP_FCL
  - SGIS.OMR_SLECHTHORENDENLUS_FCL
- SGIS.OMR_TELECOM_FDS
  - SGIS.OMR_TELECOMKABEL_FCL
  - SGIS.OMR_TELECOMLASDOOS_FCL
  - SGIS.OMR_TELECOMMODULE_FCL
  - SGIS.OMR_TELECOMZAKSTIJGPUNT_FCL
- SGIS.OMR_AANSTURING_FCL
- SGIS.OMR_AANSTURING_HOOFDCENTRALE_REL
- SGIS.OMR_AANSTURING_SUBCENTRALE_REL
- SGIS.OMR_ACHTERGRONDMUZIEKZONE_FCL
- SGIS.OMR_ACHTERGRONDMUZIEKZONE_RVW
- SGIS.OMR_AUDIOKABEL_AUDIOMODULE_REL
- SGIS.OMR_AUDIOKABEL_LUS_REL
- SGIS.OMR_AUDIOKABEL_RVW
- SGIS.OMR_AUDIOLASDOOS_AUDIOKABEL_REL
- SGIS.OMR_AUDIOLASDOOS_RVW
- SGIS.OMR_AUDIOMODULE_AANSTURING_REL
- SGIS.OMR_AUDIOMODULE_HOOFDCENTRALE_REL
- SGIS.OMR_AUDIOMODULE_RVW
- SGIS.OMR_AUDIOMODULE_SUBCENTRALE_REL
- SGIS.OMR_AUDIOZAKSTIJGPUNT_AUDIOKABEL_REL
- SGIS.OMR_AUDIOZAKSTIJGPUNT_RVW
- SGIS.OMR_HOOFDCENTRALE_FCL
- SGIS.OMR_LUS_AUDIOMODULE_REL
- SGIS.OMR_LUS_RVW
- SGIS.OMR_LUS_TAB
- SGIS.OMR_OMROEP_LUS_REL
- SGIS.OMR_OMROEP_OMROEPZONE_REL
- SGIS.OMR_OMROEP_RVW
- SGIS.OMR_OMROEP_SUBCENTRALE_REL
- SGIS.OMR_OMROEPZONE_FCL
- SGIS.OMR_OMROEPZONE_RVW
- SGIS.OMR_SLECHTHORENDENLUS_OMROEPZONE_REL
- SGIS.OMR_SLECHTHORENDENLUS_RVW
- SGIS.OMR_SLECHTHORENDENLUS_SUBCENTRALE_REL
- SGIS.OMR_SUBCENTRALE_FCL
- SGIS.OMR_SUBCENTRALE_HOOFDCENTRALE_REL
- SGIS.OMR_SUBCENTRALE_RVW
- SGIS.OMR_TELECOMKABEL_RVW
- SGIS.OMR_TELECOMKABEL_TELECOMMODULE_REL
- SGIS.OMR_TELECOMLASDOOS_AUDIOKABEL_REL
- SGIS.OMR_TELECOMLASDOOS_RVW
- SGIS.OMR_TELECOMMODULE_AANSTURING_REL
- SGIS.OMR_TELECOMMODULE_HOOFDCENTRALE_REL
- SGIS.OMR_TELECOMMODULE_RVW
- SGIS.OMR_TELECOMMODULE_SUBCENTRALE_REL
- SGIS.OMR_TELECOMZAKSTIJGPUNT_AUDIOKABEL_REL
- SGIS.OMR_TELECOMZAKSTIJGPUNT_RVW
- SGIS.OMR_TYPE_RVW
- SGIS.OMR_TYPE_TAB

## *Frameworks (TOPO)*

- SGIS.TOPO_VAK1000_FCL
- SGIS.TOPO_VAK1000_RVW
- SGIS.TOPO_VAK250_FCL
- SGIS.TOPO_VAK250_RVW
- SGIS.TOPO_VAK500_FCL
- SGIS.TOPO_VAK500_RVW

## *Transportation*

- SGIS.TRP_PASSAGIERSBRUGGEN_EXT
- SGIS.TRP_PASSAGIERSBRUGGEN_EXT_REL
- SGIS.TRP_PASSAGIERSBRUGGEN_FCL
- SGIS.TRP_PASSAGIERSBRUGGEN_G
- SGIS.TRP_PASSAGIERSBRUGGEN_RVW

## Cable route

- SGIS.TRC_BKOKER_KOKER_REL
- SGIS.TRC_BUITENKOKER_FCL
- SGIS.TRC_BUITENKOKER_RVW
- SGIS.TRC_GEUL_FCL
- SGIS.TRC_GEUL_LIJN_RVW
- SGIS.TRC_GEUL_RVW
- SGIS.TRC_KABEL_RVW
- SGIS.TRC_KABEL_T
- SGIS.TRC_KABELDRAAGSYSTEEM_FCL
- SGIS.TRC_KABELDRAAGSYSTEEM_RVW
- SGIS.TRC_KABELDSYS_ELEMENT_RVW
- SGIS.TRC_KABELDSYS_LIJN_RVW
- SGIS.TRC_KOKER_FCL
- SGIS.TRC_KOKER_KABEL_T_REL
- SGIS.TRC_KOKER_RVW
- SGIS.TRC_KOKERBED_FCL
- SGIS.TRC_KOKERBED_RVW
- SGIS.TRC_RESERVERING_FCL
- SGIS.TRC_RESERVERING_RVW
- SGIS.TRC_TRACEBED_FCL
- SGIS.TRC_TRACEBED_RVW

## Access control

- SGIS.TGB_FDS
  - SGIS.TGB_CENTRALE_FCL
  - SGIS.TGB_FDS_Net
  - SGIS.TGB_FDS_Net_Junctions
  - SGIS.TGB_MODULE_FCL
  - SGIS.TGB_SIGNAALKABEL_FCL
  - SGIS.TGB_TOEGANG_FCL
  - SGIS.TGB_TOEGANGSBEHEER_FCL
  - SGIS.TGB_VEILIGHEIDSZONE_FCL
- SGIS.TGB_CENTRALE_RVW
- SGIS.TGB_MODULE_CENTRALE_REL
- SGIS.TGB_MODULE_RVW
- SGIS.TGB_MODULE_TOEGANG_REL
- SGIS.TGB_MODULE_TOEGANGSBEHEER_REL
- SGIS.TGB_SIGNAALKABEL_RVW
- SGIS.TGB_TOEGANG_RVW
- SGIS.TGB_TOEGANG_TAB
- SGIS.TGB_TOEGANG_TAB_RVW
- SGIS.TGB_TOEGANG_TOEGANGTAB_REL
- SGIS.TGB_TOEGANGSBEHEER_RVW
- SGIS.TGB_TOEGANGSBEHEER_TOEGANG_REL
- SGIS.TGB_VEILIGHEIDSZONE_RVW

## Surface

- SGIS.SUR_BLS_FCL
- SGIS.SUR_BLS_G
- SGIS.SUR_BLS_RVW
- SGIS.SUR_LVNL_FCL
- SGIS.SUR_LVNL_G
- SGIS.SUR_LVNL_RVW
- SGIS.SUR_OLS_FCL
- SGIS.SUR_OLS_G
- SGIS.SUR_OLS_RVW
- SGIS.SUR_RUNWAYCL_FCL
- SGIS.SUR_RUNWAYCL_G
- SGIS.SUR_RUNWAYCL_RVW
- SGIS.SUR_SURFACECRITICAL_FCL
- SGIS.SUR_SURFACECRITICAL_G
- SGIS.SUR_SURFACECRITICAL_RVW
- SGIS.SUR_SURFACEGRENS_FCL
- SGIS.SUR_SURFACEGRENS_G
- SGIS.SUR_SURFACEGRENS_RVW
- SGIS.SUR_SURFACESENSITIVE_FCL
- SGIS.SUR_SURFACESENSITIVE_G
- SGIS.SUR_SURFACESENSITIVE_RVW
- SGIS.SUR_THRESHOLD_FCL
- SGIS.SUR_THRESHOLD_G
- SGIS.SUR_THRESHOLD_RVW

## VVV

- SGIS.VVV_ALL_MR_FCL
- SGIS.VVV_ALL_MR_RVW
- SGIS.VVV_BOORKERNEN_EXT
- SGIS.VVV_BOORKERNEN_EXT_REL
- SGIS.VVV_BOORKERNEN_FCL
- SGIS.VVV_BOORKERNEN_G
- SGIS.VVV_BOORKERNEN_RVW
- SGIS.VVV_BOORKERNLAAG_T
- SGIS.VVV_CONDITION_PCI_FCL
- SGIS.VVV_CONDITION_PCI_G
- SGIS.VVV_CONDITION_PCI_RVW
- SGIS.VVV_INVENTORY_FCL
- SGIS.VVV_INVENTORY_RVW
- SGIS.VVV_SECTION_CONDITION_FCL
- SGIS.VVV_SECTION_CONDITION_RVW

## Sprinkler

- SGIS.SPK_FDS
  - SGIS.SPK_AFSLUITER_FCL
  - SGIS.SPK_AFTAKKING_FCL
  - SGIS.SPK_AFVOER_FCL
  - SGIS.SPK_ALARMKLEP_FCL
  - SGIS.SPK_ALARMKLEP_MEETPUNT_REL
  - SGIS.SPK_BEUGEL_FCL
  - SGIS.SPK_BOCHT_FCL
  - SGIS.SPK_DUBBELPUNTEN
  - SGIS.SPK_KOP_FCL
  - SGIS.SPK_LEIDING_FCL
  - SGIS.SPK_LEIDINGCOMPONENT_FCL
  - SGIS.SPK_MEETPUNT_FCL
  - SGIS.SPK_Net
  - SGIS.SPK_Net_Junctions
  - SGIS.SPK_POMP_FCL
  - SGIS.SPK_WATERBUFFER_FCL
  - SGIS.SPK_ZAKSTIJGPUNT_FCL
- SGIS.SPK_AFSLUITER_RVW
- SGIS.SPK_AFTAKKING_RVW
- SGIS.SPK_AFVOER_RVW
- SGIS.SPK_ALARMKLEP_BN_FCL
- SGIS.SPK_ALARMKLEP_BN_G
- SGIS.SPK_ALARMKLEP_BN_RVW
- SGIS.SPK_ALARMKLEP_ON_FCL
- SGIS.SPK_ALARMKLEP_ON_G
- SGIS.SPK_ALARMKLEP_ON_RVW
- SGIS.SPK_ALARMKLEP_RVW
- SGIS.SPK_ALARMKLEP_TN_FCL
- SGIS.SPK_ALARMKLEP_TN_G
- SGIS.SPK_ALARMKLEP_TN_RVW
- SGIS.SPK_ALARMKLEPRUIMTE_BN_FCL
- SGIS.SPK_ALARMKLEPRUIMTE_BN_G
- SGIS.SPK_ALARMKLEPRUIMTE_BN_RVW
- SGIS.SPK_ALARMKLEPRUIMTE_ON_FCL
- SGIS.SPK_ALARMKLEPRUIMTE_ON_G
- SGIS.SPK_ALARMKLEPRUIMTE_ON_RVW
- SGIS.SPK_ALARMKLEPRUIMTE_TN_FCL
- SGIS.SPK_ALARMKLEPRUIMTE_TN_G
- SGIS.SPK_ALARMKLEPRUIMTE_TN_RVW
- SGIS.SPK_ALARMKLEPSECTIE_BN_FCL
- SGIS.SPK_ALARMKLEPSECTIE_BN_G
- SGIS.SPK_ALARMKLEPSECTIE_BN_RVW
- SGIS.SPK_ALARMKLEPSECTIE_ON_FCL
- SGIS.SPK_ALARMKLEPSECTIE_ON_G
- SGIS.SPK_ALARMKLEPSECTIE_ON_RVW
- SGIS.SPK_ALARMKLEPSECTIE_TN_FCL
- SGIS.SPK_ALARMKLEPSECTIE_TN_G
- SGIS.SPK_ALARMKLEPSECTIE_TN_RVW
- SGIS.SPK_BEUGEL_RVW
- SGIS.SPK_BOCHT_RVW
- SGIS.SPK_KOP_RVW
- SGIS.SPK_LEIDING_RVW
- SGIS.SPK_LEIDINGCOMPONENT_RVW
- SGIS.SPK_MEETPUNT_RVW
- SGIS.SPK_POMP_RVW
- SGIS.SPK_WATERBUFFER_RVW
- SGIS.SPK_ZAKSTIJGPUNT_RVW

## Evacuation

- SGIS.ORI_FDS
  - SGIS.ORI_AANSTURING_FCL
  - SGIS.ORI_BRANDCOMPARTIMENT_FCL
  - SGIS.ORI_LASDOOS_FCL
  - SGIS.ORI_LUSZONE_FCL
  - SGIS.ORI_MODULE_FCL
  - SGIS.ORI_ONTRUIMING_FCL
  - SGIS.ORI_ONTRUIMINGSZONE_FCL
  - SGIS.ORI_SIGNAALKABEL_FCL
  - SGIS.ORI_SUBCENTRALE_FCL
  - SGIS.ORI_ZAKSTIJGPUNT_FCL
- SGIS.ORI_AANSTURING_RVW
- SGIS.ORI_BRANDCOMPARTIMENT_RVW
- SGIS.ORI_LASDOOS_RVW
- SGIS.ORI_LUSZONE_ONTRUIMINGSZONE_REL
- SGIS.ORI_LUSZONE_RVW
- SGIS.ORI_MODULE_RVW
- SGIS.ORI_MODULE_SUBCENTRALE_REL
- SGIS.ORI_ONTRUIMING_LUSZONE_CENTRALE_REL
- SGIS.ORI_ONTRUIMING_RVW
- SGIS.ORI_ONTRUIMINGSZONE_BRANCOMPARTIMENT_CENT
- SGIS.ORI_ONTRUIMINGSZONE_RVW
- SGIS.ORI_SIGNAALKABEL_RVW
- SGIS.ORI_SUBCENTRALE_RVW
- SGIS.ORI_ZAKSTIJGPUNT_RVW

## SRE

- SGIS.SRE_AANKOOPPERCELEN_FCL
- SGIS.SRE_AANKOOPPERCELEN_REL
- SGIS.SRE_AANKOOPPERCELEN_RVW
- SGIS.SRE_AGRARISCHGEBRUIK_FCL
- SGIS.SRE_AGRARISCHGEBRUIK_REL
- SGIS.SRE_AGRARISCHGEBRUIK_RVW
- SGIS.SRE_AQUIFER_FCL
- SGIS.SRE_AQUIFER_RVW
- SGIS.SRE_BEHEER_PERCELEN_FCL
- SGIS.SRE_BEHEER_PERCELEN_RVW
- SGIS.SRE_BEHEERPERCELEN_REL
- SGIS.SRE_EIGENDOM_TIJDLIJN_FCL
- SGIS.SRE_EIGENDOM_TIJDLIJN_RVW
- SGIS.SRE_EIGENDOM_ZN_TIJDLIJN_FCL
- SGIS.SRE_EIGENDOM_ZN_TIJDLIJN_RVW
- SGIS.SRE_GEBIEDEN_FCL
- SGIS.SRE_GEBIEDEN_RVW
- SGIS.SRE_GELUIDSCONT_LIB_FCL
- SGIS.SRE_GELUIDSCONT_LIB_RVW
- SGIS.SRE_GRONDGBVERKLARINGEN_FCL
- SGIS.SRE_GRONDGBVERKLARINGEN_RVW
- SGIS.SRE_GRONDVERKLARING_REL
- SGIS.SRE_HUISNR_BEREIK_FCL
- SGIS.SRE_HUISNR_BEREIK_RVW
- SGIS.SRE_JACHTHUUROVKMS_FCL
- SGIS.SRE_JACHTHUUROVKMS_REL
- SGIS.SRE_JACHTHUUROVKMS_RVW
- SGIS.SRE_JACHTVERGUNCONTRACT
- SGIS.SRE_JACHTVERGUNCONTRACT_RVW
- SGIS.SRE_JACHTVERGUNING_REL
- SGIS.SRE_JACHTVERGUNNINGEN_FCL
- SGIS.SRE_JACHTVERGUNNINGEN_RVW
- SGIS.SRE_KADASTRALE_PERCELEN_FCL
- SGIS.SRE_KADASTRALE_PERCELEN_RVW
- SGIS.SRE_LEIDINGEN_FCL
- SGIS.SRE_LEIDINGEN_RVW
- SGIS.SRE_LIB_BANEN_FCL
- SGIS.SRE_LIB_BANEN_RVW
- SGIS.SRE_LIB_BEPERKING_FCL
- SGIS.SRE_LIB_BEPERKING_RVW
- SGIS.SRE_LIB_GROND_FCL
- SGIS.SRE_LIB_GROND_RVW
- SGIS.SRE_LIB_HOOGTELIJNEN_FCL
- SGIS.SRE_LIB_HOOGTELIJNEN_RVW
- SGIS.SRE_LIB_LHG_FCL
- SGIS.SRE_LIB_LHG_FCLCORR
- SGIS.SRE_LIB_LHG_RVW
- SGIS.SRE_LIB_LHG_RVWCORR
- SGIS.SRE_LIB_VLAK_FCL
- SGIS.SRE_LIB_VLAK_RVW
- SGIS.SRE_LIB_VOGEL_FCL
- SGIS.SRE_LIB_VOGEL_RVW
- SGIS.SRE_LUCHT_AIR_GEBIEDEN_FCL
- SGIS.SRE_LUCHT_AIR_GEBIEDEN_RVW
- SGIS.SRE_MILIEU_INRICHTING_FCL
- SGIS.SRE_MILIEU_INRICHTING_RVW
- SGIS.SRE_MILIEU_RELEVANT_FCL
- SGIS.SRE_MILIEU_RELEVANT_RVW
- SGIS.SRE_MILIEUOPSTELPLAATS_FCL
- SGIS.SRE_MILIEUOPSTELPLAATS_RVW
- SGIS.SRE_NAW
- SGIS.SRE_NAW_RVW
- SGIS.SRE_OBSTAKEL_BHN_FCL
- SGIS.SRE_OBSTAKEL_BHN_RVW
- SGIS.SRE_ONDERGRONDSETANKEN_FCL
- SGIS.SRE_ONDERGRONDSETANKEN_RVW
- SGIS.SRE_ONDERHOUD_PERCELEN_FCL
- SGIS.SRE_ONDERHOUD_PERCELEN_RVW
- SGIS.SRE_OPSLAGPLAATS_FCL
- SGIS.SRE_OPSLAGPLAATS_RVW
- SGIS.SRE_PARKEREN_FCL
- SGIS.SRE_PARKEREN_RVW
- SGIS.SRE_POSTCODE_LIJNEN_FCL
- SGIS.SRE_POSTCODE_LIJNEN_RVW
- SGIS.SRE_POSTCODEGEBIEDEN_FCL
- SGIS.SRE_POSTCODEGEBIEDEN_RVW
- SGIS.SRE_ROOKGASPUNTEN_FCL
- SGIS.SRE_ROOKGASPUNTEN_RVW
- SGIS.SRE_STRAATNAMEN_FCL
- SGIS.SRE_STRAATNAMEN_RVW
- SGIS.SRE_TAR_AANVLIEGROUTE_FCL
- SGIS.SRE_TAR_AANVLIEGROUTE_RVW
- SGIS.SRE_TAR_CONUS_FCL
- SGIS.SRE_TAR_CONUS_RVW
- SGIS.SRE_TAR_LIJNEN_FCL
- SGIS.SRE_TAR_LIJNEN_RVW
- SGIS.SRE_TAR_TEKST_FCL
- SGIS.SRE_TAR_TEKST_RVW
- SGIS.SRE_VERKOOPPERCELEN_FCL
- SGIS.SRE_VERKOOPPERCELEN_REL
- SGIS.SRE_VERKOOPPERCELEN_RVW
- SGIS.SRE_ZAKELIJKRECHT_FCL
- SGIS.SRE_ZAKELIJKRECHT_RVW
- SGIS.SRE_ZAKELIJKRECHTLEIDING_FCL
- SGIS.SRE_ZAKELIJKRECHTLEIDING_RVW

## Weak voltage

- SGIS.ZWK_NOMOS_EXT
- SGIS.ZWK_NOMOS_EXT_REL
- SGIS.ZWK_NOMOS_FCL
- SGIS.ZWK_NOMOS_G
- SGIS.ZWK_NOMOS_RVW
- SGIS.ZWK_RADIOANTENNES_FCL
- SGIS.ZWK_RADIOANTENNES_G
- SGIS.ZWK_RADIOANTENNES_RVW
- SGIS.ZWK_RADIODEKKINGSMEETPUNT_FCL
- SGIS.ZWK_RADIODEKKINGSMEETPUNT_G
- SGIS.ZWK_RADIODEKKINGSMEETPUNT_RVW
- SGIS.ZWK_RADIOMEETWAARDE_T

## Topography

- SGIS.TC_ANNO
- SGIS.TC_BEBOUWING_FCL
- SGIS.TC_BEBOUWING_RVW
- SGIS.TC_GROEN_FCL
- SGIS.TC_GROEN_RVW
- SGIS.TC_GROND_FCL
- SGIS.TC_GROND_RVW
- SGIS.TC_HEK_FCL
- SGIS.TC_HEK_RVW
- SGIS.TC_INRICHTINGSELEMENT_FCL
- SGIS.TC_INRICHTINGSELEMENT_RVW
- SGIS.TC_KUNSTWERK_FCL
- SGIS.TC_KUNSTWERK_RVW
- SGIS.TC_MARKERING_FCL
- SGIS.TC_MARKERING_RVW
- SGIS.TC_METING_FCL
- SGIS.TC_METING_RVW
- SGIS.TC_TERREIN_FCL
- SGIS.TC_TERREIN_RVW
- SGIS.TC_WATER_FCL
- SGIS.TC_WATER_RVW
- SGIS.TC_WEG_FCL
- SGIS.TC_WEG_RVW
- SGIS.TG_ANNO
- SGIS.TG_BEBOUWING_FCL
- SGIS.TG_BEBOUWING_RVW
- SGIS.TG_GROEN_FCL
- SGIS.TG_GROEN_RVW
- SGIS.TG_HEK_FCL
- SGIS.TG_HEK_RVW
- SGIS.TG_KUNSTWERK_FCL
- SGIS.TG_KUNSTWERK_RVW
- SGIS.TG_LIJN_FCL
- SGIS.TG_LIJN_RVW
- SGIS.TG_WALBESCHERMING_FCL
- SGIS.TG_WALBESCHERMING_RVW
- SGIS.TG_WATERKANT_FCL
- SGIS.TG_WATERKANT_RVW
- SGIS.TG_WEG_FCL
- SGIS.TG_WEG_RVW

## Traffic light installation

- SGIS.VRI_FDS
  - SGIS.VRI_ARMATUUR_FCL
  - SGIS.VRI_BESTURINGSKAST_FCL
  - SGIS.VRI_DETECTIELUS_FCL
  - SGIS.VRI_DRUKKNOP_FCL
  - SGIS.VRI_LANELIGHT_FCL
  - SGIS.VRI_MAST_FCL
  - SGIS.VRI_MODULE_FCL
  - SGIS.VRI_PORTAAL_FCL
  - SGIS.VRI_RADARKOP_FCL
  - SGIS.VRI_SCHEMERSCHAKELAAR_FCL
  - SGIS.VRI_SIGNAALKABEL_FCL
- SGIS.VRI_ARMATUUR_MAST_REL
- SGIS.VRI_ARMATUUR_MODULE_REL
- SGIS.VRI_ARMATUUR_PORTAAL_REL
- SGIS.VRI_ARMATUUR_RVW
- SGIS.VRI_ARMATUUR_SIGNAALKABEL_REL
- SGIS.VRI_BESTURINGSKAST_RVW
- SGIS.VRI_BORD_ONVERLICHT_EXT
- SGIS.VRI_BORD_ONVERLICHT_EXT_REL
- SGIS.VRI_BORD_ONVERLICHT_FCL
- SGIS.VRI_BORD_ONVERLICHT_G
- SGIS.VRI_BORD_ONVERLICHT_RVW
- SGIS.VRI_DETECTIELUS_MODULE_REL
- SGIS.VRI_DETECTIELUS_RVW
- SGIS.VRI_DETECTIELUS_SIGNAALKABEL_REL
- SGIS.VRI_DRUKKNOP_MODULE_REL
- SGIS.VRI_DRUKKNOP_RVW
- SGIS.VRI_DRUKKNOP_SIGNAALKABEL_REL
- SGIS.VRI_LANELIGHT_MODULE_REL
- SGIS.VRI_LANELIGHT_RVW
- SGIS.VRI_LANELIGHT_SIGNAALKABEL_REL
- SGIS.VRI_MAST_PORTAAL_REL
- SGIS.VRI_MAST_RVW
- SGIS.VRI_MODULE_BESTURINGSKAST_REL
- SGIS.VRI_MODULE_RVW
- SGIS.VRI_PORTAAL_RVW
- SGIS.VRI_RADARKOP_MODULE_REL
- SGIS.VRI_RADARKOP_RVW
- SGIS.VRI_RADARKOP_SIGNAALKABEL_REL
- SGIS.VRI_SCHEMERSCHAKELAAR_MODULE_REL
- SGIS.VRI_SCHEMERSCHAKELAAR_PORTAAL_REL
- SGIS.VRI_SCHEMERSCHAKELAAR_RVW
- SGIS.VRI_SCHEMERSCHAKELAAR_SIGNAALKABEL_REL
- SGIS.VRI_SIGNAALKABEL_MODULE_REL
- SGIS.VRI_SIGNAALKABEL_RVW

## Water management

- SGIS.WHH_AFSLUITER_EXT
- SGIS.WHH_AFSLUITER_EXT_REL
- SGIS.WHH_AFSLUITER_FCL
- SGIS.WHH_AFSLUITER_G
- SGIS.WHH_AFSLUITER_RVW
- SGIS.WHH_AFSTROMINGSGEBIED_EXT
- SGIS.WHH_AFSTROMINGSGEBIED_EXT_REL
- SGIS.WHH_AFSTROMINGSGEBIED_FCL
- SGIS.WHH_AFSTROMINGSGEBIED_G
- SGIS.WHH_AFSTROMINGSGEBIED_RVW
- SGIS.WHH_GEBIED_FCL
- SGIS.WHH_GEBIED_G
- SGIS.WHH_GEBIED_RVW
- SGIS.WHH_GEMALEN_EXT
- SGIS.WHH_GEMALEN_EXT_REL
- SGIS.WHH_GEMALEN_FCL
- SGIS.WHH_GEMALEN_G
- SGIS.WHH_GEMALEN_RVW
- SGIS.WHH_GRENSWATERBEHEER_EXT
- SGIS.WHH_GRENSWATERBEHEER_EXT_REL
- SGIS.WHH_GRENSWATERBEHEER_FCL
- SGIS.WHH_GRENSWATERBEHEER_G
- SGIS.WHH_GRENSWATERBEHEER_RVW
- SGIS.WHH_KRITISCHEHOOGTEN_FCL
- SGIS.WHH_KRITISCHEHOOGTEN_G
- SGIS.WHH_KRITISCHEHOOGTEN_RVW
- SGIS.WHH_OPENWATER_EXT
- SGIS.WHH_OPENWATER_EXT_REL
- SGIS.WHH_OPENWATER_FCL
- SGIS.WHH_OPENWATER_G
- SGIS.WHH_OPENWATER_RVW
- SGIS.WHH_PEILGEBIED_EXT
- SGIS.WHH_PEILGEBIED_EXT_REL
- SGIS.WHH_PEILGEBIED_FCL
- SGIS.WHH_PEILGEBIED_G
- SGIS.WHH_PEILGEBIED_RVW
- SGIS.WHH_WATERMEETPUNT_EXT
- SGIS.WHH_WATERMEETPUNT_EXT_REL
- SGIS.WHH_WATERMEETPUNT_FCL
- SGIS.WHH_WATERMEETPUNT_G
- SGIS.WHH_WATERMEETPUNT_RVW