OULUN AMMATTIKORKEAKOULU

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INTEGRATION OF 3D MEP SYSTEM DESIGN SOFTWARE FOR MULTIDISCIPLINE DESIGN PROJECT

INTEGRATION OF 3D MEP SYSTEM DESIGN SOFTWARE FOR MULTIDISCIPLINE DESIGN PROJECTS

Rosamaria Kalpio
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ABSTRACT

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The goal of this bachelor's thesis was to examine the suitability and accessibility of Revit MEP and MagiCAD for Revit for multidiscipline MEP design projects. The profitability to switch design applications for increase in efficiency on a general level of engineering is also examined.

The Thesis was executed by comparing Revit MEP and MagiCAD for Revit applications by independently familiarizing with the applications in practise and in theory. Information obtained was then compared with AutoCAD software and its way of working. The suitability of Common BIM Requirements for Revit based designing was also examined.

On the basis of the results obtained, no obstacle for Revit MEP's commissioning as a BIM software was found. MagiCAD for Revit was proven to be a functional application for HVAC design work which can be done quicker and more efficiently when compared with AutoCAD. Revit MEP as a design tool does not meet the level of requirements. When changing the application, comprehensive training of the employees and the resulting costs are emphasized.

Keywords: MEP, HVAC, BIM, AutoCAD, Revit, MagiCAD, COBIM 2012

TIIVISTELMÄ

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Insinöörityön tavoitteena oli tutkia Revit MEP- ja MagiCAD for Revit-suunnittelutyökalujen sopivuutta ja käyttömahdollisuuksia monialaisten MEP-projektien suunnitellussa. Lisäksi tarkasteltiin kannattavuutta vaihtaa suunnitteluohjelmistoa suunnittelutehokkuuden optimoimiseksi/lisäämiseksi.

Työ toteutettiin tutustuen itsenäisesti ohjelmistoihin ja niihin liittyviin aineistoihin. Tämän jälkeen saatuja tietoja sovellettiin LVI-suunnittelussa ja vertailtiin nykyiseen suunnittelutyökaluun ja työtapoihin. Lisäksi tutkittiin tietomallintamista ohjaavaa julkaisusarjaa ”Yleiset tietomallivaatimukset 2012” ja sen soveltuvuutta Revit-pohjaiseen mallintamiseen.

Työn perusteella ohjelmistomuutokselle AutoCADistä Revitiin ei ole esteitä. MagiCAD for Revit osoittautui toimivaksi suunnittelutyökaluksi ja Revit kilpailukykyiseksi tietomallinnusohjelmisto-vaihtoehdoksi. Revit suunnittelutyökaluna ei täytä yrityksen vaatimustasoa. Muutoksen myötä korostuu työntekijöiden tarvitsema kattava koulutus ja siitä aiheutuvat kustannukset.

Asiasanat: MEP, HVAC, BIM, AutoCAD, Revit, MagiCAD, COBIM 2012

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30.11.2018

Rosamaria Kalpio

CONTENTS

1 INTRODUCTION

In Finland, the leading MEP system-design software has for a long time been AutoCAD by Autodesk and expansion application MagiCAD by Program Oy. AutoCAD is not developed for building designing, let alone for building information modelling. To compensate this, Autodesk bought Revit Technology Corporation in 2002. Autodesk has published new versions of Revit ever since and in these days a new version is published yearly. In Finland, Revit is mainly used by architects but globally the software is spread widely. Lately, especially with MagiCAD for Revit, Revit has reached a point with development where other fields of engineering have started to show interest towards it.

Revit in its current form is a quite good application for building information modelling but as a MEP tool it has a lot of room to improve. Program Oy has published a version of MagiCAD that works for Revit which allows modelling with real products. Today the MagiCloud catalogue has over a million MEP products from manufactures across the world which can be downloaded straight to Revit when the MagiCAD extension is installed. Each product is visualized as a data-rich 3D model and contains multiple parameters.

The project was undertaken at the request of Citec Oy Ab which is a global consulting and engineering company. Citec was founded in 1984 and the company has 1200 employees in nine different countries. Citec provides plant, product and technical documentation services to clients to over 120 countries. Citec's mission is to provide high-quality engineering in a flexible, cost competitive, safe and sustainable way. To accomplice functional and efficient cooperation between fields and departments, a prerequisite, is efficient design software.

AutoCAD is not the most efficient way to do multidiscipline design work anymore. Nowadays having a 3D model that includes design work from all fields is considered almost mandatory, AutoCAD simply is not enough. The lack of 3D modelling in AutoCAD creates a need to use multiple design applications which leads to more work, constant export/import and a bigger risk of human error.

These are factors that create a need to repeat work tasks and therefore decrease productivity.

The aim of this thesis is to compare Revit and MagiCAD for Revit applications by familiarizing with the applications in practice and in theory. Information obtained was then compared with current design software and the way of working. The profitability to switch design applications to increase efficiency on a general level of engineering is also examined. The central theme is the compatibility of Revit as company's primary building information modelling software.

2 BUILDING INFORMATION MODELLING

Building Information Modelling (BIM) is an intelligent model-based process that connects architecture, engineering, and construction (AEC) professionals. Accurate and realistic models of buildings are constructed digitally using BIM technology and, with these models, building and construction design is supported in all phases of design. These computer models contain data and precise geometry which are needed to support the procurement, construction, and fabrication. Additionally, compared with manual process, BIM models allow better control of entirety and analysis. (1, p. 1.)

BIM model is a presentation of building's physical and functional features and it consist of parametric objects which are geometrically accurate with associated data and rules. This makes the model an information model instead of just a visual presentation of a building in 3D. Parametric objects have rules and they know what they are and to which category they belong. For example, an object categorized as a door can only be fitted to a wall. When an object fulfils BIM requirements, it can be modified in any view or schedule, and the BIM application automatically reflects the changes to the entire model. (1, p. 17.)

The EU has set up a BIM Task Group which also shows the significance of BIM. The task group was composed of Members States of EU and their intent was to set guidance on how to get the best out of BIM design. The handbook is aimed towards public policy users, national or local public clients and procurers, and operator users. (2.)

2.1 BIM Maturity model

The level of BIM implementation of a region, an organization, or a project can be assessed with maturity of the BIM model. There are four maturity levels of BIM and as the project proceeds through the levels, the collaboration between the various sides is increasing. The BIM maturity model is shown in Figure 1 and the levels are described in more detail below.

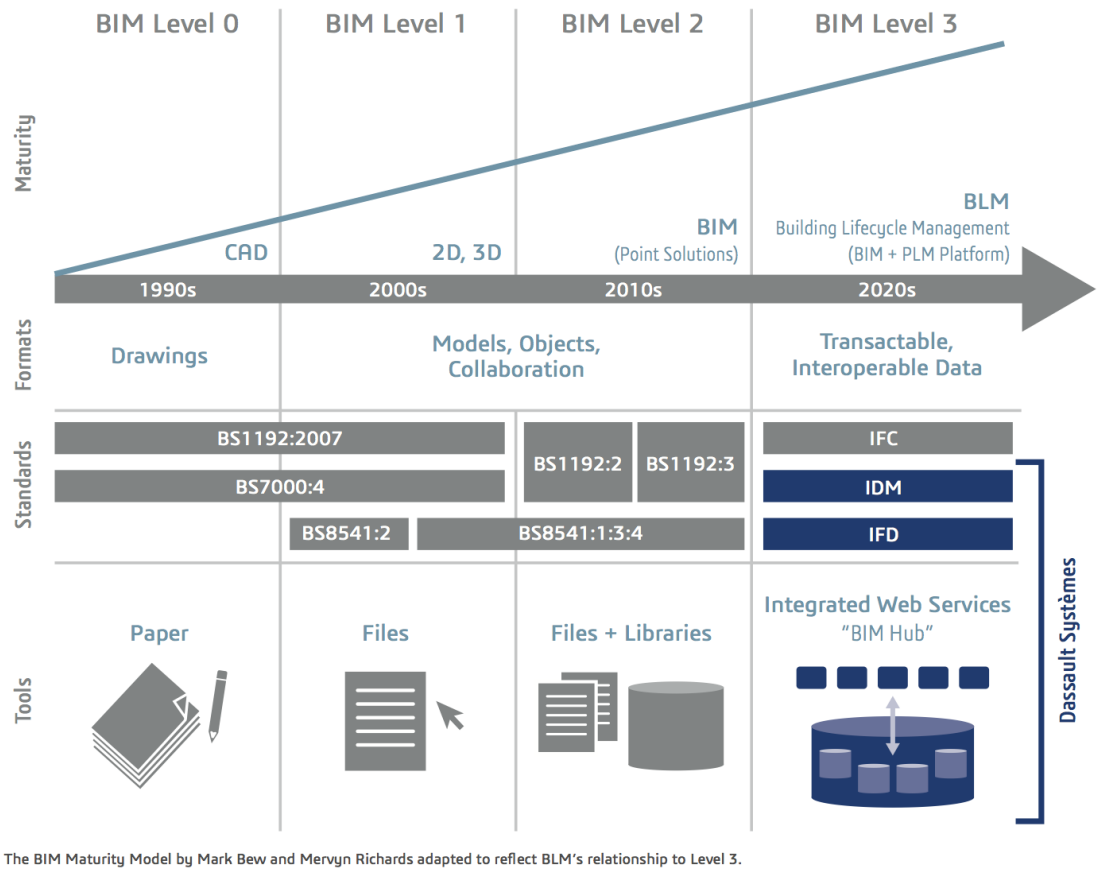

Figure 1 The BIM maturity model by Mark Bew and Mervyn Richards (3.)

BIM Level 0 is the simplest form of design and is the next step from hand-drawing. This level is reached by using computer aided design (CAD) tools to create 2D designs that are outputted via paper, electronic prints or combination of both. There is no collaboration. (1, p. 15.)

BIM Level 1 comprises a mixture of 2D for technical drawing, and 3D CAD for concept work. This is considered to be the level at which many organisations are currently operating. There is no collaboration between disciplines and each maintains and publishes its own data. (1, p. 15.)

BIM Level 2 uses collaborative working. Even though all parties create their own 3D CAD models, it is not necessary to work on a single, shared model. Design information is in a common file format which enables all organisations to open and read that data. It also enables combination with other organization's data into their own BIM model. This requires organizations to use a CAD software that

supports exporting in common file forms like IFC or COBie. This level has been considered as a minimum level in many companies. (1, p. 15.)

BIM Level 3 is considered as a goal in a construction industry and it is also referenced as a Building Lifecycle Management (BLM). There is full collaboration between all organizations and disciplines which is done using a single, shared model. ‘Open BIM’ means that everyone can access and modify same model. This removes the risk of conflicting information definitively. Working in BIM Level 3 requires paying more attention to copyright and liability issues. (1, p. 16.)

2.2 Common BIM Requirements

In order for all parties of a construction project to have a unified view of what should be included in BIM and with what accuracy these thing should be presented, there has to be a document where these are appointed. In Finland the first BIM requirements were published by Senate Properties in 2007. The appointed requirements were to be fulfilled in construction projects that were worth over a million euros. Requirements were based on the wishes of construction industry who believed that the use of BIM could lead to more efficient way of working. BIM requirements for architects were published in 2007 and for MEP and other design disciplines in 2009. (4, p. 8.)

When updating BIM Requirements became topical in 2010, the project was undertaken by BuildingSMART Finland. The nine existing series by Senate Properties were rewritten and four new series were added. The authors were the leading design and consultancy agencies and contractors in Finland. As a result, in 2012 a fourteen-part publication series called Common BIM Requirements 2012 (COBIM) was published. The series is maintained by BuildingSMART Finland which a part of the BuildingSMART organization that develops common methods for building and the exchange of information. (4, p. 8.)

At the beginning of a project, the desired BIM Content Level has to be determined for each construction stage. COBIM distributes these levels into three groups depending on their extent of content. They differ from communication and collaboration between designers and coordinating the models in Level 1 to

scheduling and contractor purchasing in Level 3. Even though the use of a specific BIM Content Level is agreed at the start of a project, it can be deviated from, if so agreed between parties. Deviations have to be documented to the Model Description Document which includes real time information, about the content of the model, design methods and applications used, by all disciplines. It also includes a description of for what purpose and with what accuracy the model has been published. Model Description Document should be updated every time the model is published to the use of other parties. (5, p. 8.)

2.3 Different phases of BIM Project

Building Construction project consists of several consecutive and overlapping stages, during which, numerous of models with variable precision and content are created. These models are used for different purposes at different stages of the project and not all projects include all these models. COBIM distributes these models into seven phases and these are listed below. (6, p. 11.)

- Requirements BIM
- Site BIM
- Inventory BIM
- Spatial Group BIM
- Spatial BIM
- Building Element and System BIM
    - Preliminary Building Element BIM
    - Building Element BIM, Quantity take-off phase
    - Building Element BIM, Construction phase
- As-Built model

2.4 BIM in MEP System Design

Utilizing a BIM is more versatile, the more meticulously the model is made. Like the use of a model, the BIM Content Level has to be decided at the beginning of the project so the modelling can be done as required.

Utilizing 3D models begins at the proposal design stage, when early models can be used for demonstrating alternative technical solutions and performing simulations of ambient conditions, energy analysis and life-cycle cost calculations. The main routes of MEP-systems are modelled tentatively to get an overall picture of how much technical equipment there is going to be and where it is going to be located. This way an architect can easily make spatial reservations in the early stage of design. (6, p. 15.)

The system solutions selected in the proposal design phase are processed in early design stage. Now the main routes of MEP-systems are modelled for closer examination of the needed spatial reservations. Also the joint assessment of models of different disciplines is done in the early stage to notice any clashes between structures and MEP-systems. With simulation of ambient conditions, the specific needs of ventilation, heating and cooling are determined for each space. (6, p. 16.)

The plans made in the early design stage are particularised in the detailed design stage to the point where a call for tenders can be made. When BIM is done precisely and using correct tools, bills of quantities and cost estimations can be generated from the BIM. This excludes the need of manual calculation and reduces the risk of human error. At the end of this phase, BIM no longer cannot have any significant clashes. (6, p. 18.)

During construction, BIM is used especially for visualization of building plans which are considerably easier to perceive with the combination of 2D and 3D views. There is also a significant benefit for production planning since it is possible to combine construction scheduling with BIM. This is called 4D-BIM and it shows in visual form the past and future stages of the project. An example of 4D-BIM is shown in Figure 2. Staying on schedule is an important part of a project for both contractor and client. (7, p. 10.)

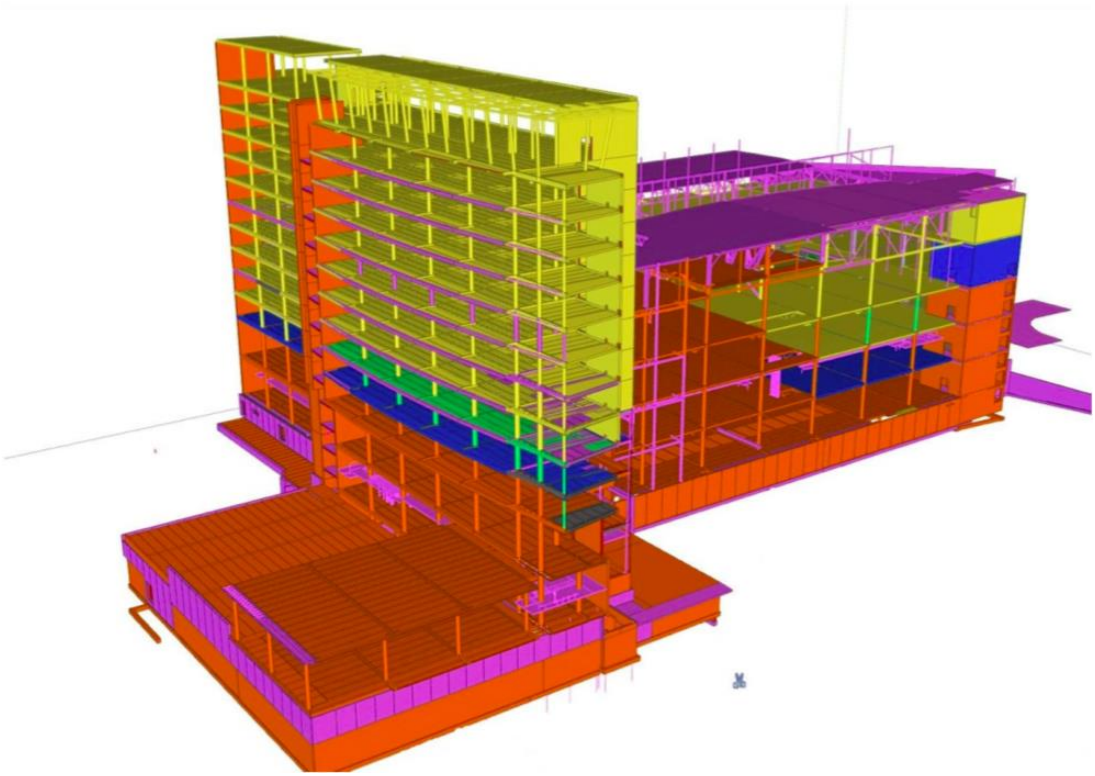

Figure 2 An example of a colour-coded 4D-BIM where each colour presents a differ stages of a project. (7, p. 11.)

Despite everything, there are still shortcomings in building information modelling, especially in post-construction use. According to a study by Senate Properties, the requirements for the maintenance phase of buildings lifecycle are not adequately taken into account when making BIM. Usually lifespan of materials and maintenance cycles of equipment are not included in BIM. Partly because of this, currently, the use of BIM in a maintenance phase is not common, but it is going to be exploited more efficiently in the future. It is also necessary to take into account that the long-term use of a model might not be clear during the design phase. Perhaps the future use has not even been invented. (4, p. 2.)

3 BIM SOFTWARE APPLICATIONS

There are two MEP system design applications that are mainly used in Finland: MagiCAD from Program Oy and CADS Hepac from Kymdata Oy. CADS is an independent application mainly used in smaller companies and MagiCAD is almost invariably used in global companies. MagiCAD is an AutoCAD extension which makes it more expensive since two licenses are needed. Recently Revit has started to raise interest in MEP design field. Revit, more specifically Revit MEP in HVAC design, can be used independently or MagiCAD can be used as an extension. (8, p. 18.)

3.1 AutoCAD

AutoCAD is a CAD application (Computer-Aided Design) released by Autodesk in 1982. The application has been constantly developed and multiple additional parts has been built to use its extension which use AutoCAD features. CAD application is suitable for example 3D design of machine parts, but the lack of parametric objects makes it only a satisfactory tool for HVAC design. (9.)

HVAC design is done using AutoCAD, or more commonly MagiCAD for AutoCAD. Each design area is modelled separately to their own files, one for each floor or level. This is mostly because a file can be edited by one user at a time and often designers from different fields work simultaneously. Depending on the extent of the project, a great number of files are created. Each file needs a layout view which is manually made to fulfil the needs of that specific design. Also a view specific title box needs to be made that includes needed information. (9.)

AutoCAD based building information modelling usually happens with using two programs simultaneously. AutoCAD is used for design and a second application like Navisworks is used to bring together all models and for examination of BIM. This way it isn’t possible to see in real time how alternations go with the existing models. To make changes to BIM, design must be redesigned in AutoCAD, converted to a required file type and imported to 3D application. This procedure might have to be repeated multiple times a day which lowers the efficiency.

3.2 Revit

Revit is Autodesk-developed extensive BIM application used by architects, structural, HVAC and electrical engineers. In Finland Revit is more commonly used by architects but other fields are starting to show interest towards it. In United States and elsewhere in Europe the use of Revit has spread widely and when talking about building information modelling it often implies Revit. (10.)

To make a change from AutoCAD to Revit multiple things needs to be taken under consideration. License prices for Revit are higher than for AutoCAD and if it is decided to use MagiCAD for Revit a MagiCAD license is also needed. Training employees to use a new application and getting to a point where work speed and efficiency achieve the same point compared with a familiar application add additional expenses. Switching application doesn't exclude the need of AutoCAD since the older projects designed using AutoCAD has to be supported. This is necessary when a client needs modifications or additional corrective actions.

3.2.1 General information

As mentioned before, in AutoCAD each design area is modelled separately to their own files, one for each floor or level. In Revit the basic idea is different. Instead of having separate floor models the whole building is designed to one model. Floor levels and other views are just views of the model.

In addition to technical systems, other models like architectural and structural models can be shown as a linked model. This is another major difference between Revit and AutoCAD. Different models can be linked to a project in IFC-format or in the Revit native format. Only the fact that structures and technical systems are shown in one model can be modified, speeds up design work significantly. A 3D model of a three-storey office building modelled with Revit is shown in Figure 3. (10.)

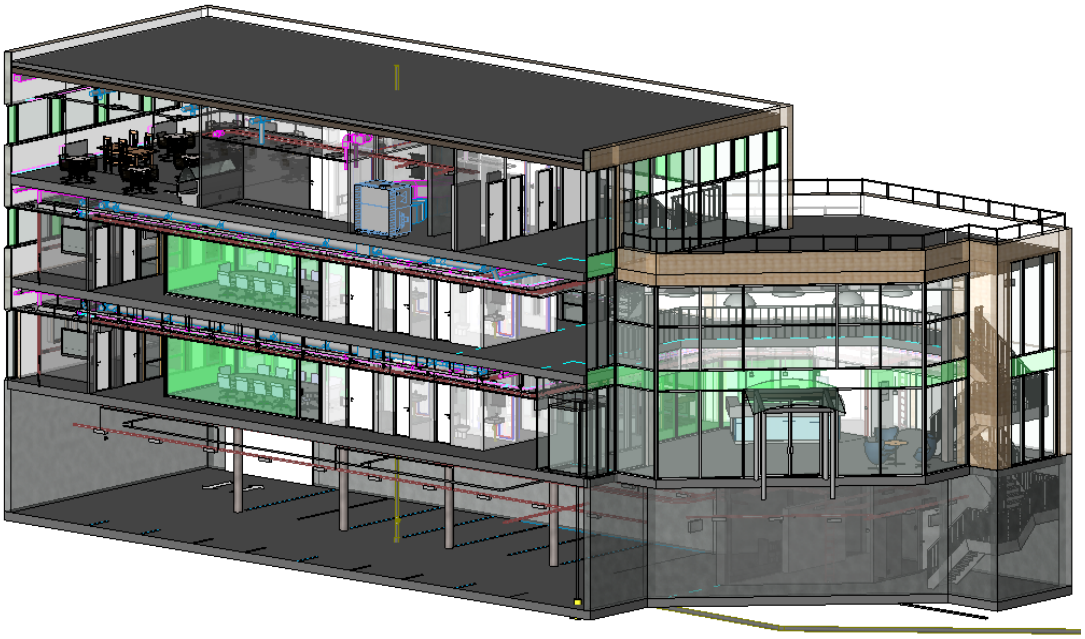

Figure 3 Section view of three storey office building in Revit

Revit can be considered to be a one big database software where every single object can have numerous different attributes and parameters. Parameters are database fields that include information about elements and the whole project. A change made to an object's parameter in one place automatically updates it to the whole model regardless in which view the change is made. At the same time other parameters which are connected to original are updated. This has been demonstrated in Figure 4 in which on the right is an air terminal schedule that includes the objects shown in the middle. An object can be changed or modified either in floor plan or in schedule in which case a menu appears where a new object can be chosen from objects that include in a model. The flow can be changed in all of the views shown in Figure 4.

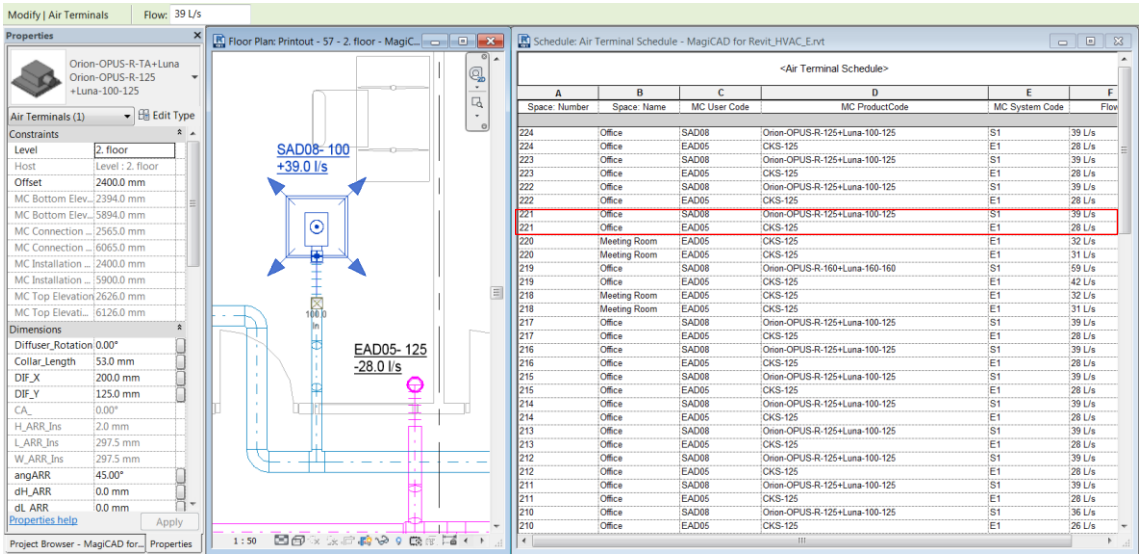

Figure 4 Part of project's properties, design view and plumbing schedule

In addition to relatively high threshold initialization, Revit has some disadvantages. The program doesn't allow saving a project to a format that can be opened with a previous version of Revit. Which means everyone using the application has to have the same version to make linking a Revit model possible. Although this can be bypass by linking the model in IFC-format which has been possible since Revit 2015 version. (11.)

3.2.2 Worksharing

When working with Revit it is possible to do all HVAC design work to the same model. Since it is not possible for more than one person to work with a model at a time there has to be a mechanism which allows multiple team members to work with a model simultaneously.

Worksharing is a functionality that allows multiple team members to edit a model simultaneously. When worksharing is enabled in a project, the original file becomes a central model. Each team member has a local file which is a copy of the central file. Changes are made to these local files and then uploaded to the central file. Connection between Central file and local files is shown in Figure 5. (12.)

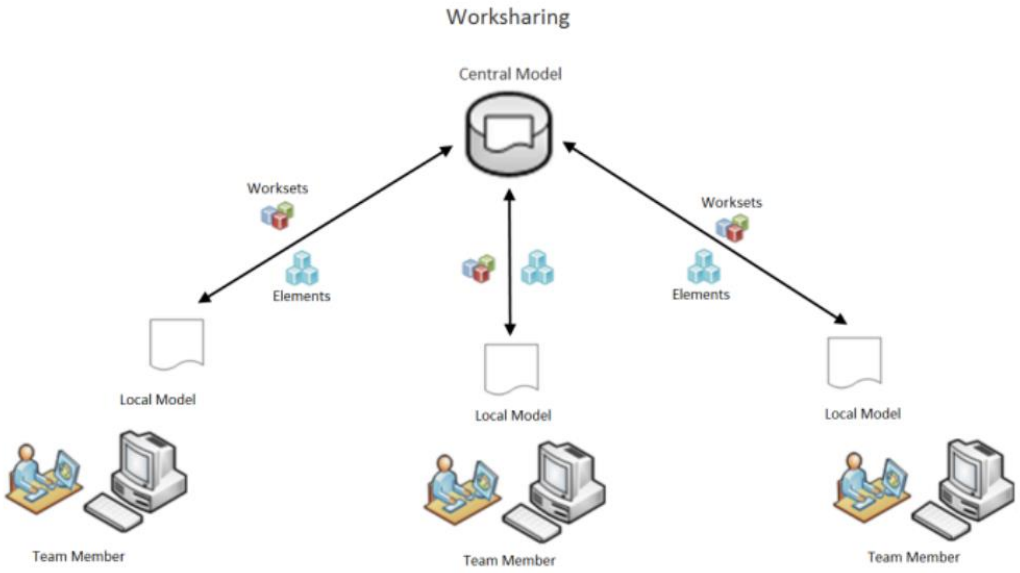

Figure 5 Connection between Central file and Local files (13.)

Since multiple team members can make changes to a model simultaneously Revit has a functionality that prevents making changes to an object by multiple people at the same time. Changes made to a local file do not forward to central model in real-time which would unnecessarily burden a server. Instead, only editing rights is reserved from the central model if the wanted object is free. Reserving editing rights happens in real-time. Other team members only see the status of the reserved object. Status shows whether the object is reserved and if yes by whom. If another team member tries to edit a reserved object Revit sends notifications to both parts. Team member trying to edit a reserved object places an editing request and the one holding the editing rights receives the request which includes information like which model and which object is in question, who sent the request and an additional message. Request can be granted or denied. Granting editing rights is not possible until local file is synchronized with central model. (12.)

When the local files are synchronized with central file they are identical. Local files can even be deleted after each workday, which can even be recommended. This way it can be made sure that every time a project is opened it is the latest version from the central file. Synchronizing to a central file before deleting a local file is extremely important. If not done, all changes made after the last synchronization are lost.

Main feature of worksharing is a possibility to create worksets. These are freely definable entities in a model which can be reserved for a single user at a time. When user has reserved a workset, other members of the team cannot make changes to objects in that workset. (14.) Especially in bigger projects using worksets is a necessity. Typically, in a project that includes HVAC design, worksets are categorized by a field. In this case the workset list could be the following:

- Heating system
- Ventilation system
- AC system
- Plumbing and sanitary systems
- Electricity and automation systems

There are also plenty more options to categorize worksets. A part of a building or a single floor of a building could also be a workset. It is possible to make changes without reserving a workset if nobody else hasn't reserved a workset that includes the objects you are making changes to either. If worksets are not used actively, team members working on a project have to have clear knowledge of everybody's tasks to avoid doing the same work simultaneously and, in this way, replace each other's work. (13.)

Benefits of using worksets are not only limited in coordinating design work but can also be used to optimize resources. For example, if a project has multiple buildings, modelling all buildings for a same central model would result to one too large file. As the project progresses, it is difficult to make changes to worksets so it is rational to take time and think how to distribute the project at the beginning. Worksets can be used to limit which parts of the model as shown at each time. When downloading local file from a central file it can be determine which worksets are downloaded. Like in a previous case when a project had multiple buildings, a local file with only worksets for building 1 can be downloaded. Downloading worksets for buildings 2 and 3 is unnecessary in this case. In addition, each building's worksets can be categorized by field. (14.)

3.2.3 Revit server

When Revit project uses worksharing, synchronization with central model is relatively quick when both server and workstation are in Local Area Network (LAN). If a company's offices are located geographically over a large area, large project files are shared using Wide Area Network (WAN) which is considerably slower than LAN. Revit Server is widely used globally and large number of users have shown it to be a reliable product. It is also an efficient way to control locations of Local Models. It is recommended to team members working on a project to update central model multiple times a day to avoid system collisions. This might often be neglected if employee knows synchronization to take over a long time. (15.)

Revit Server is the server application for Autodesk Revit. Using the server application, synchronization with a central model happens in LAN although the central model would be located elsewhere. This has been made possible by having one or multiple servers specified to work as a Server Host and the rest of the servers as Accelerators. This is demonstrated in Figure 6. Hosts are located geographically near to users, usually in headquarters. Every office has an accelerator in LAN where user can download and update central model. Accelerator gets the newest models from Revit Server Host and saves them to LAN. When the user is downloading the newest version of a model, data is only transferred from accelerator which at the time of the download gets the newest version from the Server Host. If accelerator isn't available for a user, the connection is routed straight to the Server Host. Once the fault is fixed, the connection to the accelerator will be automatically restored. For User, use of Revit Server only shows as a quicker user experience. (15.)

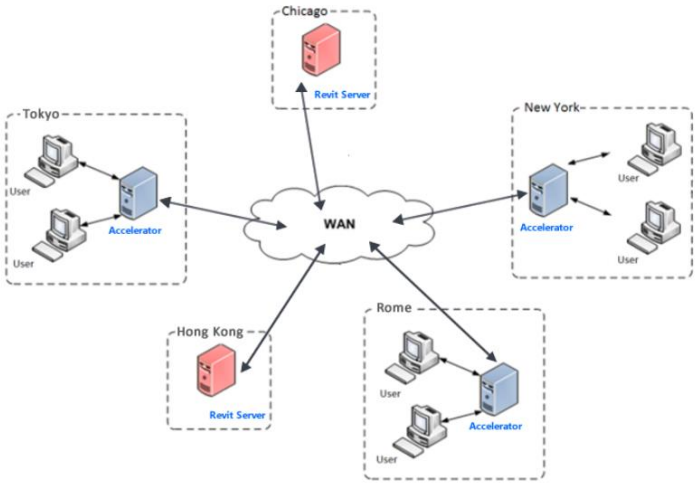

Figure 6 Server-based worksharing across a WAN (13.)

Even though Revit Server is a free addition to Autodesk's Revit platform and doesn't add any additional software costs to company, servers and their maintenance do create additional costs. Commissioning of Revit Server needs comprehensive knowledge of information technology from a company. Since this is designed to work in a single domain only, collaboration between companies is not possible. If it is needed for architects, structure and MEP designers from different companies, to update their models to same place, from where they can be deployed directly, Revit Server is not a working solution. If access to Revit Server has been allowed for a consultant company, then they are able to see everything that is on that server. This can be solved by having multiple servers which can be problematic, inefficient and costly or buying a third party applications. Also the central model cannot be overwritten with same name and backing up Central Model is cumbersome. Workshare monitoring will not be functional to give notifications. (16.)

3.2.4 BIM 360 Team

Autodesk has lately invested a lot to cloud services and BIM 360 Team is a tool used for internal project coordination and saving and sharing project files. Autodesk's goal is to have a cloud service which is simple to use, easy to access, exploits cloud base collaboration and data management solution to fill companies' day to day needs. (17.)

BIM 360 Team is one location where members of the team can publish, share and view files and do markups. Service can be accessed on a Web or using mobile device that has Android or iOS. More than 50 different file formats including 3D-moddeling, office software and video formats can be added and read in addition to Autodesk files. The viewer in BIM 360 Team allows viewing of 2D and 3D design files on any device without plugins or downloads. It is possible to examine sheets or a whole model using several available tools. A single component can be isolated and examined more closely. (17.)

Sharing files with BIM 360 Team can done through a browser. Model can be shared by sending a link where it is possible to specify if the receiving part has a right to download the file. If the file is downloaded it can be worked on and then saved back to the cloud. Files downloaded to the cloud service can be shared with a third party even if they are not otherwise using BIM 360 Team. The third party can examine the model in progress and add comments to 2D and 3D views. (17.)

Members of the team can comment and make markups to model's 2D or 3D views. Commenting is also possible in the comment section integrated to Revit or in message board located in BIM 360 Team browser interface. The last two ways are not connected to each other so discussions had in comment section integrated to Revit are not visible in the cloud service. When comments or markups are made, other members of the team get notifications, and are able to react. Also comments and markups can be controlled through various versions of the file so it is possible to check what has and hasn't been done. (18.)

BIM 360 Team also allows live review. Multiple people can be invited to view the model in real time within a web browser. By sending a link it is possible to share a screen and everyone who received and opened the link are able to see the same screen. During this process it is possible to interact and live comment with other team members. (18.)

When a new version of the file is downloaded to the cloud, the older version of the file with the same name is not removed. Different versions can be compered

so it is easy to notice when something is added, removed or modified. These older versions can also be opened later on and edited. (18.)

3.2.5 Collaboration for Revit

Sharing and viewing files through a cloud service has been made possible by BIM 360 Team but integration with Revit limits viewing and commenting to models. Collaboration for Revit (C4R) is built on Autodesk's cloud collaboration work space A360 which makes possible for multiple team members to work simultaneously on a model. C4R isn't free and comes with a quarterly or annual cost but additional hardware and IT-staff are not necessary. IT-work like hosting, configuration and set-up is done by Autodesk. (19.)

Just as in Revit Server, the central file gets stored on a Host Server, the Host Server then synchronizes the changes with a local computer called Accelerator and users then connect to that synchronized local copy of the central file. The main difference between Revit Server and C4R is where the Host Server is located. Unlike in Revit Server where company provides the hardware and acts as both Host and Accelerator in C4R Autodesk's servers act as the Host and each user acts as their own accelerator. The core concept behind the products is essentially the same, the difference is just how it is deployed. (18.)

When a project is created to C4R, first version is automatically published in BIM 360 Team. This gives access through web browser to team members who does not have Revit. Later versions are published when necessary. This is shown in Figure 7. Synchronizing to C4R does not automatically publish the latest version to BIM 360 Team for everybody to see and this way getting feedback on unfinished job is eliminated. (22.)

A Revit file located in C4R can be linked to other Revit files located in C4R. Other file types like IFC models cannot be linked directly. This has to be done through company's internal network or using third party cloud services. (21.)

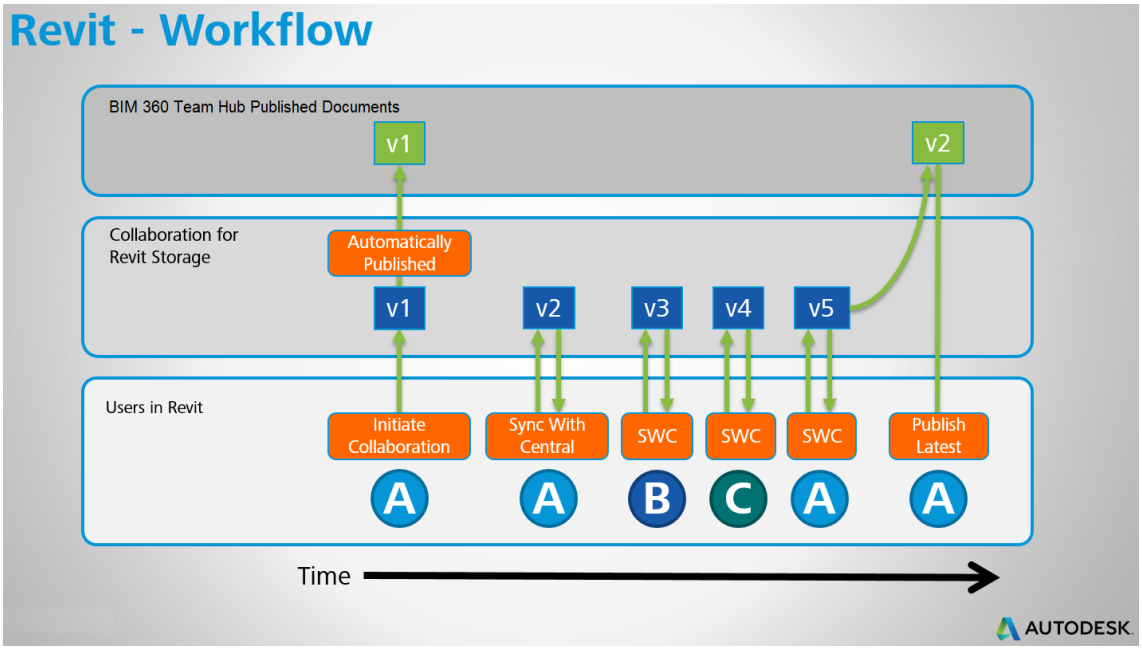

Figure 7 A difference between synchronizing and publishing a Revit model when Collaborate for Revit is used (22.)

If cloud service crashes or network connection is lost, working is still possible with the local file saved on the user's computer and changes can be saved to a local hard drive. After network connection is restored changes can be synchronized to C4R. For security C4R is subject to the same agreements as Autodesk's managed cloud services. In addition to this there is a level of security that is set in the project themselves. A key point is when it comes to security on a project's level is to manage the team member's access to review and download files. When a cloud-based service is used, the company has complete control over who sees what. This is especially important when consulting companies are involved. If a project includes outside consultants, C4R allows their participation to the same model leaving exporting and importing multiple files unnecessary. (18.)

Revit 2018 enables an intelligent connection between Revit and a schematic but this requires a subscription to Autodesk Collaboration for Revit which includes BIM 360 Team. It confirms cohesion between the model and the schematic, by minimizing manual entry. Piping and instrumentation diagram (P&ID) projects files can be accessed via cloud. In case that the model and the schematic doesn't match, the P&ID modeller informs this by showing green and yellow hatch pattern on those places. When fixed, parts turn to solid green. (23.)

3.2.6 Template

When switching from previously used AutoCAD to Revit, new templates have to be created. Creating a template would be one of the first and one of the most time consuming aspects of switching the application. The template is a base which serves as a basis for starting a new project. It includes all pivotal information and settings which are specified in this paragraph. Doing the same work phases at the beginning of every project can be avoided by creating a well-designed working template. A meticulously executed template has standardised settings. When the whole department uses the same template, projects are designed using the same settings and this way it can be made sure that the settings and system data are correct.

The most common way is to do all HVAC design into a one model and use one template that includes information of all fields used in HVAC design. Another way is to design every HVAC field separately to their own models and link other designs to them. In this case a template can be created to only serve a need of a single design field. Template can be created on top of existing template provided by Revit since all data included can be modified or deleted if necessary. A template should be able to be edited to the needs of a project if needed. This means it shouldn't contain too much data.

This paragraph lists segments that has to be taken into consideration when creating a Revit template. It also works as a guideline as to how large the creation process would be and how it differs from AutoCAD. If MagiCAD for AutoCAD application is used, Revit template only includes views, print settings, tag families and title box families since products and sizing methods are determined in a Dataset.

3.2.6.1 Views

Design work in Revit is done in Views. This is one of the biggest differences between Revit and currently used AutoCAD when it comes to actual design work. Multiple views can be created for the template where the HVAC design can be created and the architect's model can be examined. These views can be

elevations from each compass point, 2D views of each floor for designing and 3D views for examination of the model. Temporary views can be created which can be saved but these should not be included to the template since they are building-specific.

For HVAC design using Revit MEP, views need to be created for each design field separately, and the way that is most efficient for that field. Since Revit uses building information modelling, all HVAC design can be made in one model but should not be made in one view. These view templates can be created and modified in Assign View Template.

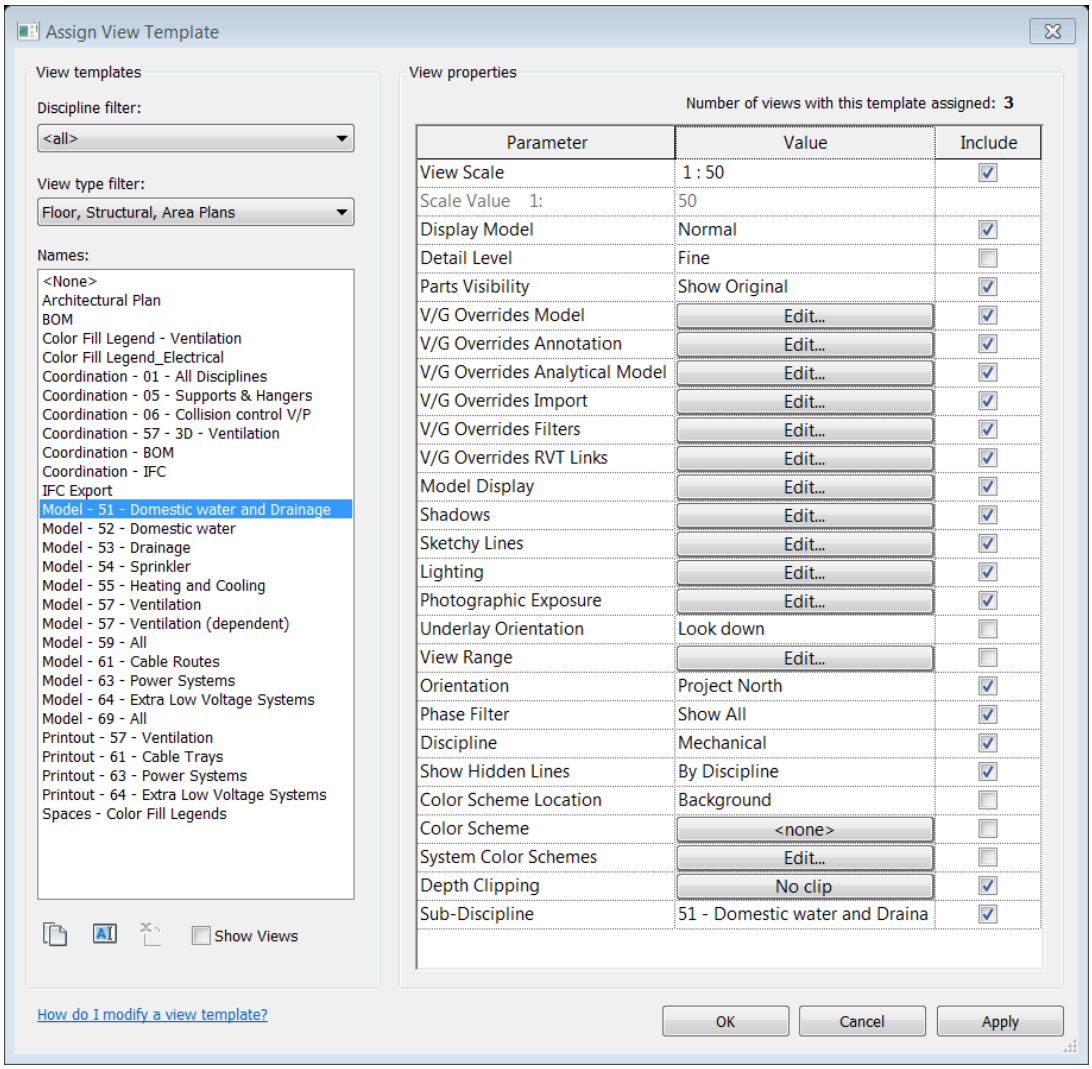

Figure 8 Assign View Template

From the menu shown in Figure 8 views can managed. By using filters and manipulating visibility settings each view can be made to service a specific need. For example, when doing plumbing design, showing ductwork is not necessary but on the other hand when making an AC design there might be a need to show pipe work. As many views as needed can be created. All created views are shown in project browser shown in Figure 9.

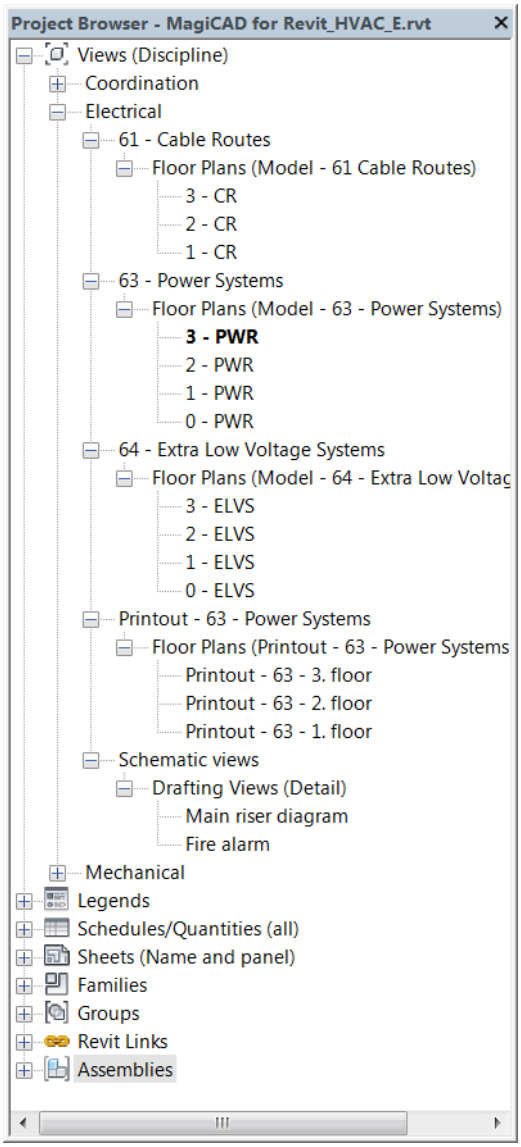

Figure 9 Project Browser

Starting view is used as a view that opens every time project is opened. This is used to open a model faster. After Revit opens assigned starting view, the user is able to use any view in the project. Without starting view Revit opens the last view that has been used before closing the program. Adding a starting view could

prevent the program to open with a complicated 3D model. Starting view could contain essential information about the project or reminders.

3D-views are created so that every system can be examined separately and that all systems can be examined simultaneously. Also a view that shows all systems and architects model should be included to the template. When systems are designed to correspond to reality and are in scale, their location can be examined immediately from 3D-view. Unlike in AutoCAD where system has to be exported to a separate 3D application to do this. Designer can create temporary 3D views from a specific rooms or areas. Manipulating visibility settings, parts of MEP and architect's model can be made either hidden or visible. Since this is designers own view, which is not part of the template, these setting can be changed without accidently making changes to a template. In 3D-views hide/isolate function can also be used. It makes possible to hide unnecessary elements from the view without having to create a new temporary 3D-view. This is demonstrated in Figure 10 where a bathroom is isolated from the rest of the model and architects' model is hidden. These two methods work differently and with hide/isolate function you can quickly hide the whole architect's model or parts of MEP system. A more specific outcome can be done by manipulating visibility settings. This way you can specify which parts of an architect's model or MEP system you want to be visible, hidden or transparent.

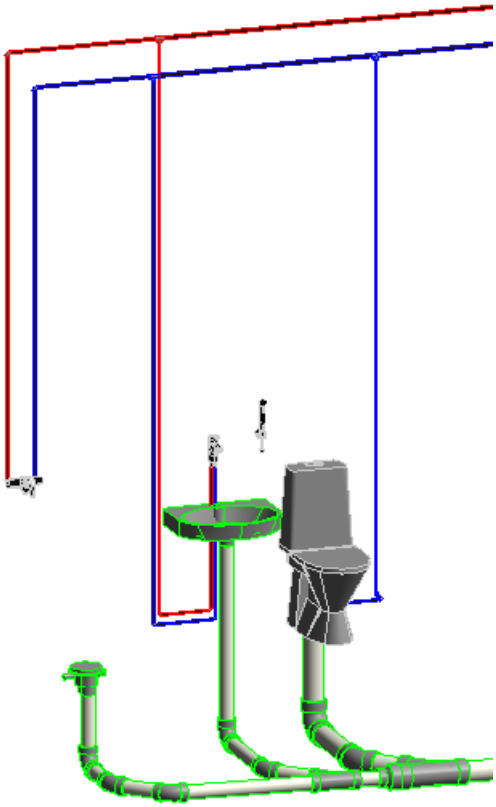

Figure 10 3D-view where HVAC technology is shown and the architect model is temporarily hidden.

Design view or Floor plan is a 2D view where the design work is made. This view most resembles what is used currently in AutoCAD. Design views are made for each floor or level and all design fields has their own. Importance of filters is emphasized since information like room names, sealing height or door tags can be shown or hidden depending of the need of that specific view. Settings of which information from the architects' model is shown or hidden is most efficiently done as a part of a template. Most of the time the same information is needed and since designs are made to their own views, settings can be specified for every field. View settings can be changed and saved to a project or a specific view manually without being part of a template. To keep floor plans cleaner and simpler it is recommended to create a printout view for each floor plan. Printout view is simply a copy of the floor plan where tags are added. Creating a view just to add tags may sound a bit extreme but tagging objects in Revit isn't as smooth as in AutoCAD.

With Revit, schematics can be created in a Drafting View. After a family of symbols and lines needed is created, they can be placed to a schematic. An example of a ventilation schematic is shown in Figure 11. Working in a drafting view doesn't differ much from drawing schematics in AutoCAD. Unlike with P&ID tool, a schematic created this way doesn't have intelligent connections between the model and the schematic.

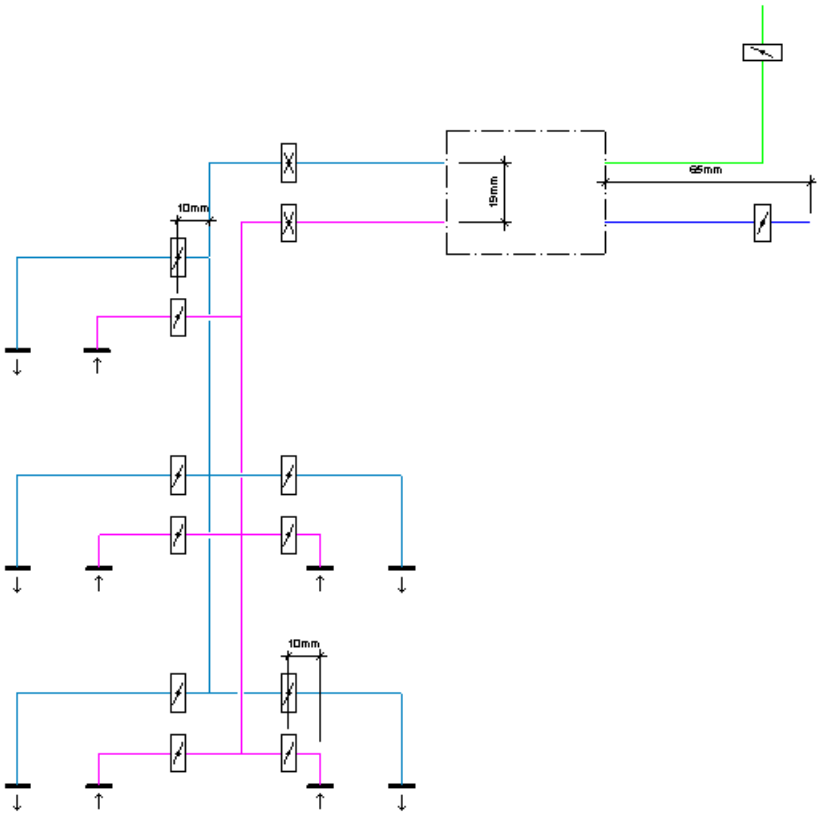

Figure 11 Example of a ventilation schematic.

Creating a finished print view in Revit takes a lot less time than in AutoCAD since all designs and legends are finished up in other views. Print view is used to arrange wanted elements and adding a company specific title box. If the right information is inserted to the model and the title box has the correct parameters, the title box doesn't have to be filled manually. Line weight and colour settings can be specified to a template. This way everyone uses the right standardized settings for system recognition and black and white printing is done correctly. These setting can be edited in Visibility/Graphics tab and in system settings. Line

weights and colours of architecture's model for printing view can be adjusted with Halftone/Underlay tool. Requirements of line weights and colours of HVAC systems for 1D, 2D and 3D are specified in Finnish in Common BIM Requirements 2012, series four, appendix 2.

3.2.6.2 Families

Modelling in Revit is based on families. Revit distributes elements to Category, Family, Type and Instance. This hierarchy is presented in Figure 12 where the location of KTI-C air terminal is shown. Plumbing fixtures, Air terminals, text notes and tags are groups of elements that are used in modelling. These groups are called categories. Objects in a "Family" can have differences on parameters but the names of the parameters and the use of the objects are identical. Graphical presentation only usually varies in size. A family can contain multiple types which are different sizes of a same family. When a type is used in a building design and it gets a specific location it is called an Instance.

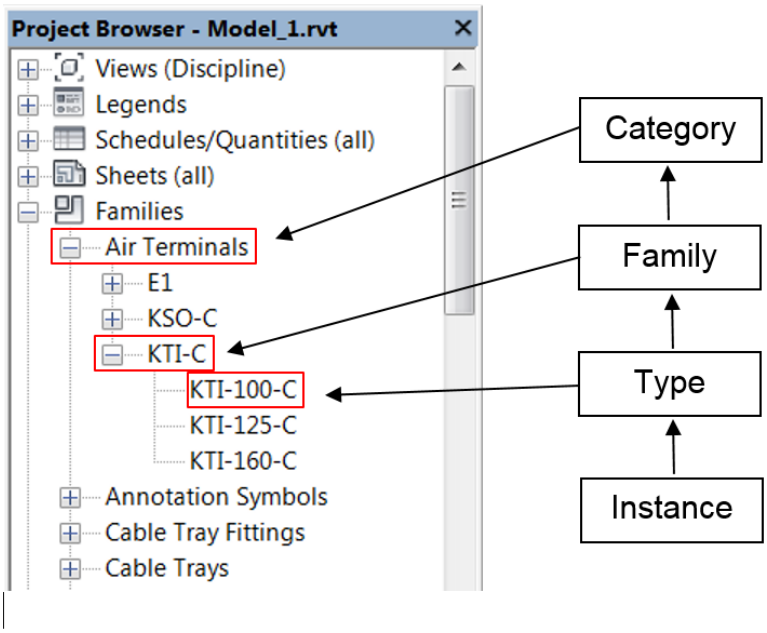

Figure 12 KTI-C Air Terminal location in Project Browser.

Families are distributed to System families, Loadable families and In-place families. System families include basic elements and settings like pipes, ducts, dimensions and levels. These are predefined by Revit and cannot be downloaded from external file sources but transfer between projects is possible. Loadable

family is the most commonly used Revit family type. Loadable family elements are for example air terminals and plumbing fixtures which are imported externally as a RFA format to a project. Settings and graphical presentation of elements in this family type can be edited if needed. In-place families are project-specific and are used only when loadable families are unsuitable. When an object is created as an In-place family it cannot be monitored or copied. This may cause compatibility issues between linked models. (24.)

In addition to be able to edit objects Revit offers tools to create an object from scratch. Parameters and additional information can be added to these objects and they can be saved as a family. Like other families, self-created ones can be then imported to a project or added to be a part of a template.

3.2.6.3 Levels

The amount of levels created for template should be kept to minimum due to the features allowed by Revit. It is not necessary to create multiple levels since an architect has already created levels for each known storey and for other references needed for the building design. These levels can be copied to the MEP model after the architect's model is linked to it. Copying levels from a linked model makes them automatically monitored. This means that designer is informed every time, when a component's location information or properties are changed. When level is being monitored, a heartbeat icon appears as shown in Figure 13. Monitoring can be stopped anytime if needed.

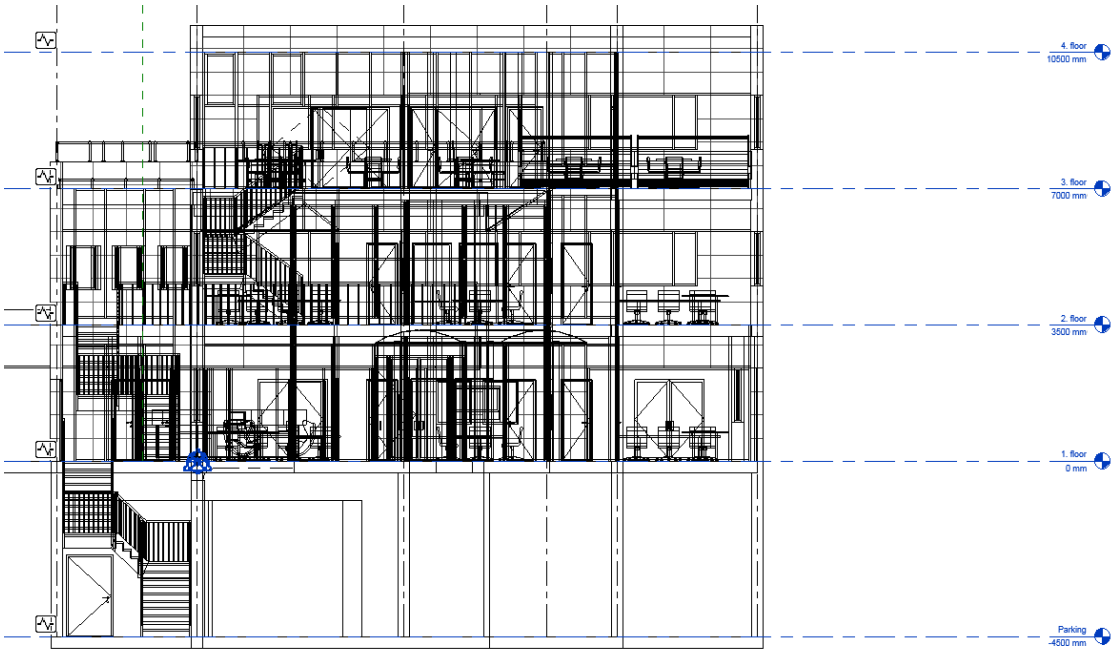

Figure 13 Copied and Monitored Levels

3.2.6.4 Tags

Revit doesn't offer comprehensive options when it comes to tagging components on a design. This means that the tags need to be created and modified to resemble the ones previously used in AutoCAD. Name, size, font and colour of the text can be modified in menu shown in Figure 14. In Figure 15 there is an example of parameters used to show pipe type, size and height. Also prefix and suffix can be added to each parameter if needed. Tags are a Revit family. Creating a family first is necessary which can then be downloaded to template.

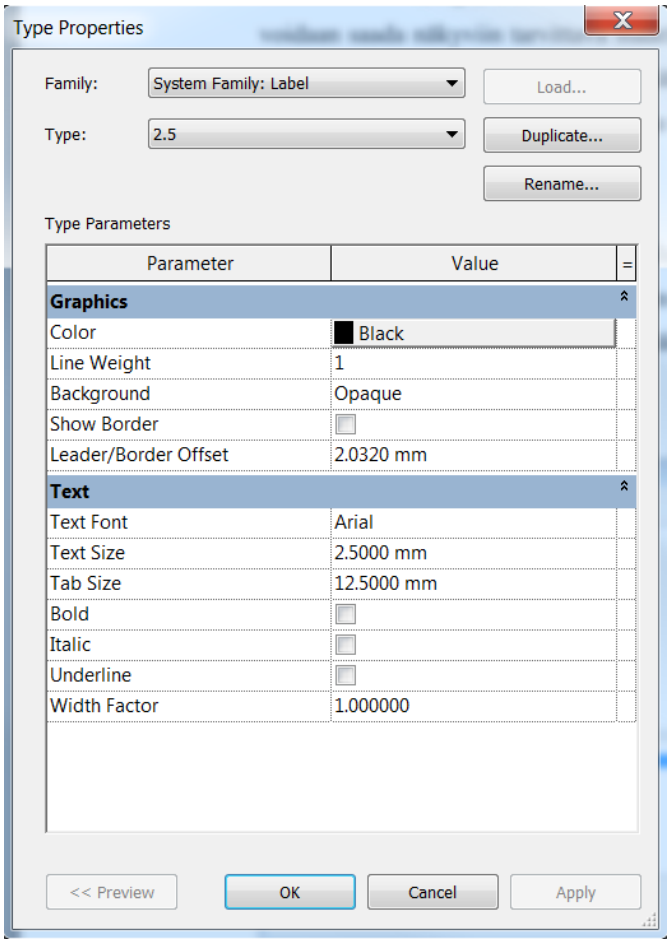

Figure 14 Type Properties

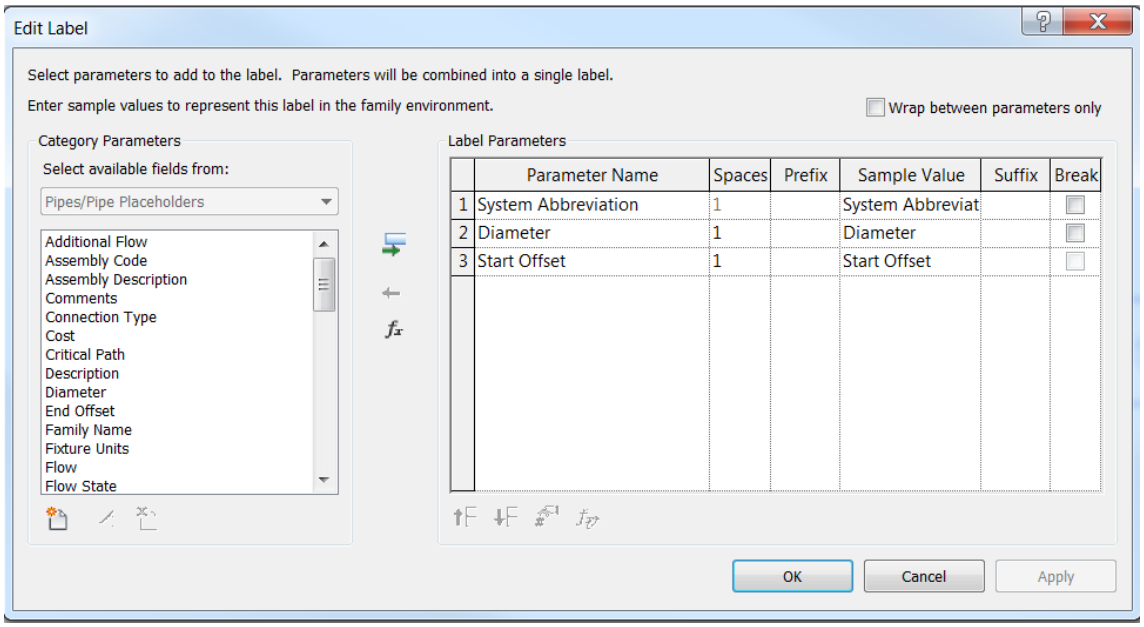

Figure 15 Label Parameters

Since Revit doesn’t offer needed layout settings for modifying tags it is not possible to create them to resemble the ones used currently in AutoCAD. There are deficiencies in modifying reference lines and adding information from more than one element to one tag. A tag, where the size and elevation of hot and cold-water pipes are shown is presented in Figure 16. When a design has multiple tags close to each other it is considerably easier to move and interpret them with AutoCAD. AutoCAD also gives an option to add more than one element to one tag when Revit doesn’t give this option.

Figure 16 Plumbing Tag in Revit

3.2.6.5 Sizing methods

In MEP-settings, the properties of fluids can be edited. Using a right fluid with correctly specified dynamic viscosity and density is key for system sizing. Revit provides a list of fluids and their properties by temperature which can be edited to match the need of a system. This list should be included to a template.

Revit offers tools for sizing and also pressure drop and flow calculating. Duct sizing can be done by velocity, friction, static regain or equal friction. Pipe sizing can be done by velocity and/or friction. It is important to remember that Revit doesn’t offer a tool for balance a designed system which is an essential part of HVAC design. (25.)

3.2.6.6 Schedules

Properties of the objects in a project can be shown in a tabular display, called a schedule. Schedule can be used as a tool to control a project and it is an easy and a quick way to follow what and what kind of information the project includes. An example of an Air Terminal Schedule is shown in Figure 17. Creating a schedule is easy and quick but the tool to work it requires that all instances include right information and parameters. When changes are made to a project,

the schedule is updated automatically. This also works the other way around, when changes are made to a schedule, parameters in all other views are changed. A schedule can be exported to excel.

<Air Terminal Schedule>

A	B	C	D	E	F
Space: Number	Space: Name	MC User Code	MC ProductCode	MC System Code	Flow
224	Office	SAD08	Orion-OPUS-R-125+Luna-100-125	S1	39 L/s
224	Office	EAD05	CKS-125	E1	28 L/s
223	Office	SAD08	Orion-OPUS-R-125+Luna-100-125	S1	39 L/s
223	Office	EAD05	CKS-125	E1	28 L/s
222	Office	SAD08	Orion-OPUS-R-125+Luna-100-125	S1	39 L/s
222	Office	EAD05	CKS-125	E1	28 L/s
221	Office	SAD08	Orion-OPUS-R-125+Luna-100-125	S1	39 L/s
221	Office	EAD05	CKS-125	E1	28 L/s

Figure 17 Example of an Air Terminal Schedule

Even though with Revit multiple types of schedules can be created and they can be edited, the schedule tool doesn't work efficiently for exporting material lists. When making for example a material list of ventilation system, air terminals are in one schedule, ducts are in another one and duct fittings are in a third one. To collect all needed information, using this tool would create multiple schedules which is not considered efficient and can lead to mistakes easier.

3.3 MagiCAD for Revit

MagiCAD is an extension application developed by Progman Oy. MagiCAD includes multiple applications that are used to make mechanical, electrical and plumbing (MEP) designing easier, less time-consuming and more flexible. Revit without MagiCAD extension has versatile modelling features but it is missing many features that designers who are familiar with MagiCAD extension for AutoCAD are used to having. MagiCAD for Revit includes applications like ventilation, piping, electrical, sprinkler and schematics. Newest addition is Supports & Hangers application which is examined more closely in chapter **Error! Reference source not found.**. (26.)

MagiCAD has Europe's largest online product catalogue which is being expanded all the time. Today MagiCloud catalogue has over a million MEP products from manufactures across the world which can be downloaded straight to Revit when

MagiCAD extension is installed. Each product is visualized as data-rich 3D model and contains information like pressure drop. MagiCAD extension includes functions like automatization of drawing functions and device connection, system sizing and balancing and space sound calculation. Some of these functions are available in Revit but not in the same extent. (27.)

3.3.1 Dataset

Dataset is MagiCAD application's own Revit template like file. It resembles AutoCAD's epj-file but in MagiCAD for Revit the file is in mrv-form which means that datasets created for AutoCAD cannot be used in Revit. Dataset includes settings, products, insulation series and sizing methods and if done well, can be used in multiple projects. Products added to a dataset do not raise the size of project file but makes working a lot faster since the need of searching products every time when starting a project is eliminated. Revit families can be added to a dataset even though they are not made specifically to be used with MagiCAD. Multiple datasets can be created to fit the needs of projects. Using MagiCAD for Revit does not exclude the need of creating a Revit template.

3.3.2 Benefits of MagiCAD for Revit

MagiCAD application gives more features for HVAC design work compared with using only Revit. It also makes the transition from AutoCAD to Revit easier for users that are familiar with MagiCAD for AutoCAD application. The intention of this paragraph is not to list all features MagiCAD offers, but to concentrate to those basic features that makes everyday design work easier and more efficient.

An essential feature that is missing from Revit completely, is system balancing. Revit can calculate flow and pressure drop of a system but balancing is only possible when MagiCAD application is installed. This means that adjustment values of valves and dampers have to be calculated some other way when using Revit. Adjusting values are calculated automatically in MagiCAD when parametric products are used.

Creating material and device lists with Revit, there is room for improvement. MagiCAD for Revit has the same tools for creating Bills of Materials and Spread

Sheet as it has for AutoCAD. Although the list creating process is the same as in AutoCAD, the Selection file uses a different file form which means a new one has to be made.

Both Revit and MagiCAD offer selection filters but with MagiCAD's tool it is possible to get more detailed filters. When components have to filtered from a design view, with Revit it is possible to filter for example all air terminals or pipes of a hot water system. What cannot be done is to filter for example only exhaust air ventilation units or more specific types of exhaust air ventilation units which is possible with MagiCAD. Also all components of a specific system can be filtered.

Find and Replace is a feature in MagiCAD which can be used to change a component that has already been added to a model. The component transfers information, like flow, that has been given to it from the new substitutive component. With Revit's comparable feature flow has to be added manually to the new component. Revit can only replace a component to one that already exist in a project family. MagiCAD can use every component found in the project's dataset. Application gives a warning if a reimbursable component is not suitable.

When modelling using Revit, it is not easy to determine what types of elbows are going to be used for example when the elevation of a pipe is changed. To be able to control the elbow types, designer has to first create a section view of the design and then model the elbow in that view. With MagiCAD this can be done in design view while determining elevation settings. The same problem occurs when Revit determines the types of joints and elbows to when air terminals are connected to a system. MagiCAD offers a feature that allows designer to determine the types of elbows used to connect objects.

When modelling pipes and ducts with Revit, it is only possible to determine their centre elevation. This makes designing large pipes and ducts to tight spaces particularly complicated and adding insulation makes working even more challenging. In addition to determine central elevation MagiCAD allows to determine top and bottom elevation in which case the application also takes into account possible insulation and extra width that comes along it. Unlike in MagiCAD where insulation is added while modelling pipes or ducts, In Revit it is

done afterwards. Even then Revit can’t determine the right width for the insulation according to the pipe or duct size.

Connecting a duct as a branch to a main duct with Revit doesn’t happen automatically. Branches do not divide the main duct into sections which leads to Revit not calculating flow and duct sizes correctly. A separate T-fitting has to be added manually between the main duct and each branch, for Revit to be able to correctly size the system.

In HVAC design, especially in ventilation design, it is important to pay attention to noise levels. Requirements are strict for residential buildings but office and work places also have their demands. MagiCAD can not only calculate sound levels of singular air terminals but also the overall sound level of a space. This is based on Revit spaces. This is a significant improvement from MagiCAD for AutoCAD where total sound level of a space has to be calculated manually. The sound level calculation is based on the selected air handling unit and the sound level that unit generates. MagiCAD takes into account attenuation of different duct components and attenuation of the space itself which is based on absorption coefficient or reverberation time. Directivity coefficient which depends on the location of the air terminal also has an effect on the sound level. Calculation is based on either absorption coefficient or reverberation time. A height level of the calculation point of the levels can also be determined. The input of parameters can be done either selecting a correct space type from a list that the application provides. Selecting a space type automatically inserts absorption coefficient and reverberation time suitable for a selected type. These parameters can also be inserted manually. If an architect has already determined the type of the space which includes the needed parameters for sound calculations, these predefined parameters can be used.

MagiCAD can export required parameters to Excel where they can be edited. After editing, the data can be imported back to Revit. Revit shown what data has been modified and user can either approve or decline them.

MagiCAD also allows defining simultaneous water points. This feature allows to designer to determine what water points are be used simultaneously and this way the application knows how to size the system correctly instantaneously. The simultaneous factor can be between 0 and 100%. If the entered value is zero, MagiCAD doesn't take the factor into account when calculating dimension flow. Factor affected range can be determined by selected objects, branch, space or area.

In the case of a collision, MagiCAD offers a Crossing and Multi-Crossing features for horizontal ducts, pipes and cable trays. A single or multiple pipes can be selected simultaneously to determine which object is to be crossed and with what angle. This can be done while modelling or afterwards. The same process with Revit requires creating a section view and crossing pipes manually in that view.

3.3.3 IFC-export

When using IFC-export by Revit, the application creates one big IFC model of the entire model and all data that it includes. This does not meet the requirements of information content set by Common BIM Requirements 2012 (COBIM). The general guideline is that every building is modelled as independent models by story and also in MEP design every system is combined into one storey-specific BIM. If a requirement is based on that, usually models are analysed by story. Contractors, users and clients handle design by storey and in present day, still in paper form. (6, p. 9.)

As mentioned earlier Revit doesn't offer the needed tools to create a storey by storey system IFC model but MagiCAD can do this. Content of an IFC model can be decided to detail and create a template only for exporting IFC models that is recommended for controlling what information is exported. Every system can have their own storey by storey view and additionally a view that has all HVAC design can be created. Also IFC-export can be done without parameters when only graphics are exported. IFC-export tool by MagiCAD for Revit is shown in Figure 18.

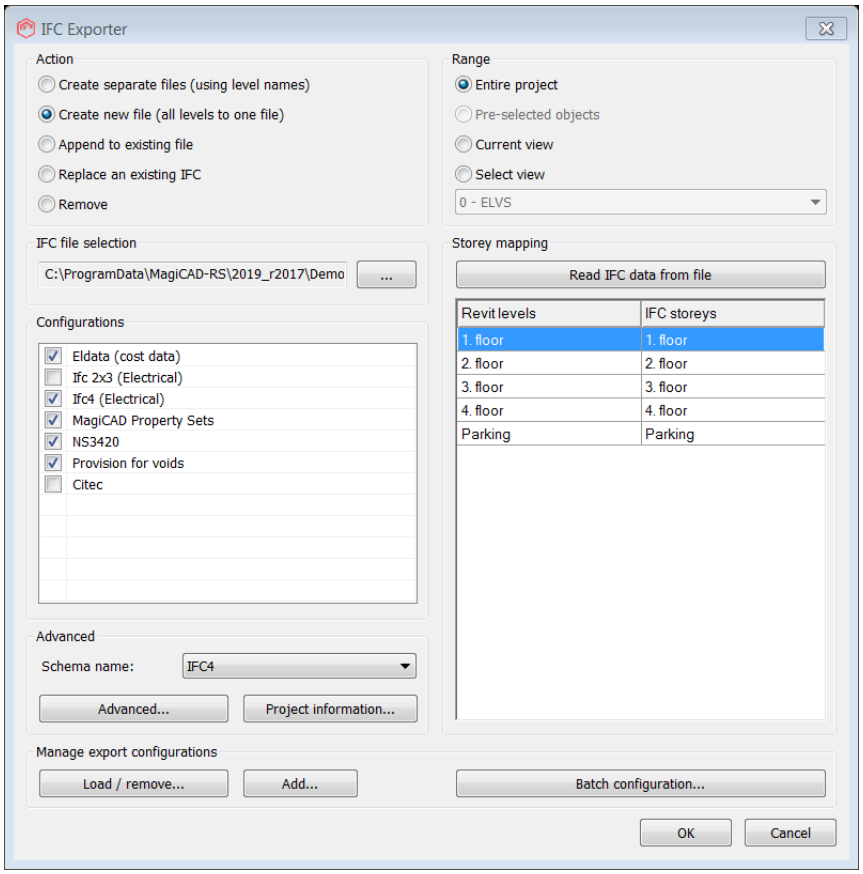

Figure 18 IFC-export tool by MagiCAD

COBIM requires that design models have to be presented to third parties of a project both in IFC-form and in project's native form. For receiver part to have a working model, the model given in native form includes the company's owned Revit families and templates. Creating families and templates is a big investment for a company and they own the copyrights to them. Projects should include a contract that defines families' copyrights. (6, p. 9.)

3.3.4 MagiCAD Support and Hangers

Support and Hangers application was published 2016 by Program Oy. The application enables efficient and easy way to design support systems for pipes, ducts and cable trays. It makes designing with both manufacturer-specific and generic components possible. What can and cannot be done regarding to fabrication parts is shown with more detail in **Error! Reference source not found.**. The application recognizes surrounding objects automatically and

mounts support systems to them correctly. This is the main reason S&H application isn't available for AutoCAD. (28.)

Table 1 What can and cannot be done regarding to fabrication parts

Routing element	Can this design element be converted to fabrication element?	Can this routing element be modelled with fabrication commercial lengths?	Can this fabrication element use the "route and Fill feature?	Can this element host hangers from fabrication catalogue?	Does this element have fabrication parts available?
Duct	Yes	Yes	Yes	Yes	Yes
Pipe	Yes	Yes	Yes	Yes	Yes
Cable tray	No	Yes	Yes	Yes	Yes

It is important to pay attention to which support, and hanger components are used and where. If designed incorrectly, problems like increase of noise levels or corrosion of pipes might occur. In worst case scenario badly planned support system might cause work occupational fatalities. When installing support systems lack of space might lead to a situation where a construction worker has to install the systems to differ from the design. This might have unfavourable effects to a system. Fire resistance classes have to be taken into account when sprinkle system or fire insulated pipes or ducts are used. Used support elements has to be the same rating as supported system. (28.)

When changes are made, the application automatically recalculates new measurements. Also when the sizes of pipes, ducts or cable trays are changed, support and hanger elements adjust automatically. If the automatic adjustment values of support and hanger elements does not work for the specific needs of that project they can be easily edited. (28.)

The level of detail can be adjusted depending of the need. It is recommended to use the low-detail mode while doing design work for better system performance. In this mode only the essential details of suspension elements are shown. To give more realistic graphics, detail level can be enhanced when the model is being exported and because every suspension element is parametric, material list can be created automatically and accurately. (28.)

3.4 Other BIM Platforms

Vertex BD (Building Design) is a Finnish object-oriented 3D-modeling software by Vertex Systems Oy. The company has seven different applications that each uniquely serves the customer's operations in the machine or building construction industry. Vertex BD is used in steel and wood design and modelling. The application doesn't support work-sharing, which means only one user can work with the model at the time. (29.)

Allplan was developed by Nemetschek Group in 1984. It is a thoroughly parametric rule-based modelling software with a lot of automation and it can cope with complex geometry. Application uses 2D drawings, 3D models, and then combines 2D and 3D elements in a project structure that facilitates creation of combined 2D and 3D information. Allplan is considered as a complex application and MEP system modelling requires a third party application. (1, p. 65.)

ArchiCAD is the oldest BIM application for architectural design and it was development by Graphisoft in the early 1980's. Application's user interface is well-crafted and is easy to use. It has large object libraries and objects can be customized. ArchiCAD supports all phases of architectural design work except fabrication detailing. (1, p. 66.)

Bentley Systems offers an extensive library of products for engineering, architecture, constructor, and infrastructure. Application offers broad range of BIM tools which also allow modelling in complex curved surfaces. Since Bentley's product ranges are partially integrated at user interface levels and the data consistency, it takes time to navigate and learn the application. Application is a

major player in the infrastructure, civil engineering and plan marketplace. (1, p. 68.)

Tekla Structures is a Finnish object-oriented 3D-modeling software by Tekla Corp. The application supports projects entire lifecycle and allows 4D- and 5D-modelling. Tekla Structures is a Windows based application and it is designed as a design aid to model wood, steel and concrete designing. The application supports collaboration work and allows multiple users to work with the same model at the same time. (1, p. 73.)

4 CONCLUSION

This thesis examines Revit as a MEP system-design software with and without MagiCAD extension. The thesis was executed by comparing Revit MEP and MagiCAD for Revit applications by familiarisation with the applications in practise and in theory. Information obtained was then compared with current AutoCAD design software and way of working. Also the suitability of Common BIM Requirements for Revit based designing was examined.

No obstacle for Revit's commissioning as a BIM software was found. The importance of co-operation between fields stands up when BIM process is examined. Information models improve observation of designs essentially but it requires that everyone's models are up to date and available. Revit's commissioning requires comprehensive training for employees and the biggest differences between Revit and AutoCAD are outside the design work itself. Creating views and managing them can cause difficulties at the beginning and using Revit to its whole potential will take time. The software offers good tools for creating 3D objects and drawing system schematics was proven easy. Also the need of multiple project files is removed which increases the performance of working and lowers the risk of human error. Revit without the MagiCAD extension was proven unusable when it came to design work. The lack of a tool that makes balancing a system possible made the software useless since it is a crucial part of system design. Also Revit's tool for making material and device lists was proven unsuitable for company's needs.

In general, MagiCAD for Revit's commissioning was proven functional. With the MagiCAD application HVAC design work with Revit can be done quicker and more efficient when compared with AutoCAD. Bringing BIM into a part of an everyday HVAC design work is a significant improvement and especially with bigger projects the benefits can be monumental. It was noticed that if a user is already familiar with MagiCAD for AutoCAD, the learning process for actual design work is easier. Comprehensive training is still essential for overall software use.

Before employees can start working with Revit, templates and datasets have to be created. Since Revit uses different file forms than AutoCAD, product libraries made for it cannot be used in Revit. The process, to a point where design work can be started, would be time consuming and would need expertise from employees from different fields. Also all company-specific features that are currently been used in AutoCAD have to be reprogrammed into Revit. This would require close co-operation between project management, designers and IT-department.

Undoubtedly designing support and hanger systems is going to play a bigger part in HVAC design in the future and MagiCAD Support and Hangers extension is a considerable option for doing that. This would notably increase the workload for designers and it would be important to take the “support and hanger” designing into account in project’s cost estimate. Expansion should be examined more closely in the future to get a better a better view of its features.

The cost of a Revit license is approximately one and a half times that of an AutoCAD license which means bigger software costs. Also a MagiCAD license is needed and a “Support and Hangers” extension license if proven necessary. In addition to actual employee training costs, it is necessary to estimate the time that it takes for an employee to be as efficient with Revit as with AutoCAD. During this time more hours have to be budgeted for design work. In Finland, where Revit is not generally taught to HVAC engineers in colleges and universities and is not widely used among design companies, the knowledge of the software is still weak. This leads to a possibility that majority of new employees have to be trained to use Revit along with company’s other working methods. Switching to Revit doesn’t exclude the need of AutoCAD since older projects, designed using AutoCAD have to be supported as in the case where a client needs modifications or additional corrective actions to these designs. Even though transferring to Revit adds costs in the beginning, the opportunities it offers for more efficient way of working makes it a competitive option for MEP system-design.

No defects were found when BIM Requirements 2012 publication was examined considering Revit based design work. The only default found was that IFC-export by Revit does not meet the requirements of information content set by COBIM. IFC-export by MagiCAD met the requirements.

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