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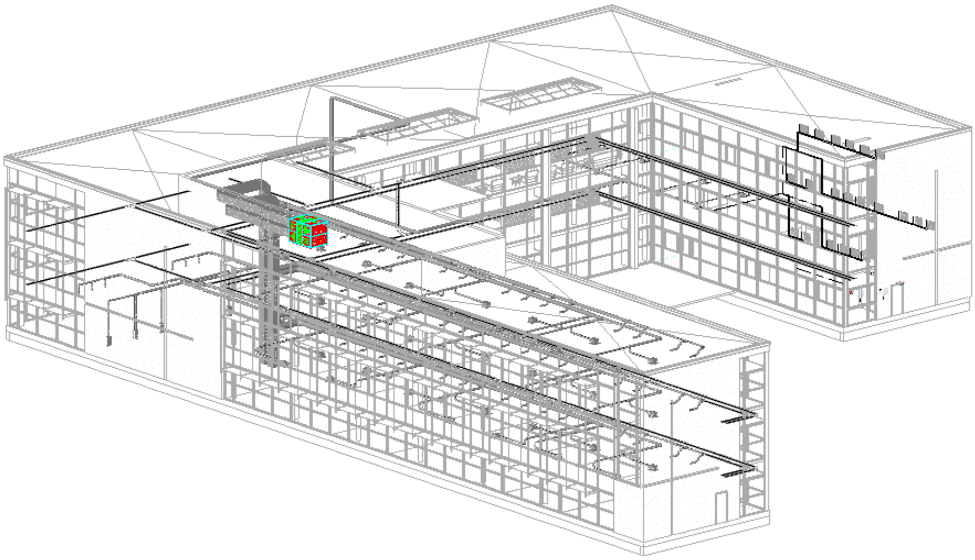

Computer Based Tools in the HVAC Design Process

Interface and data transfer between modeling in Revit and supporting draw- and simulation tools (especially with focus on handling geometries and information-/data transfer)

Master of Science Thesis in the Master's Programme Structural Engineering and Building Performance Design

JONAS SANDBERG

Department of Energy and Environment Building Services Engineering
Division of Energy and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2011
Report No. 2011:01

MASTER'S THESIS 2011: 01

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Chalmers tekniska högskola 2011:01

Department of Energy and Environment Building Services Engineering
Division of Energy and Environment
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31 – 772 1000

Cover:
Picture extracted from Revit MEP 2011, 2011-01-18.

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ABSTRACT

The purpose with the thesis is to examine the link between modeling in Revit with other drawing programs and simulation tools and to examine the possibilities and limitations for transferring data between the different program modules, i.e. which data transfer between the programs is possible. Revit MEP 2011 will be in focus and along with the purpose above a sub-purpose will be to explore and evaluate the internal features of Revit MEP 2011 and by this Revit MEP will be evaluated to which extent it can benefit to rationalize the HVAC design process.

In order to approach the concept of BIM there is a need to gather information from third party software's. The ideal scenario is that this information can be utilized by Revit, in such way information will not have to be re-defined repetitiously throughout the building process.

Revit is a relatively new program which can be compared to AutoCad, in the case for Revit though, the manufacturer claims that the program should be more user-friendly in the matter of utilizing previously defined information. Based on this, the possibilities are good for the actors in the building industry to make their operation more effective, not only regarding time and economy but also the easement in communication between different actors in the process.

The result of the analysis is that at the present date there are few third party software's that are integrated with Revit MEP on a two-way basis. The model created in Revit can be exported to most software's in some way, but in most cases this is where the loop of information stops. This means that if the original Revit model is revised then a new export has to be performed. Some software's have a tight integration with Revit though, such as the Autodesk Solar Radiation Technology Preview. This is a good example of how information exchange and update should run, with information exchange on a two-way basis and where the revised model also is updated in the external software, although the actual usage of the software can be questioned.

Regarding Revit MEP 2011 as a tool in the HVAC design process, the analyze shows that it performs well or more than well on most areas except for simulations and calculations of the energy. The calculation method is simplified and the calculation procedure is hidden for the user. This combination reduces the use of Revit MEP 2011 as a tool for the performance of simulations and calculations regarding energy, which constitutes a significant part of the HVAC design process. Nonetheless, the fact that MagiCad is integrated in Revit MEP as an "add-in" makes it a powerful tool in the HVAC design process as all the features of MagiCad is possessed in combination with the BIM approached mode of operation that Revit enables.

Key words: Revit MEP 2011, energy calculation, energy simulation, HVAC design process, information transfer, geometry and object information transfer, heating and cooling loads

Datorbaserade verktyg i VVS-projekteringen
Gränssnitt och informationsflöde mellan modellerande i Revit och biträdande rit- och simuleringsverktyg (speciellt fokus på hantering av geometrier och data-/ informationsöverföring)
Examensarbete inom Structural Engineering and Building Performance Design

JONAS SANDBERG
Institutionen för Energi och Miljö
Avdelningen för installationsteknik
Chalmers tekniska högskola

SAMMANFATTNING

Syftet med detta examensarbete är att undersöka kopplingen mellan modellerande i Revit med andra rit- och simuleringsprogram samt att undersöka möjligheterna och begränsningarna för överföring av information programmen emellan. Revit MEP 2011 står i fokus och utöver syftet beskrivet ovan är det sekundära syftet att undersöka och utvärdera de interna funktioner som finns i Revit MEP 2011 och på basis av detta utvärdera på vilket sätt Revit MEP 2011 kan bidra till att rationalisera VVS-projekteringen.

Ett steg i ledet för att byggbranschen ska kunna närma sig BIM konceptet är att möjliggöra att information från tredjepartsprogram effektivt kan förskansas. Det ideala scenariot är att denna information kan utnyttjas av Revit för att på så sätt slippa behovet av att upprepa inmatningsprocessen av information fortlöpande genom hela byggprocessen.

Revit är ett relativt nytt program som kan jämföras med AutoCad, i fallet för Revit så påstår dock tillverkaren att programmet ska vara mer användarvänligt när det gäller förskansning av tidigare definierad information. Baserat på denna information så borde det alltså finnas stora möjligheter för de olika aktörerna i byggindustrin att effektivisera sin verksamhet, inte bara tids- och kostnadsmässigt utan även i kommunikationen aktörer emellan.

Resultatet av undersökningen är att det i dagens läge är få tredjepartsprogram som är integrerade med Revit, framförallt på en tvåvägs basis. Modellen som skapas i Revit kan i de flesta fall på något sätt exporteras till de flesta program, dock så slutar allt som oftast informationsloopen just här. Detta innebär att om original modellen i Revit uppdateras så måste en ny export utföras. Det finns dock program med en tajt integration med Revit, ett sådant exempel är Autodesks Solar Radiation Technology Preview. Detta program statuerar gott exempel på hur utbyte och uppdatering av information borde fortlöpa, med ett informationsutbyte enligt två-vägsprincipen och där en ändring i Revit modellen även uppdateras i det externa programmet, dock kan den faktiska nyttan av programmet i sig diskuteras.

Rörande Revit MEP 2011 som ett verktyg i VVS-projekteringen så visar undersökningen att Revit MEP 2011 presterar bra eller mycket bra i de flesta aspekter förutom när det gäller simulering och beräkning av energi. Beräkningsmetoden som används är i förenklad och även beräkningsproceduren är för användaren dold. Denna kombination reducerar användbarheten hos Revit MEP 2011 som ett verktyg när det gäller utförandet av energiberäkningar och energisimuleringar, vilka utgör en markant del i VVS-projekteringen. Trots detta, det faktum att MagiCad är integrerat i Revit MEP som en ”add-in” gör Revit MEP till ett kraftfullt verktyg i VVS-projekteringsprocessen eftersom alla MagiCad:s funktioner blir tillgängliga i kombination med det BIM anpassade arbetssätt som Revit medför.

Nyckelord: Revit MEP 2011, energiberäkning, energisimulering, VVS-projektering, informationsöverföring, överföring av geometrier och objektsinformation, värme- och kyllaster

CONTENTS

PREFACE

This master's thesis, performed as a part of the Msc programme Structural Engineering and Building Performance Design has been conducted at Bengt Dahlgren AB in Göteborg from September 2010 to January 2011.

This project has been carried out after an initiative from Roland Magnusson, Bengt Dahlgren AB. The company's supervisor has been Roland Magnusson and Max Tillberg. Jan Gustén at the Department of Energy and Environment Building Services Engineering, Chalmers University of Technology has also been supervising the project. AEC AB has been a support during the project, especially Håkan Wikemar.

First and foremost I would like to thank these people but I would also like to thank the rest of the staff at Bengt Dahlgren AB who have been supportive during the project, especially Malin Knoop, Mattias Torberntsson and Jan-Olof Johansson.

Göteborg, January 2011

Jonas Sandberg

1 INTRODUCTION

1.1 Background

The building industry in Sweden has for the latest years been dominated by AutoCad as a tool for conveying building project related documents and by this handle the communication between different phases in the building process.

There is still a need to gather and adapt information from other programs (third party) and from other parts in the building process. In other words, a big part of the possibility to gather and use previously defined information lacks, which means that pre-defined information has to be re-defined in different steps.

Revit is a relatively new program which can be compared to AutoCad, in the case for Revit though, the manufacturer claims that the program should be more user-friendly in the matter stated in above paragraph. Based on this, the possibilities are good for the actors in the building industry to make their operation more effective, not only regarding time and economy but also the easement in communication between different actors in the process.

1.2 Purpose

The building industry has not yet fully adopted Revit as a tool to replace AutoCad since it still is relatively unexplored, specifically Revit MEP is a rather unexplored tool on Swedish territory.

The purpose with the thesis is to examine the link between modeling in Revit with other drawing programs such as AutoCad and simulation tools and to examine the possibilities and limitations for transferring data between the different program modules, i.e. which data transfer between the programs is possible. Along with this also the internal features of Revit MEP will be explored and by this Revit MEP will be evaluated according to its beneficial in the HVAC design process.

1.3 Scope

The scope of the master's thesis concerns investigating the capability of Revit MEP, not focusing on solving the problems which will be discovered. Information transfer between Revit MEP and relevant third party software's will be analyzed.

1.4 Method

First of all exploring the structure of Revit MEP and how it is used in the HVAC design process. The gathering of information is carried out by conversations with people informed about the subject, either by telephone, mail or meetings, support from program support competence and corporate promoter will be taken advantage of. Specialist literature and internet are other sources for the gathering of information and foremost personal analyses of the relevant software's.

My tutors at Bengt Dahlgren AB have guided me in the selection of which software's that is of relevance to analyze.

1.5 Organization

Building Services Engineering

Examiner: Ass Prof. Jan Gustén

The Master's thesis has been performed at:

Bengt Dahlgren AB

With support from:

AEC AB

2 FUNDAMENTAL STRUCTURE

One of the purposes of this report is to investigate and clarify the capability level of Revit as a tool to achieve BIM in the HVAC design process. The HVAC design process is not a linear procedure, it is an iterative process where a lot of information is handled, calculations and simulations are performed, specification lists are put together etc. The investigation consists of two major routines; what can be done internally inside Revit and which additional external sources are relevant to fulfill the purpose. To visualize the circuit of involved parts and to highlight critical stages a sort of "mind-map" image strategy is used in the report, this will be further explained later on. This chapter is strictly theoretical and intends to clarify involved stages and formulate the issues encountered in each stage. First of all, the core of the subject and the intention with Revit is described.

2.1 BIM – Building Information Modeling

Building Information Modeling is a relatively new concept even if the whole idea of what BIM describes goes further back in time. The main purpose with BIM is to ease and rationalize the building process. In general, BIM is a method for the building industry to produce, communicate and handle building related information. The ideal scenario is to let a database store all relevant information to which all involved actors can "log-on" and collect, add or revise information, see Figure 1. The modification will automatically make impact throughout the database structure with simultaneously updates. (Graphisoft)

The concept of BIM though does not end with "the last nail being in place", the idea is that the BIM-model will continue to live-on parallel to the specific project also during the utility phase as a database with the ability to store, add and collect relevant information such as maintenance, climate control, economy etc., see owners part in Figure 1. (d'Elia, 2010)

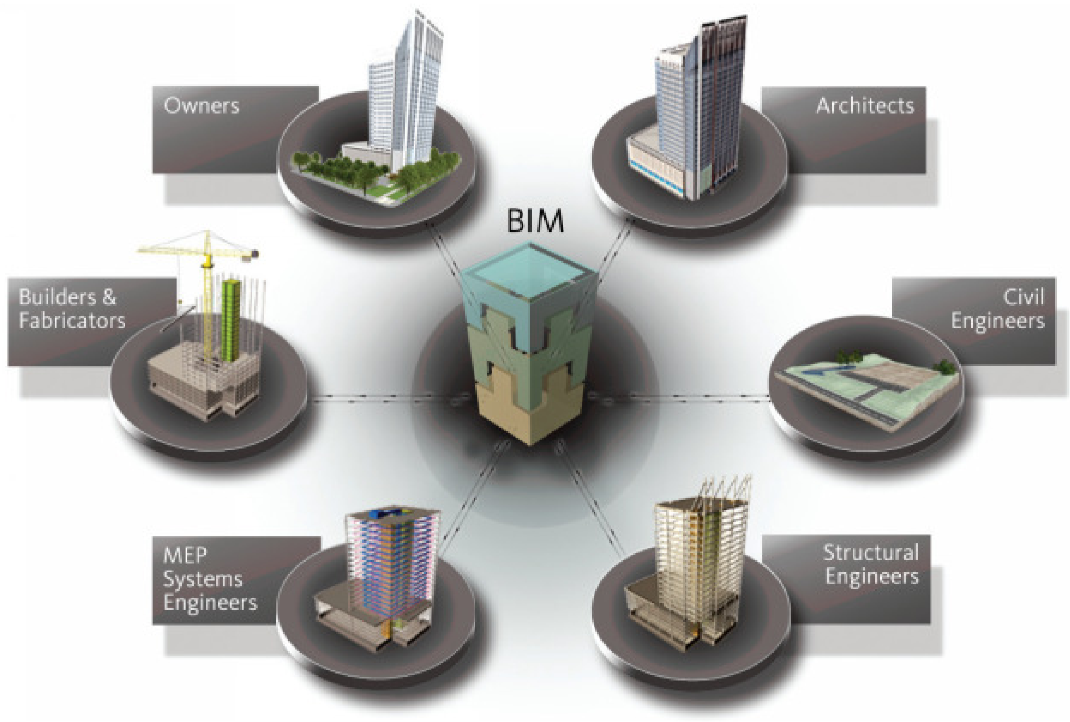


Figure 1 ***the BIM-database in the centre which different actors can "log-on" to. (Autodesk)***

Although the BIM concept at the present time is accepted by most parts in the building industry and regarded as the future appliance, there are issues which have to be dealt with. Essential is to embrace, learn and adapt to the technique suited for BIM. However, one main challenge will be to evolve a mode of operation for mutual managing of information in the BIM-models, both globally between different actors and on an internal basis. (d'Elia, 2010)

Internally, issues like information transfer between different formats and software's is of major concern when adopting BIM, issues this report will focus on.

2.2 Revit as a tool for BIM

Revit is a tool developed explicitly to meet the demands of the BIM concept. A peak at the origin of the title itself, *Revise Instantly,* reveals the purpose and main advantage with the software. The intention is to reflect the non-linear process in an actual building project, from early conceptual idea and via more established structures, in the end being able to present a thorough virtual building. This is a process composed by numerous modifications, major and minor decisions, revisions and specifications etc. (d'Elia, 2010)

The key feature with Revit is the database structure it is made up of, which allows "intelligent modeling" from the very beginning. This means that each object is assigned information such as identity (wall, column, floor etc.), content (material, specific details etc.) and location (position, thickness, height etc.)

The Revit package consists of three industry specific editions; Revit Architecture, Revit Structure and Revit MEP (Mechanical, Electrical and Plumbing), see Figure 2. Each edition custom made to benefit the respective business. This report will treat the Revit MEP edition.

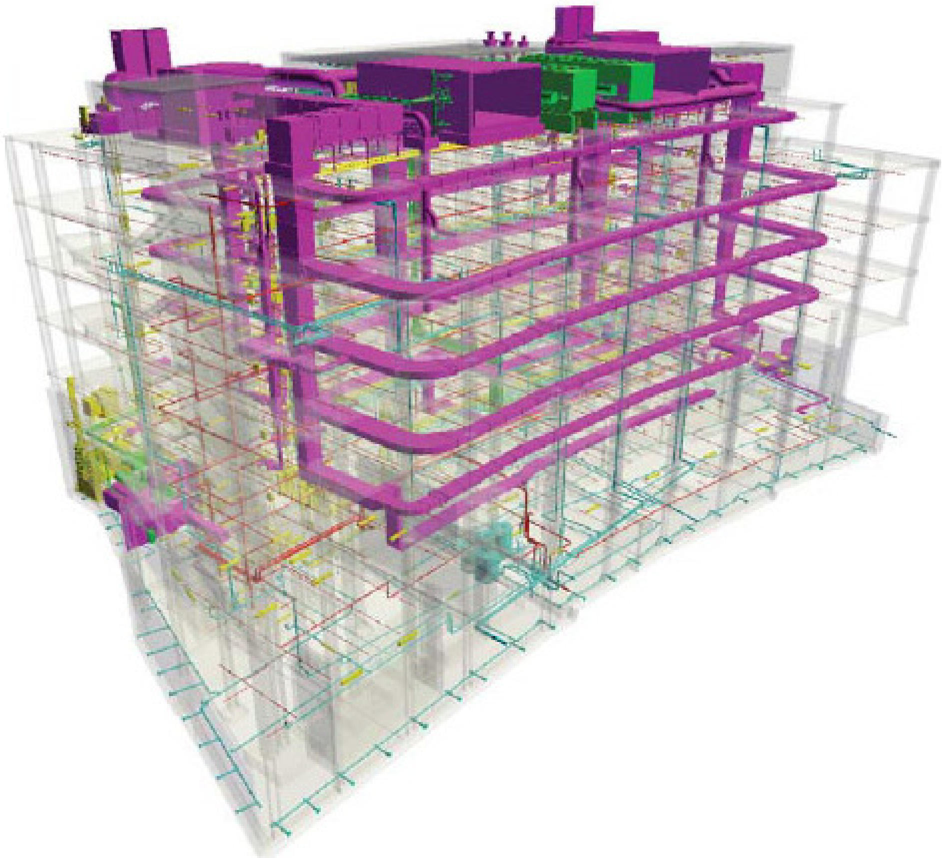


Figure 2 an example of the capability with Revit MEP. (AEC Bytes)

2.3 Inventory of relevant stages

As mentioned before, an HVAC design process consists of a lot of steps and iterations. There is a need in this report to define the workflow and the different involved parts in such a process and how Revit contributes to this process and collaborates with others involved. This relationship is visualized in Figure 3. Figure 3 solely presents the involved stages theoretically, with a preliminary connection to Revit. The actual appearance and behaviour of this network is yet to be seen and the main item to investigate. Note the green area around the Revit box, further on in this report the green area in figures will symbolize stages that are dealt with internally in Revit.

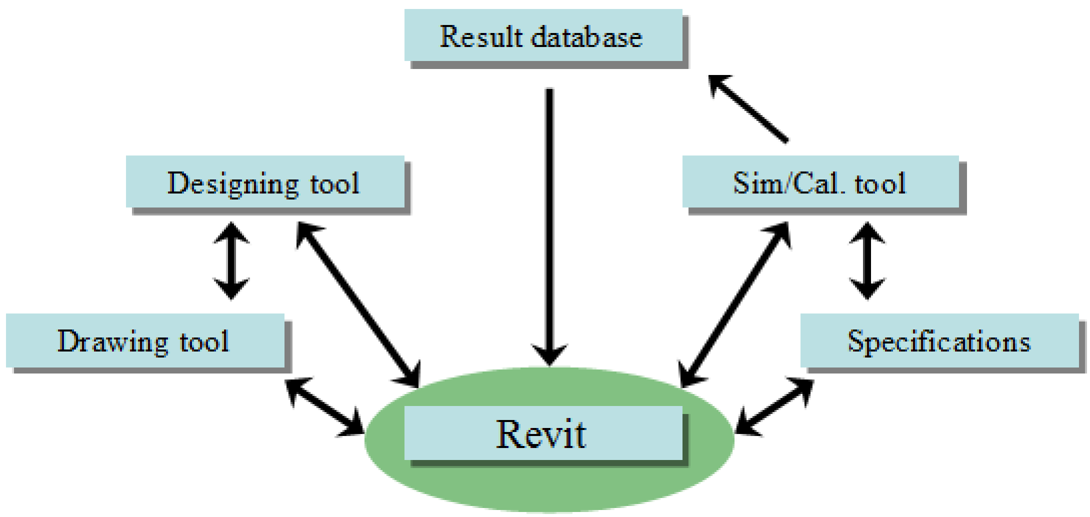


Figure 3 Overview of different stages in the HVAC design process and the connection to Revit. (by author)

According to the "green area" philosophy introduced above, Figure 4 presents an ideal workflow where all the stages are carried out internally in Revit, due to different standards or platforms for the management of information it is desirable to stick to the same application throughout the process. In present time this scenario is somewhat of a utopia though.

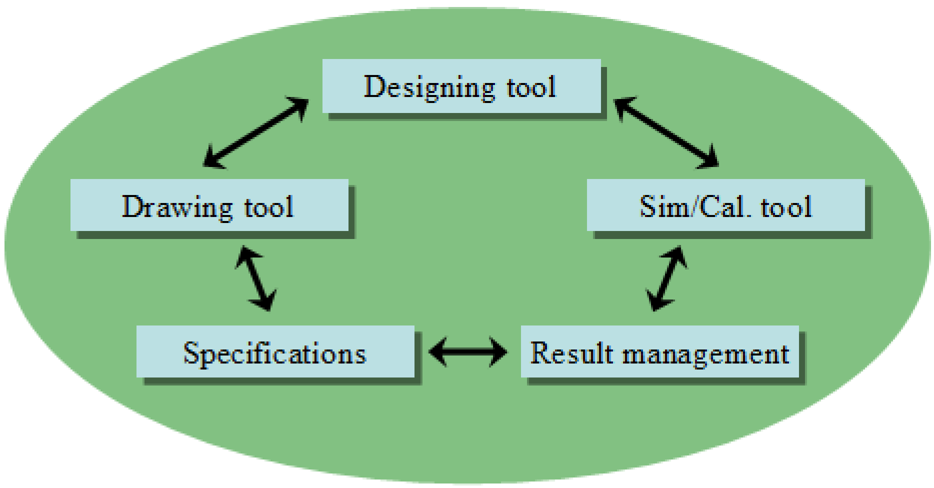


Figure 4 an ideal scenario where all the stages are integrated and performed internally within Revit. (by author)

If Figure 3 and Figure 4 are regarded as two extremities where all the information is respectively handled externally versus internally, the most realistic scenario will probably be somewhere in between. This means some stages will be possible to perform within Revit and for other stages export of information to third party software's will be necessary. When exporting information to third party software there will in many cases be issues with the transfer, both departing and arriving information. Described next are the different stages:

2.3.1 Modeling tool

This is simply the tool used for the basic modeling and geometry management. Since the feature not only exists internally in Revit, it is also highly developed, the obvious choice is to perform the modeling within Revit.

The overall ideal workflow, from architect to constructor to HVAC, is when all involved actors use Revit as their respective platform. In such cases the information transfer is carried out smoothly.

However, there are cases when the preparative modeling is performed outside Revit and passed on to the HVAC-constructor. In this case an import into Revit is necessary.

Possible issues in this stage are;

- Clashes between different file formats
- Geometry management

2.3.2 Designing tool

Early in the HVAC design process decisions are being made which affects the work routine further on in the project. Practically, this is the phase where the product establishment is performed; air-handlers, air diffusers, ducts etc. are pinpointed. This can either be done internally by Revit or by external software. Due to model modification and that more accurate calculations are demanded in different stages of a project etc. this is a repetitive procedure and it is important to distinguish which phase is in progress when designing.

The sizing procedure is another basic work piece which is lodged in this phase.

Remaining features which fall within the framework of this headline are clash control of ducts and pipes and the construction of PI-diagrams.

Possible issues in this stage are;

- Imperfect features which deliver inadequate outcome.

2.3.3 Simulation/Calculation tool

The simulation and calculation stage is a major part in the HVAC design process. Areas of interest are heating and cooling, energy, lighting, sound, pressure etc.

Possible issues in this stage are;

- Clashes between different file formats
- Geometry management
- Result management
- Calculation methods

2.3.4 Result management

The result management is of great importance in the practical use of Revit. Interesting parts to investigate here is mainly where and in which form the results are stored, i.e. is it possible to store the result in Revit and more important, is it possible to make use of the result in further calculations or presentations.

The ideal scenario is that Revit is capable to apprehend results generated from various simulation or calculation programs and being able to actually utilize the results for further use in the HVAC design process.

Possible issues in this stage are;

- Clashes between different file formats
- Access to the results from Revit

2.3.5 Specifications

This is the final part in the HVAC design process, it treats the compilation in Revit of such things as product specifications, material lists, blueprints, comments etc.

The ideal scenario in this case is that these tasks are being operated "automatically" by Revit as a sequel of the establishments made in the designing phase. Also when modifications are performed in the model, the specifications should automatically update, and vice versa.

Possible issues in this stage are;

- Imperfect features which deliver inadequate outcome..

2.4 Format clashes

In a building project with a variety of actors and disciplines it is common that not all involved possess similar software platforms, which significantly complicates mutual sharing of information within the project. In these cases export via neutral file formats is an acceptable, if not necessary, solution. For this specific task the file format IFC will be inspected in this report.

2.4.1 IFC

The IFC (Industry Foundation Classes) file format is an object oriented, open and neutral file format developed by the International Alliance for Interoperability (IAI) in order to ease the interoperability in the building industry and thereby move towards the concept of BIM. In cases when information needs to be shared between actors but their respectively internal software prevents a traditional export/import, the procedure of transferring information can be handled by the IFC file format.

The theoretic capability of IFC is vast and may appear as the solution for achieving interoperability between repelling software platforms. In practice though, depending on the complexity of the project, the procedure and the result of the procedure is in many cases far from ideal. If focus in this case is on geometry and object data transfer than obviously the most satisfactorily outcome of the transfer is when 100 percent of the information in the model of interest "survives" the transfer. Unfortunately, for more complex models this is not the case at the present time.

Regarding information transfer using IFC it is essential to be aware of what the file format is capable and not capable of transferring. With this awareness one must determine which information that is essential and to what extent the lack of transferred information affect the outcome and if this loss is acceptable, for each specific task.

2.4.2 Navisworks

Navisworks is a tool which focus on project synchronizing between disciplines, in a three dimensional environment. It enables overall clash detection of the entire project, regardless of diverging software platforms throughout the design phase.

Since IFC has limited capacity, when exporting a Revit model as IFC, an interpretation of the original model is performed into a model which suits the IFC file format. This means that information in the original model which IFC can not handle will simply be deleted or transformed in some way.

In more complex models it can be a difficult task to sort out what information that differs from the original model after an IFC export. There are alternative ways to sort this out though, either by looking into the IFC source code or by a more convenient approach, which is to review the IFC model in Navisworks. A test is performed with the purpose of comparing original Revit model, see Figure 5, with the exported IFC model, see Figure 6.

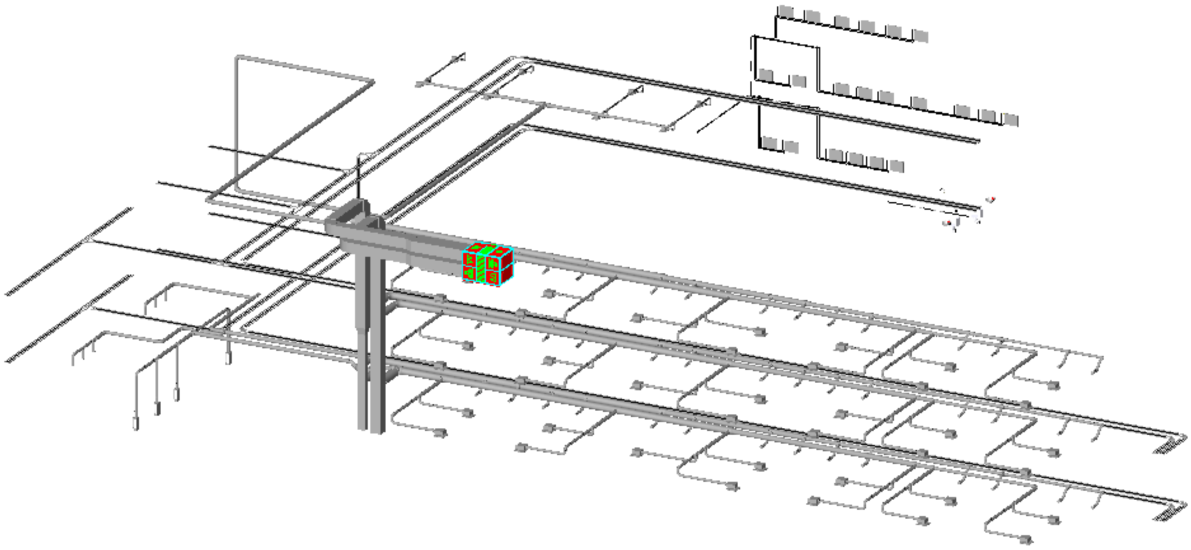


Figure 5 the original HVAC model created in Revit MEP. This model also contains the piping and electricity disciplines. (picture extracted from Revit MEP 2011)

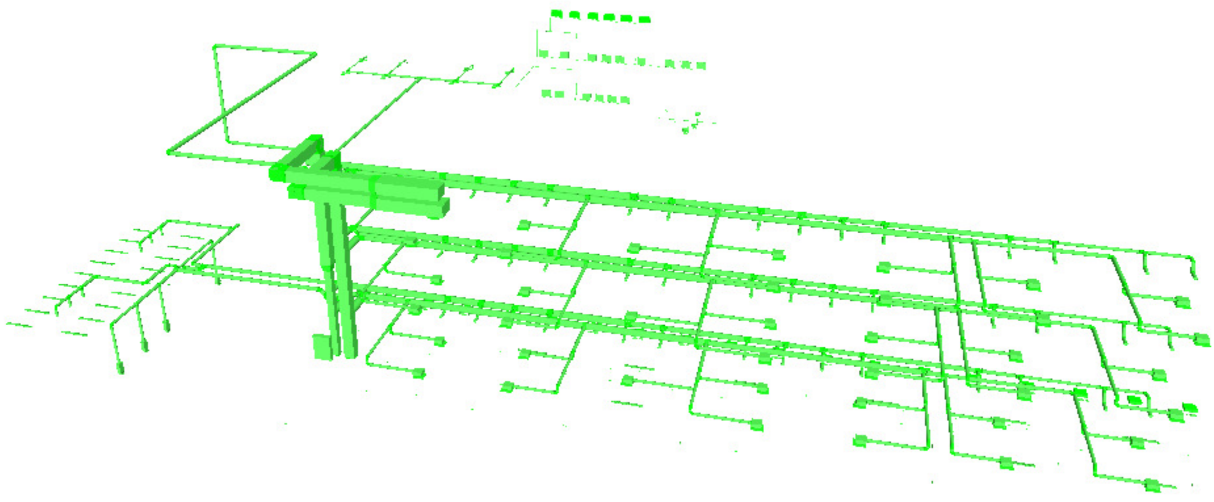


Figure 6 the IFC file viewed in Navisworks. (picture extracted from Navisworks)

When comparing the two models, at first appearance they may look alike. When comparing the system browser in Revit with the corresponding feature in Navisworks, the selection tree, it shows that all the vital parts of the ventilation system are correctly transferred such as duct systems, diffusers etc. Obvious parts that did not “survive” the transformation to the IFC standard are the air-handling unit and the cable ladders, which reveals when comparing Figure 5 and Figure 6. On the other hand there are objects that did not show in Revit which is visible in Navisworks. This can be explained as a combination of the current view used in Revit (see Figure 7) and the settings in the IFC export options in the Revit menu, see Figure 8.

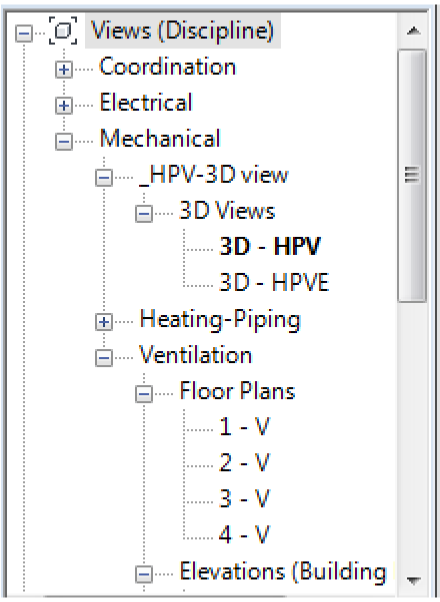


Figure 7 the current view in Revit to be exported, in this case the HPV view. (picture extracted from Revit MEP 2011)

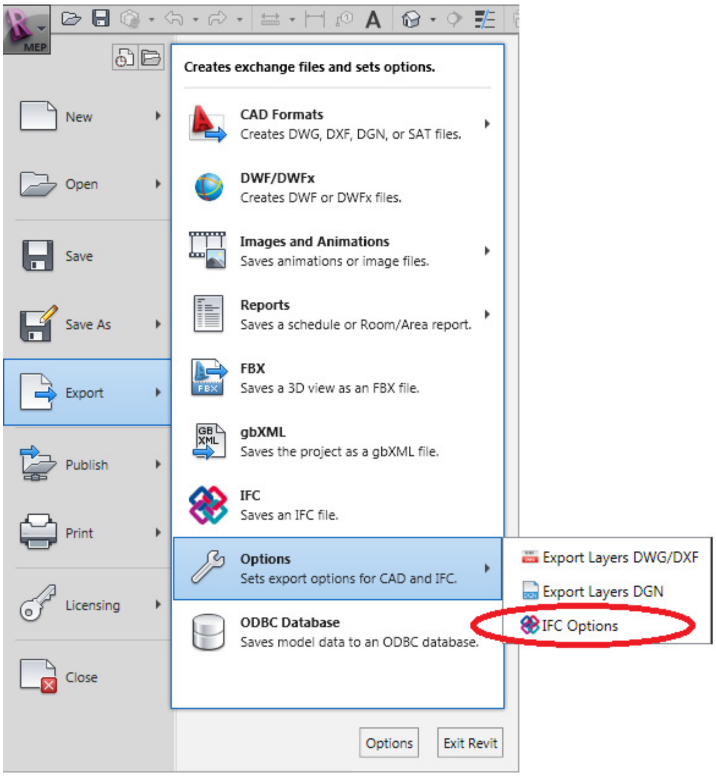


Figure 8 the tool in Revit for managing which objects to be included or excluded in the IFC export. (picture extracted from Revit MEP 2011)

It is not only the geometry that is transferred correctly between the formats, also the object properties follows. For example a diffuser, information such as name, off-set data, flow characteristics, system belonging and more shows in Navisworks and hence "survives" the transfer.

With this test as reference the IFC file format seem capable of transferring most HVAC equipment, not only the geometry relationship but also the actual object information. However, the problem seems to be more extensive for the architect and structural disciplines where IFC is not so good at handling more complex structures. (Johannes Dursun[1])

The key to succeed with the IFC export is basically a question of exporting the right view in Revit together with the appropriate IFC export settings in order to achieve a tolerable IFC model. In addition to this an appropriate measure to take is to consider which information that is of relevance for each specific transfer. So, creating an IFC export adapted to its purpose is not always an easy task, it requires some manual management in combination with knowledge of the tools and processes involved.

[1] Johannes Dursun, Sweco AB. The reference refers to the Master's Thesis "BIM projektering med Autodesk Revit – Samarbete mellan olika discipliner" by Johannes Dursun. The conclusions in Johannes Master's Thesis is based on software's of 2010

3 Local structure

As chapter two introduced the overall structure of this report in a global perspective this chapter provides a more thorough and local insight in each step in the process described in chapter two.

The idea is that this chapter presents the possible relationships in each step, investigates the actual procedure and the issues described, for a bunch of software's and finally defines obstacles and possibilities.

Each step is summed up in a similar network image as those presented in chapter two.

3.1 Modeling tool

Regarding the modeling tools, the focus of this report lies entirely on the relationship between Revit and the AutoCad-platform.

- Revit
- AutoCad

In this case three main work flow scenarios exists, either the modeling is performed exclusively within Revit or information/geometry is imported from the AutoCad platform to Revit or the other way around, the overall possible relationship between these is shown in Figure 9.

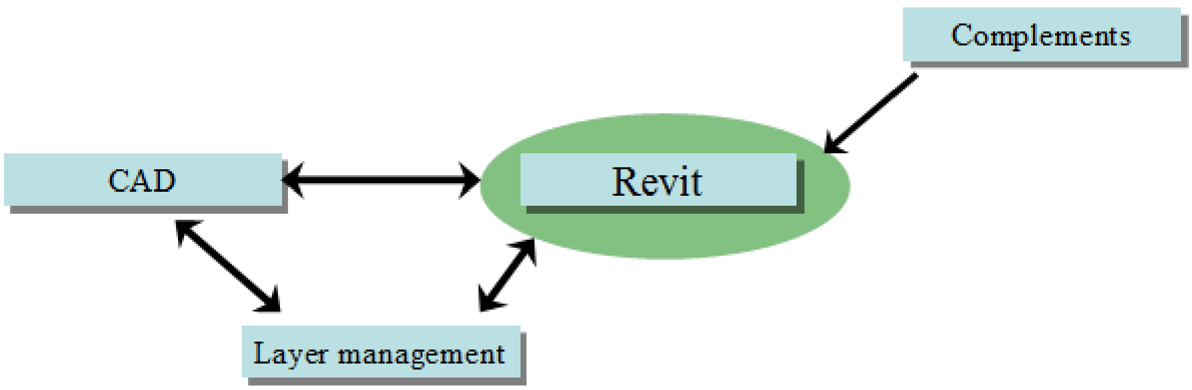


Figure 9 Overall possible relationship between modeling tools. (by author)

The three alternative routines are defined as follows;

- Revit
- Import to Revit from AutoCad
- Export from Revit to AutoCad

Revit

Since Revit itself, with its database structure and object definition modeling, is a powerful modeling tool the preferable work practice is of course when all the modeling is performed internally within Revit.

Import to Revit from AutoCad

Theoretically this procedure should not cause any problem. However it is only pure geometry, without any "intelligence", that is imported to Revit, see Figure 10.

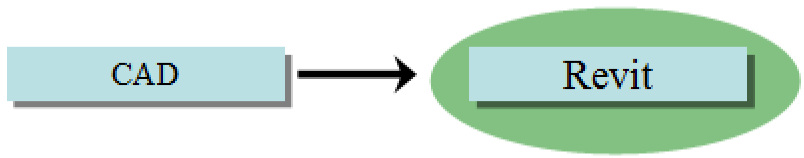


Figure 10 theoretical procedure when importing from CAD to Revit. (by author)

However, if there are several DWG files, each representing one floor of a building, the procedure when attaching these to Revit with the purpose to form a 3D model requires some manual labour. The different 2D floor plans are imported as vector data and placed as empty shells in the corresponding position in Revit. From here manual modeling, such as interior walls etc., is required in order to achieve a connective 3D model. (Fredrik Berg[2])

The procedure described above is summarized in Figure 11.

[2] Fredrik Berg, Building/Technical Chief at CityData Future CAD in Sweden AB, contact by e-mail 2010-10-26.

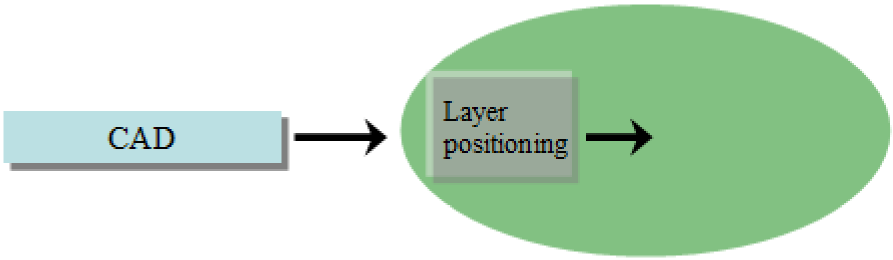


Figure 11 the practical procedure when importing from CAD into Revit, where the green area indicates what is treated internally within Revit. (by author)

Export from Revit to AutoCad

Data transfer in this direction is possible, although not without some editing. There is a conflict between the object based environment in Revit and the layer structure in the CAD formats. In order to transform the objects into layers some editing is needed in the "Layers and properties" tag in Revit before the export. This is one amongst other settings that can be accessed when choosing to export to CAD format, see Figure 12.

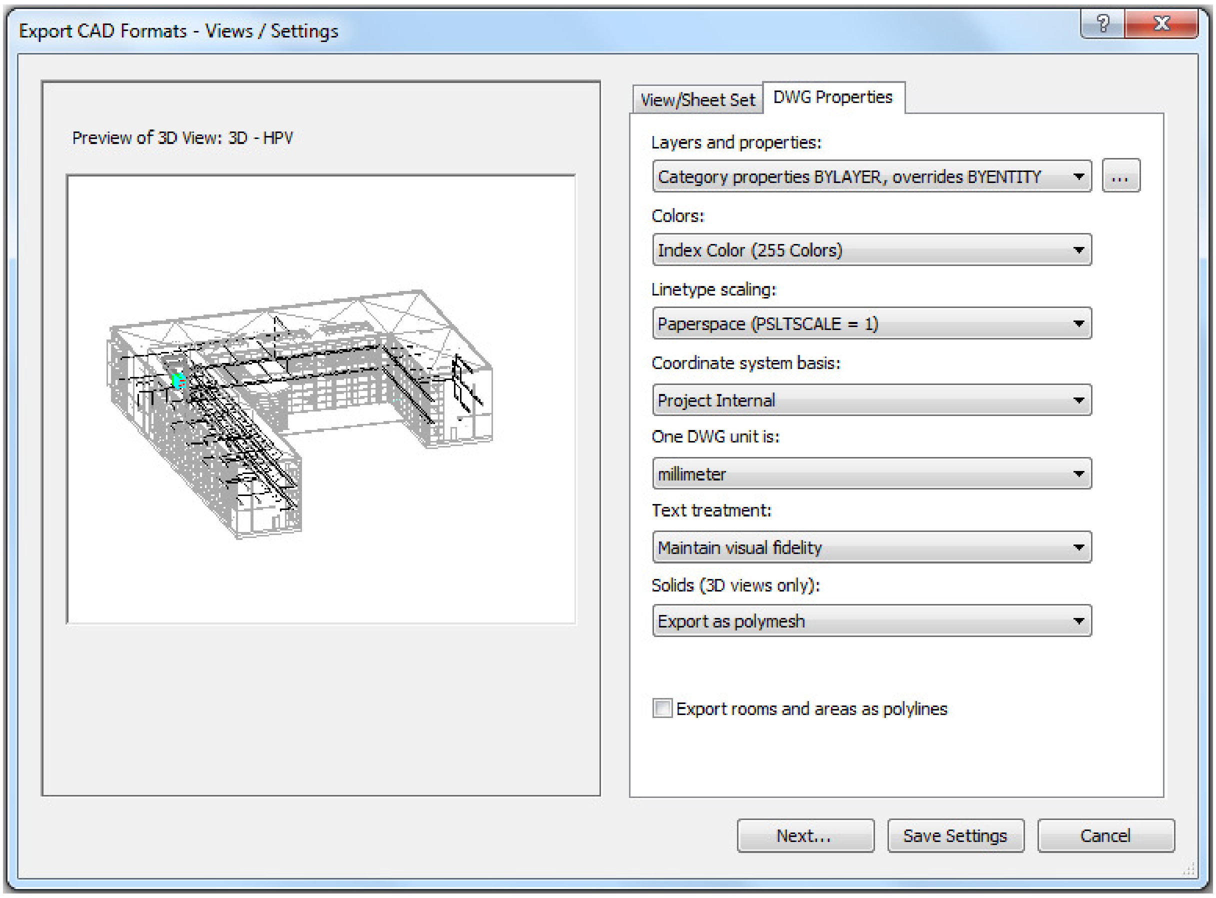
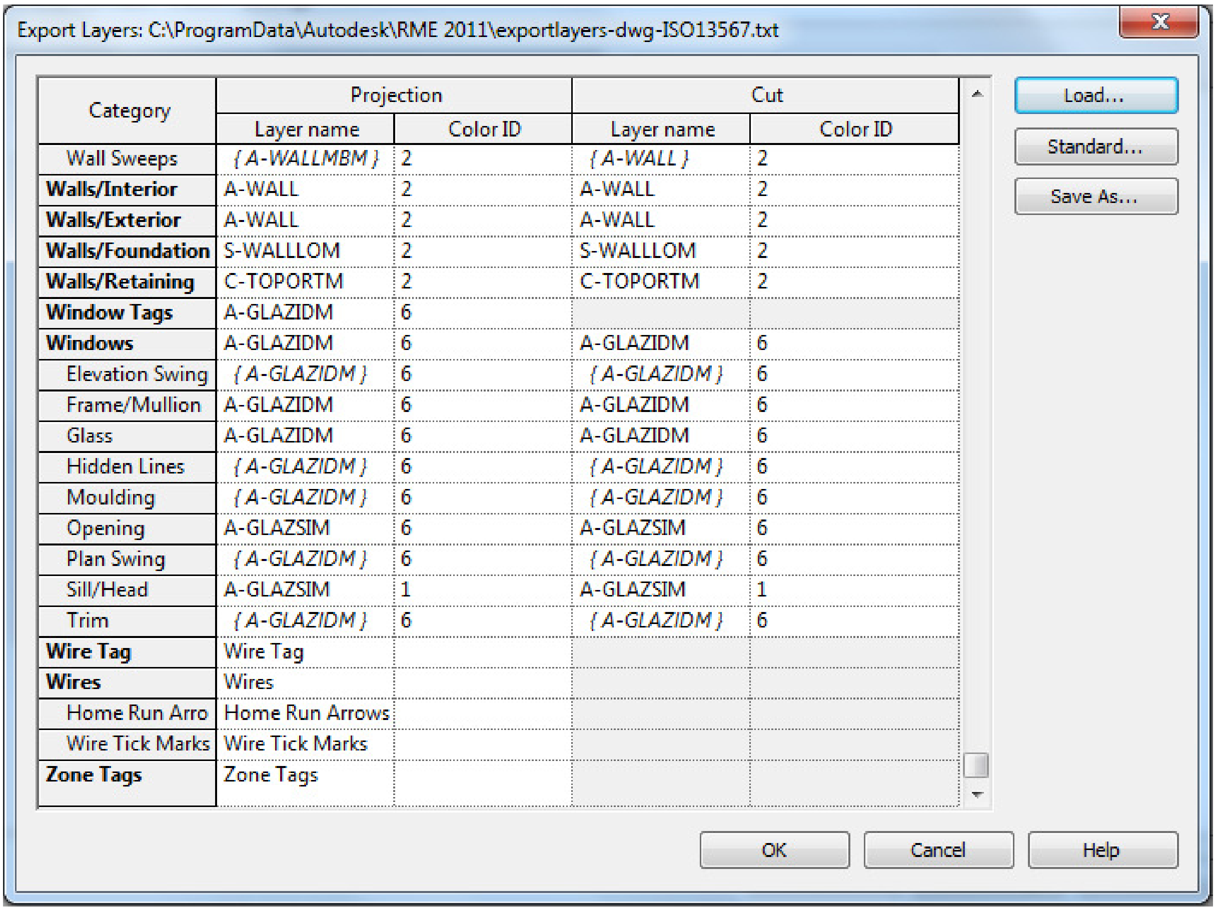


Figure 12 before export is executed some preparations are needed, in this case it is export to the DWG format. (picture extracted from Revit MEP 2011)

The transformation from object to layer is done in a preconfigured text file which maps each Revit category to a layer name, see Figure 13. For example, a door object in Revit will be mapped as A-DOOR layer in AutoCad. Each object is assigned to a layer name with a corresponding figure, which defines the colour of the layer, see Figure 13. Although the text file is preconfigured one can manually adapt it to meet the individual desire.


Export Layers: C:\ProgramData\Autodesk\RME 2011\exportlayers-dwg-ISO13567.txt

Category	Projection		Cut	
	Layer name	Color ID	Layer name	Color ID
Wall Sweeps	*{ A-WALLMBM }*	2	*{ A-WALL }*	2
Walls/Interior	A-WALL	2	A-WALL	2
Walls/Exterior	A-WALL	2	A-WALL	2
Walls/Foundation	S-WALLLOM	2	S-WALLLOM	2
Walls/Retaining	C-TOPORTM	2	C-TOPORTM	2
Window Tags	A-GLAZIDM	6		
Windows	A-GLAZIDM	6	A-GLAZIDM	6
Elevation Swing	*{ A-GLAZIDM }*	6	*{ A-GLAZIDM }*	6
Frame/Mullion	A-GLAZIDM	6	A-GLAZIDM	6
Glass	A-GLAZIDM	6	A-GLAZIDM	6
Hidden Lines	*{ A-GLAZIDM }*	6	*{ A-GLAZIDM }*	6
Moulding	*{ A-GLAZIDM }*	6	*{ A-GLAZIDM }*	6
Opening	A-GLAZSIM	6	A-GLAZSIM	6
Plan Swing	*{ A-GLAZIDM }*	6	*{ A-GLAZIDM }*	6
Sill/Head	A-GLAZSIM	1	A-GLAZSIM	1
Trim	*{ A-GLAZIDM }*	6	*{ A-GLAZIDM }*	6
Wire Tag	Wire Tag			
Wires	Wires			
Home Run Arro	Home Run Arrows			
Wire Tick Marks	Wire Tick Marks			
Zone Tags	Zone Tags			

Load... Standard... Save As... OK Cancel Help

Figure 13 In order for Revit and CAD to communicate some editing is needed to transform the Revit objects into CAD layers with names and figures as the colour ID. (picture extracted from Revit MEP 2011)

Another issue that needs to be considered in projects when exporting from Revit to CAD is to sync the coordinate systems, see Figure 12 (coordinate system basis). There are two alternatives to regard for this specific task; *project internal* or *shared* coordinates. Which one to use depends on the roll of this specific model in the global project, either it is a stand alone project or it is linked to other models.

- **Project internal** The origin of the exported file is set to the internal coordinates of the Revit project. This option is used when the Revit project is a stand alone project not linked to other models or when the actual position is irrelevant for the task.

- **Shared** The origin (0,0,0) of the exported file is set to the shared position of the global Revit project. All geometry is here exported relative to the shared coordinates. This option is used when the wish is to maintain the specific position of the project being exported. (Revit MEP User Assistance)

The procedure described above is summarized in the network in Figure 14.

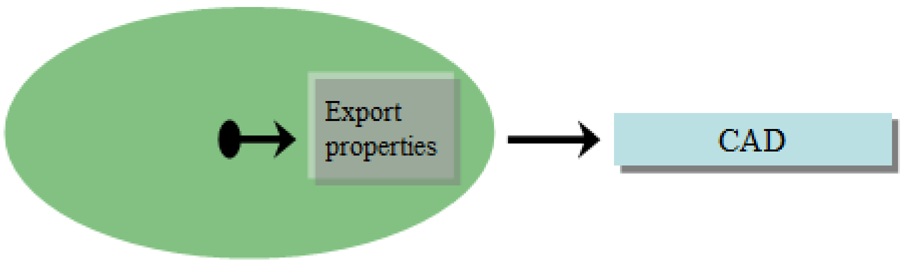


Figure 14 the practical procedure when exporting from Revit to CAD, where the green area indicates what is treated internally within Revit. (by author)

3.2 Designing tool

The definition of a designing tool in this case is not obvious, it is a transient concept with different implications for different phases in a building project. As mentioned in chapter two it is a repetitive procedure due to model modifications and varying level of accuracy in calculations and simulations. It is important to clarify that the designing tools regarded here are either implemented in Revit or such that Revit can benefit from, it is not in a global view where Revit itself as a total very likely can be regarded as a designing tool.

The definitions of designing tools in this report are as follows;

- PI-diagrams (*principscheman*)
- Choice of products
- Sizing
- Clash control

3.2.1 PI-diagrams

PI-diagrams are simple schematics performed in the initial stage of the HVAC project, basically consisting of simple lines. Revit is a modeling tool especially designed for 3D modeling and therefore not the best suited tool for these tasks. Although it certainly can be performed in Revit there are simply other tools better suited for these tasks, which makes Revit an unreasonable choice for this specific matter.

3.2.2 Choice of products

The choice of products is an important part of the design process, it is an iterative process where different categories of products are decided upon in different stages of the project.

There are two main areas interesting to investigate; what can be done internally within Revit and which external sources are relevant.

The routines for the choice of products are defined as;

- Internal management or integrated applications
    - Revit
    - MagiCad
- External management
    - Company based tools

Revit

The feature to internally establish and insert products within Revit is rather rationalized. In Revit there is a certain hierarchy to how products are classified, see Figure 15.

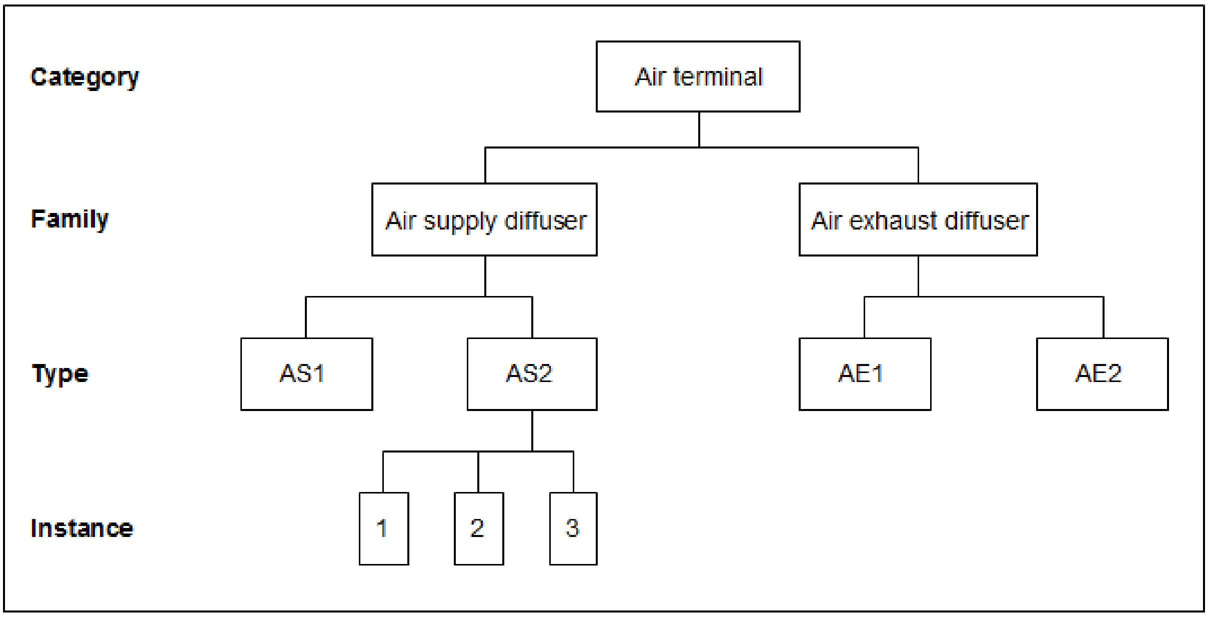


Figure 15 the information hierarchy of the Revit objects, in this case an air terminal. (picture edited by author. Original picture by d'Elia & von Knoop, 2010)

This is the basics of the object oriented structure in Revit, hence also when inserting products into the model. The hierarchy ranges from general down to a single element level of detail. A brief introduction to the components in Figure 15 follows below:

Category

A group of elements. For example doors or air terminals.

Family

Families in Revit are subordinated to categories, to stick to the example doors and air terminals comes in a variety of performances such as inner and outer doors or air supply and air exhaust diffusers.

Families play an important role in Revit. They constitute their own file format (.rfa) which enables possibilities to both create new families manually or to download from databases. One can also easily exchange families with other users. (d'Elia, 2010)

Type

Each family can vary in different types such as double and single doors or different sizes of the air diffusers.

Instance

Each specific object subsumes under instance where an air diffuser within the same family and type can vary at instance level at such things as air flows, connections and manufacturers etc. (d'Elia, 2010)

Although Revit MEP possess the "horsepower" to perform this task the feature is in present time not very adapted to the Nordic or more specific the Swedish market in such way that relevant product databases to a great deal is lacking. For now the most interesting approach is the MagiCad application in Revit.

MagiCad

MagiCad is an AutoCad application that uses its own object classes for installation objects. It is developed exclusively for the installation industry and unlike Revit MEP well established on the Nordic and Swedish market. MagiCad provides a comprehensive product database with specific focus on the Nordic and Swedish market. MagiCad is also integrated in Revit MEP, as an "application", see Figure 16.

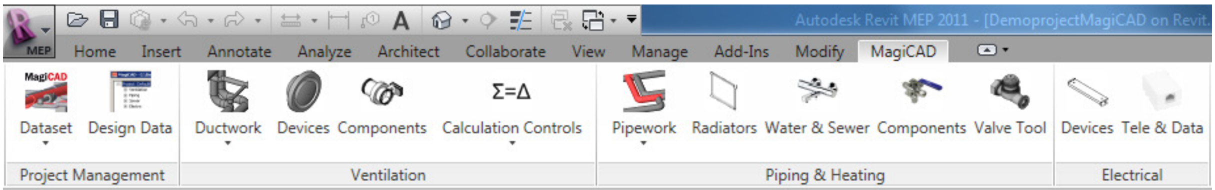


Figure 16 MagiCad as an application in Revit MEP. (picture extracted from Revit MEP 2011)

There are numerous features and calculations that can be performed in the MagiCad application in Revit MEP, these will be treated further on though. The main advantage with MagiCad integrated with Revit MEP is total access to the Nordic oriented product database, except for those manufacturers which databases are not yet upgraded to 3D.

The actual procedure when adding products into the Revit model is as good as fully integrated. The products are accessible from the menu system in Figure 16 where appropriate databases are displayed for the actual product, see Figure 17. They are delivered in 3D with the correct measures, connections and data as the real product.

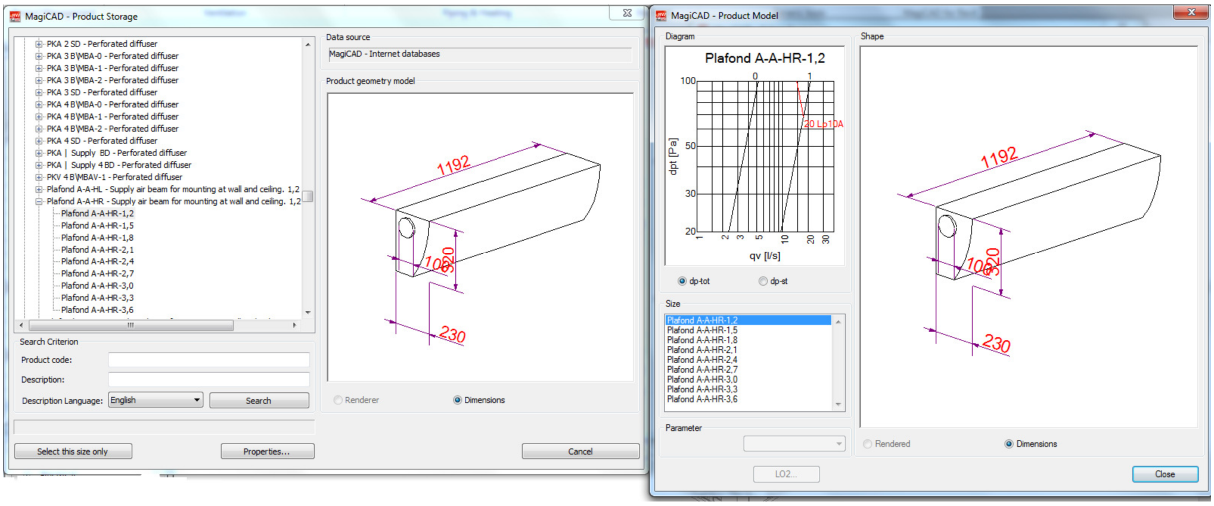


Figure 17 an example of a product from the Lindab AB product database. The left picture provides information on a family level while the right picture provides information on instance level with flow and pressure drop diagrams for the specific object. (picture extracted from Revit MEP 2011)

Regarding the product implementation when it comes to importing DWG files from MagiCad into Revit MEP it works satisfactorily, the products are imported visually and with the corresponding object information. However, the text-flags defined in MagiCad does not make it through the import process, they will have to be redefined in Revit. (David Malmgren[3]). Text-flags are the labels, or naming, of the specific objects in the model.

What is stated above is valid for the ventilation application, applications which handles this for the heating and piping and for electricity parts will be released respectively in December 2010 and May 2011. (David Malmgren, 2010-10-28)

The preferable procedure when adding products to the Revit MEP model is summarized in Figure 18.

[3] David Malmgren, Chief Executive at CADCOM AB, personal communication by telephone 2010-10-28.

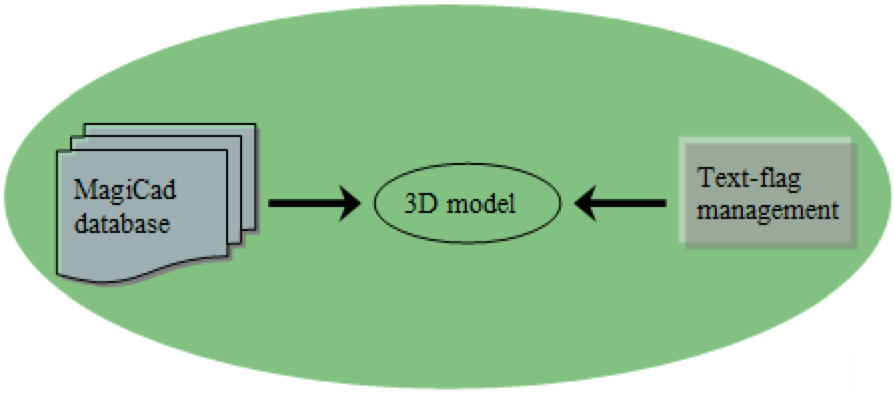


Figure 18 **the preferable procedure when adding products to the Revit MEP 3D model. In this case by the use of MagiCad. The text-flag management is only necessary if a dwg file is imported into Revit MEP. (by author)**

Company based tools

Although MagiCad offers an extensive product database it does not provide air-handling units, which is an essential part in a ventilation system. The traditional practice when choosing air-handling units is to access custom made software's developed by prescribed manufacturer. The routine is to make the appropriate settings which in the end results in an air-handling unit which is imported into the CAD program as a dxf file. This dxf file, which is supported by Revit, consists of pure geometry, a box with the correct measures, no intelligence accompanies though, see Figure 19. To import the air-handling unit to Revit MEP choose the "import CAD" button in the Revit menu, then choose import dxf. Make the appropriate settings, such as unit of measurement and scaling and the air-handling unit is imported into Revit as a 3D object, see Figure 19.

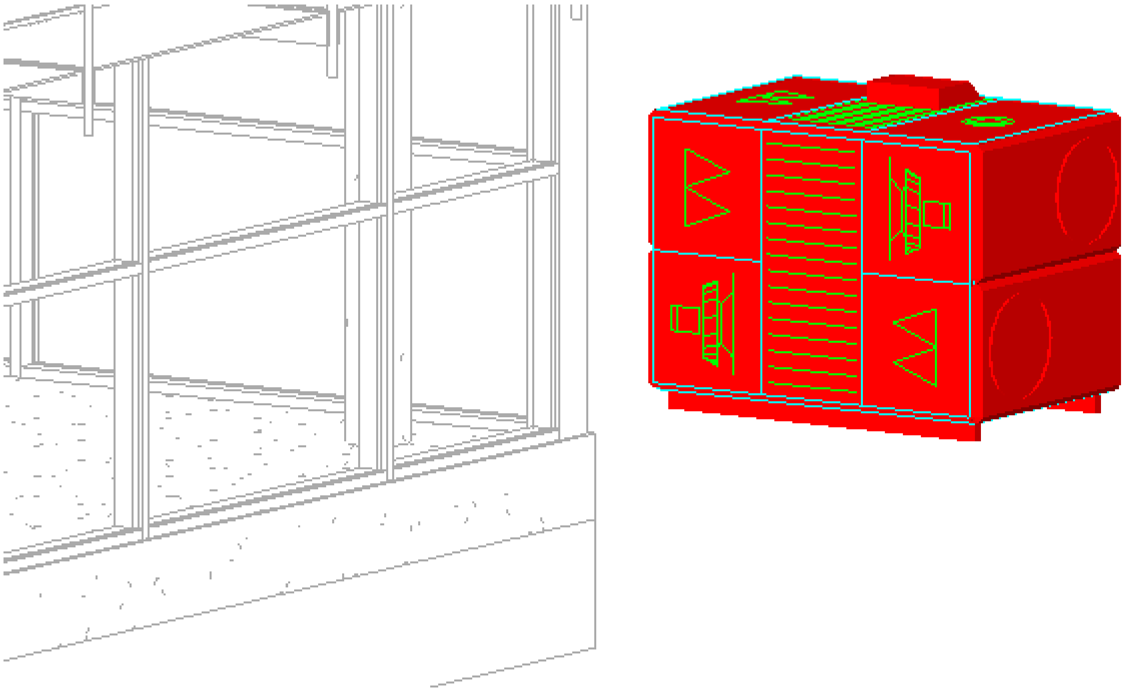


Figure 19 an air handling unit produced in a manufacturer developed software, imported into Revit as a dxf file. (picture extracted from Revit MEP 2011)

The statement about the air-handling unit being imported as a non-intelligent object is true in most cases, however, Swegon offers a plug-in called ProUnit in MagiCad which also delivers information such as sound data and duct connections etc. In the present time such a plug-in does not exist for Revit but an investigation is in progress with the intention to sort out if this is possible. (Camilla Pettersson[4])

Another actor on the market is CadVent, a similar tool as and a contestant to MagiCad. CadVent lack all sort of compatibility with Revit though, except for their product database. (Kai Bingström[5])

I have not discovered any other software's developed by manufacturers (on the Nordic market), such as dimensioning, comfort, silencer programs etc. that are compatible with Revit.

3.2.3 Sizing

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[4] Camilla Pettersson, Swegon AB, personal communication by telephone 2010-10-29.

[5] Kai Bingström, Lindab AB, personal communication by telephone 2010-10-29.

As mentioned in the previous paragraph, software's for this purpose developed by manufacturers are not compatible with Revit. However there is a sizing feature integrated within Revit MEP well worth a closer look.

In Revit MEP, dynamic sizing can be performed on selected sections or on entire systems. There are liberties regarding the choice of sizing method. From a drop-down menu the following standard calculation methods reveals, see Figure 20;

- Friction
- Velocity
- Equal friction
- Static regain

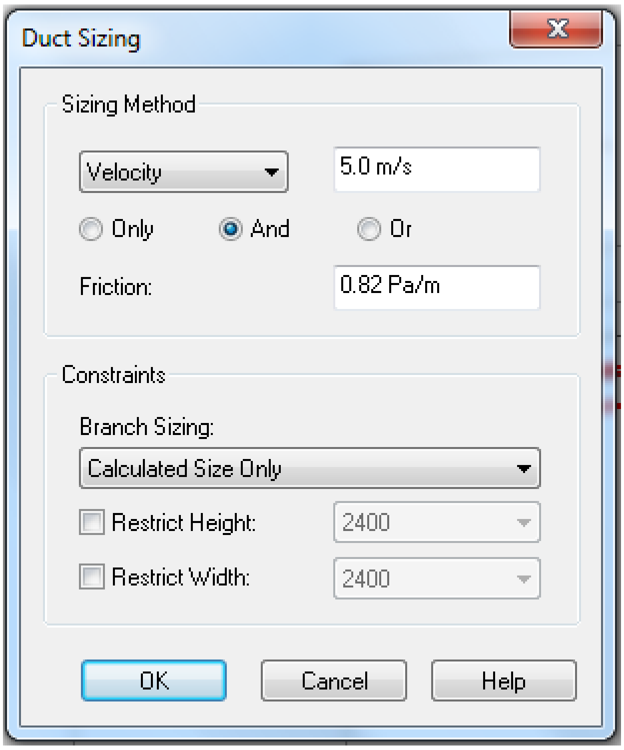

Figure 20 the available choices and settings when sizing ducts in Revit MEP. (picture extracted from Revit MEP 2011)

When either the friction or the velocity alternative is chosen, additional alternatives are electable which makes it possible to combine these two, see Figure 20;

- Only
- And

- Or

These options enables logical combinations of the two methods, where the sizing can be based on the parameters for one of the methods exclusively (only) or to force the ducts to meet the specified parameters for both the velocity and the friction (and) or to size the ducts to the least restrictive of the two (or), see Figure 21 and Figure 22. (Revit MEP User assistance)

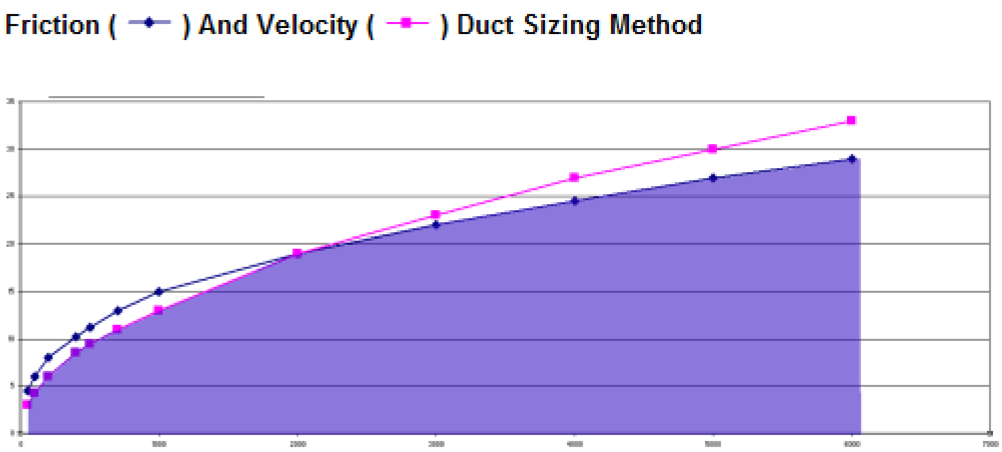

Figure 21 the diagram shows the analogy when both the friction and the velocity boundaries are complied. (Revit MEP User Assistance)

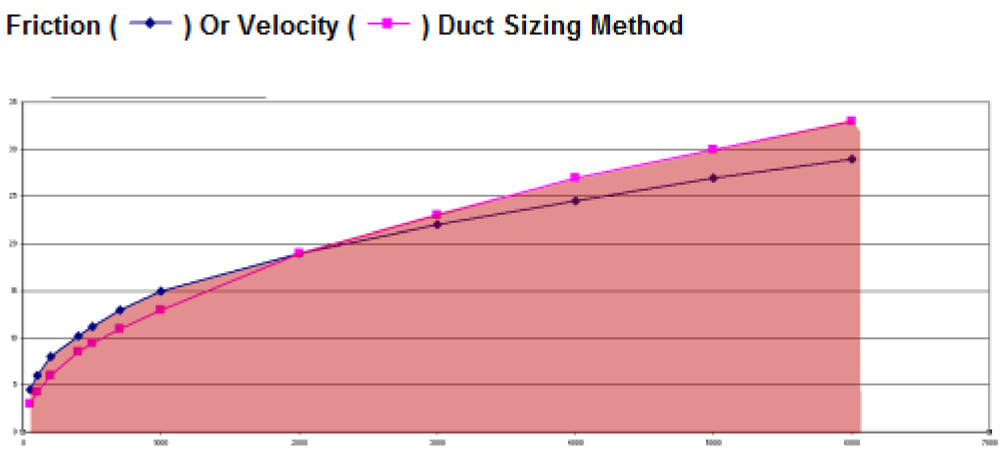

Figure 22 the diagram shows the analogy when either the friction or the velocity boundary are complied. (Revit MEP User Assistance)

The remaining calculation methods, “equal friction” and “static regain” estimates the duct sizes based on the ASHRAE Duct Fitting Database, which holds information about losses for a great amount of duct fittings. (Revit MEP User assistance)

In excess of the calculation methods some restraints to the sizing are possible which specifies absolute limits for the size of the ducts, see Figure 20;

- Calculated size only

    the size of the duct is only constrained by the selected calculation method.

- Match connector size

    the size of the duct is determined by the size of the connector used between the branch and the main, up until the first junction.

- Larger of connector and calculated

    if the calculated size is smaller than the connector size than the duct size will be adapted to the connector size. If the calculated size is bigger than the connector size than the calculated size is used. (d'Elia, 2010)

Furthermore one can restrict the height and the width by specifying maximum measures for the selected ducts, see Figure 20. (d'Elia, 2010)

Above, the theoretic content of the sizing feature is described, in practice however it is not a flawless procedure. Research reveals obvious issues with the feature. A questionnaire[6] concerning the duct sizing feature in Revit MEP 2011 is made up of the following questions;

1. *Does the duct sizing feature in Revit MEP 2011 work satisfactorily,*
2. *Is it reliable,*
3. *Which are the main hang-ups*

This questionnaire was responded by Joel Londenberg[7], as follows (quoting):

" 1. No.

2. No.

3. The biggest issue seems to be that it is inconsistent in APPLYING the correct size. Often I've set the sizing criteria and used it to adjust the size of a run - then the next run the size does not adjust. No error message, no feedback of any sort - just no change to the duct size. This inconsistent behaviour has consistently been in effect from the release of Revit Systems through Revit MEP 2011."

---

[6] Questionnaire created by author and published on the Augi Forum.

[7] Joel Londenberg, BIM manager at ACH Mechanical Contractors Inc.

This seems to be a consistent issue with the feature and a draw-back in functionality. This detail should be subject for development.

The MagiCad application in Revit MEP also contains a sizing feature. It is the same feature as in the stand alone MagiCad version, although some improvements are made in the Revit application; logical displaying of errors is one of them which in the result report (see Figure 23), highlight the objects which does not fulfil the criteria. This eases the scrutiny procedure. (David Malmgren, 2010-10-29)

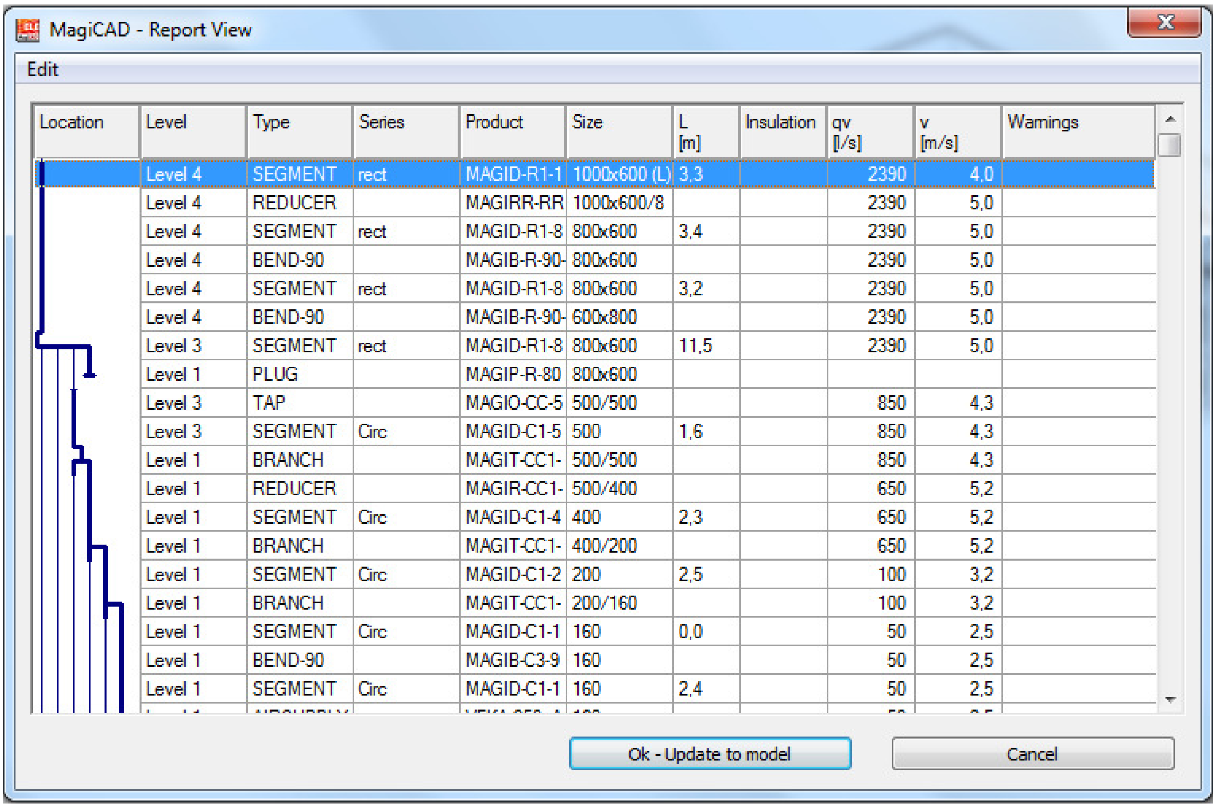

Figure 23 the result report of the duct sizing in the MagiCad application in Revit MEP. (picture extracted from Revit MEP 2011)

Also pressure drop and sound calculations are possible to perform in the MagiCad application. In order to generate reliable results, one criterion when using either of these features, including the sizing, is that all of the products in the section of interest are defined by the MagiCad product database. (David Malmgren, 2010-10-29)

3.2.4 Clash detection

A major advantage with the synchronized three dimensional mode of operation is the eased procedure of clash detection, both internally and between different actors. Revit MEP possesses this feature as well, with the option to scan either current model or linked-in models from other disciplines.

The approach for this specific task in Revit MEP is to run the interference check, which is a part of the collaboration feature, see Figure 24.

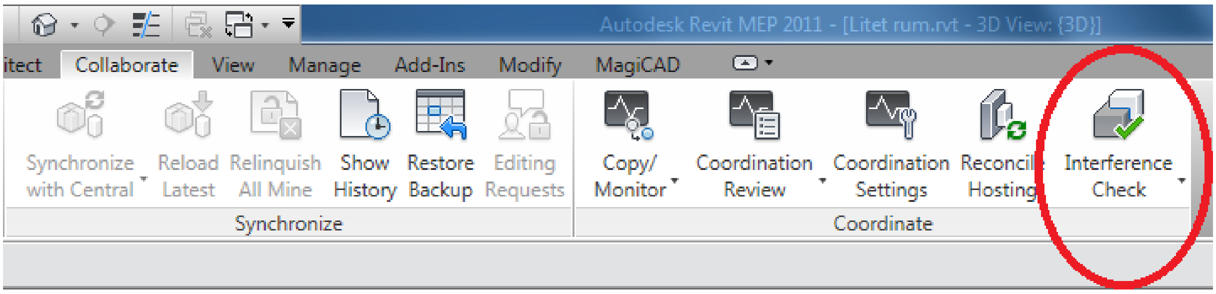

Figure 24 the location of the clash detection feature in Revit MEP 2011. It is found in the collaborate tag. (picture extracted from Revit MEP 2011)

In large models the interference check can be quite comprehensive, especially when scanning several disciplines simultaneously. In order to speed-up the process one can manually select which elements that is of interest to review, see Figure 25.

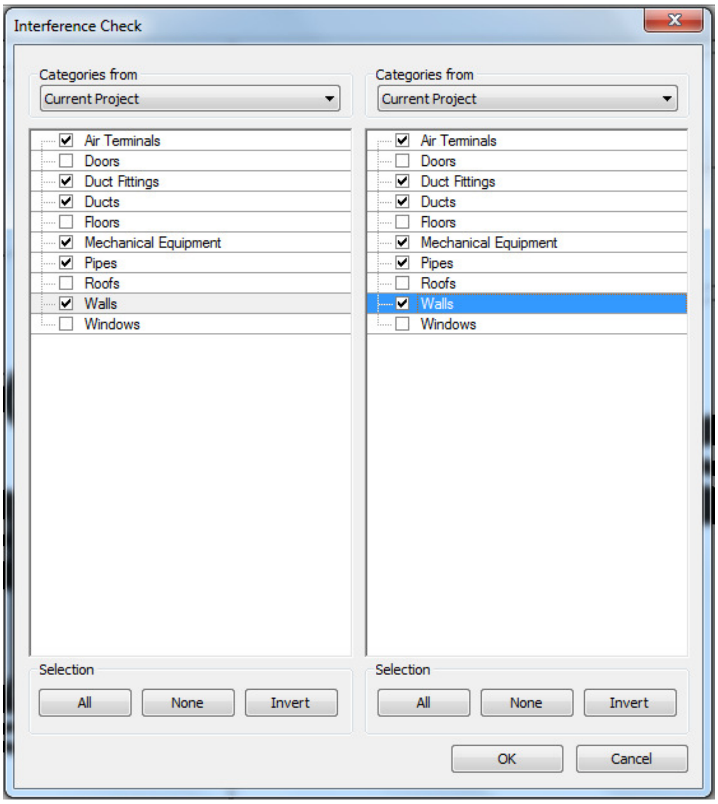

Figure 25 In order to speed up the interference check procedure the element selection is manual. There is also the alternative to select all. (picture extracted from Revit MEP 2011)

Revit alerts the user in case of clashes in the shape of an interference report, see Figure 26 , which lists all the occurred interferences. One can choose to more intimately view specific clashes by clicking them in the report, Revit then highlights the selected part in the model, see Figure 26. Which view in Revit the interference is examined in is also adaptable.

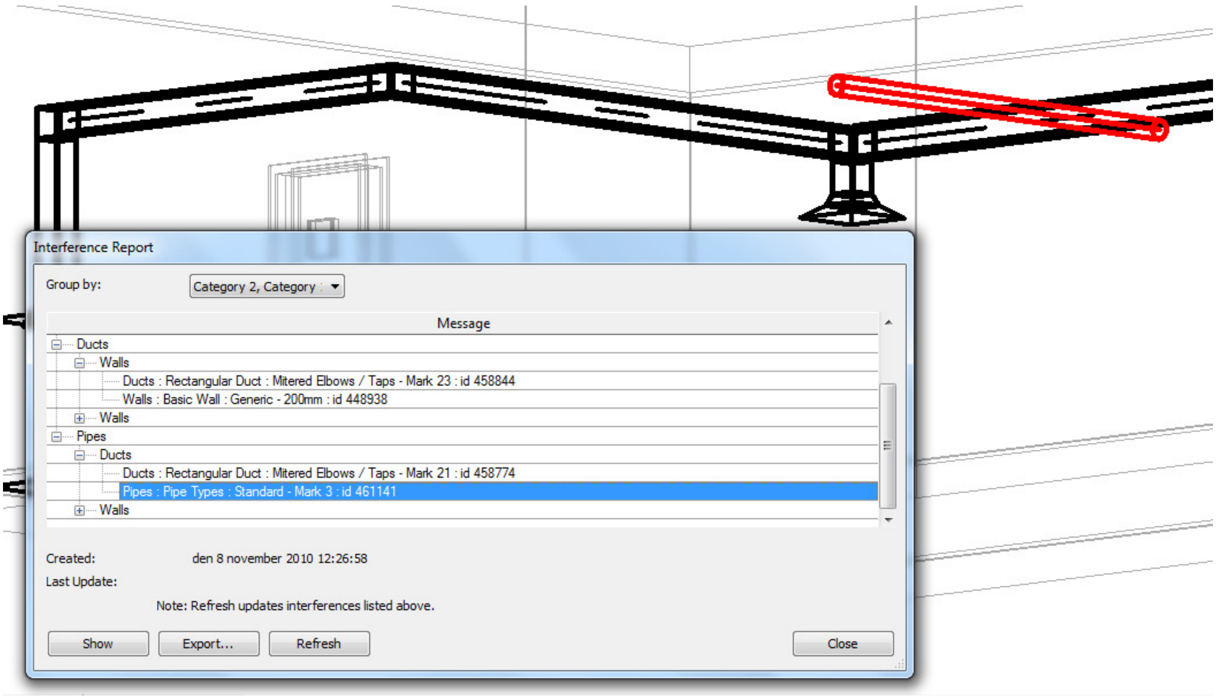

Figure 26 the result of the interference check is the interference report which lists the occurred clashes. By selecting a specific interference it is highlighted in the model, see the pipe marked as red in the background. (picture extracted from Revit MEP 2011)

Overall the feature works satisfactorily, it is not a totally automated process though, each interference has to be manually corrected and then revised and approved by other involved disciplines. My personal request is a tool that actively warns the user of interferences as he is modeling, retailers claim that this feature already exists in Revit MEP. Simple tests however have proved the opposite, the pipe penetrating the duct in Figure 26 is one example when this kind of active warning system was absent. A source of irritation in the tests performed is that all of the duct fittings seem to cause interference when running the check. Research shows that this is not a unique problem, the question is if it is a bug in the software or if it is due to inaccurate defined settings by the user.

Issues can occur when interference check is to be carried out between disciplines using different modeling platforms. In this case the best solution is probably to perform the clash detection in third party software which is neutral regarding file format treatment, such as Navisworks.

3.3 Simulation/Calculation tool

Regarding the analyze of simulation and calculation tools, the judgement is that software's with a theoretic relatively tight integration with Revit MEP is worth evaluating in this report. For many of the software's on the market the Revit geometry is importable, either by IFC or by other means, however this is often where the loop of information stops, i.e. no transfer of information on a two-way basis. Such software's are for example IDA Indoor Climate and Energy (IDA ICE), VIP-Energy and IES Apache. IDA ICE and VIP-Energy are very briefly treated in this chapter. This judgement is made in collaboration with Max Tillberg[8].

3.3.1 Daylight

The amount of daylight entering the building is a major part of the experienced comfort. It is of significant relevance for the health and well-being of the human kind. Science proves that daylight has a positive impact on the ability to learn and concentrate. (SP)

Windows convey daylight into the building, the amount of daylight entering the building is therefore greatly dependant on the composition of the window. The amount of glass panes, sun-protective and low emission films, sun shadings, orientation etc. are all parameters which affect the level of transmitted daylight. (SP)

In office buildings, which often suffer from heat excesses, the ideal scenario is to let as much daylight as possible enter the building and at the same time prevent the entering of the heat generated by the sun. This however is, due to the law of the physics, an unsolvable equation since light consists of heat. (Pilkington)

The amount of daylight in a room is considered as acceptable if the intensity of the illumination is sufficient and relatively anti-dazzling. In order to measure and rate the intensity of the illumination the daylight factor is introduced. The daylight factor is decided as the ratio between the exterior and the interior amount of daylight at a specific point in the room, expressed in percent. (SP)

Velux Daylight Visualizer 2

The purpose of this software is to provide a simple tool for daylight design and analysis. It generates 3D-simulations with the following simulation outputs; daylight factor, luminance and illuminance. It enables import of 3D models which in this report is the main function of interest with the program. This test origin from a 3D-model created in Revit, see Figure 27. Note that all conclusions are based on tests performed by author.

[8] Max Tillberg, Bengt Dahlgren AB.

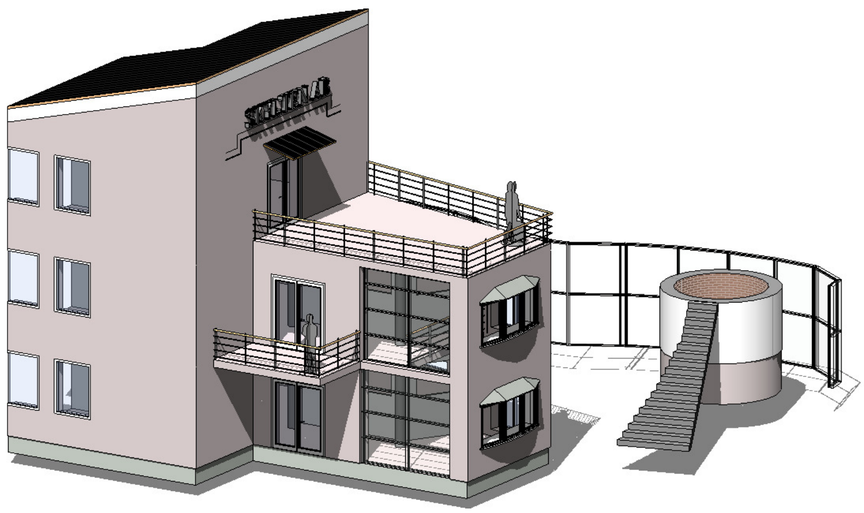

Figure 27 **3D-model created in Revit. (picture extracted from Revit MEP 2011)**

In order to get the 3D-model created in Revit into Velux Daylight Visualizer 2, the Revit model has to be exported as a dwg file format. Once imported into Velux Daylight Visualizer 2 the different objects, or construction elements, defined in Revit ends up as AutoCad layers, see Figure 28.

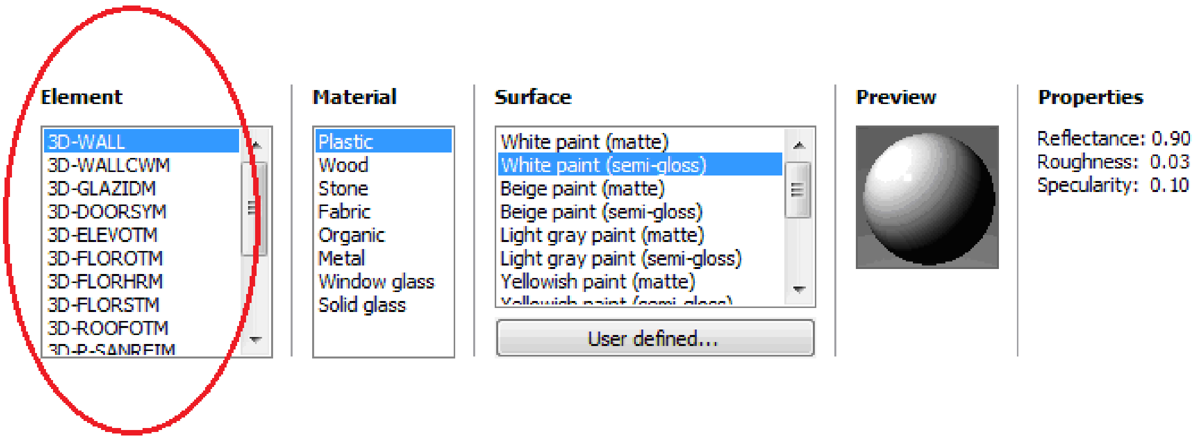

Figure 28 **Layer management in Velux Daylight Visualizer 2. (picture extracted from Velux Daylight Visualizer 2)**

Once the layers are imported they can be adjusted in regard to optical properties, as seen in Figure 28, not any of the material properties once defined in Revit "survives" the export procedure though. Issues with import of 3D models from Revit into this software is that users do not get any kind of verification of which layer that is actually active when selecting it and that different window types arranges to the same layer. The software does not recognize the amount of panes in a window, it is just simulated as a single block which is delivered optical properties, see the surface column in Figure 28. Since the titling of the layers is not always obvious and also to get rid of irrelevant layers either an intermediate export to AutoCad for some layer management or editing in the export properties in Revit before export is an appropriate measure.

The result of the rendering is presented visually, see Figure 29. Three different outcomes are possible to render, luminance, illuminance and daylight factor. When the desired outcome is luminance and illuminance the view can be manually adjusted regarding position, height and angle. If the desired outcome is the daylight factor the only available rendering view is a plan view. Depending on the degree of resolution the rendering is relatively fast or more time consuming. There is an option, see Figure 29, to adjust the visual result in various shapes; false colour or ISO contour, either with or without a gridline with presented values in the result image. An example of the rendering possibilities is presented in Figure 30.

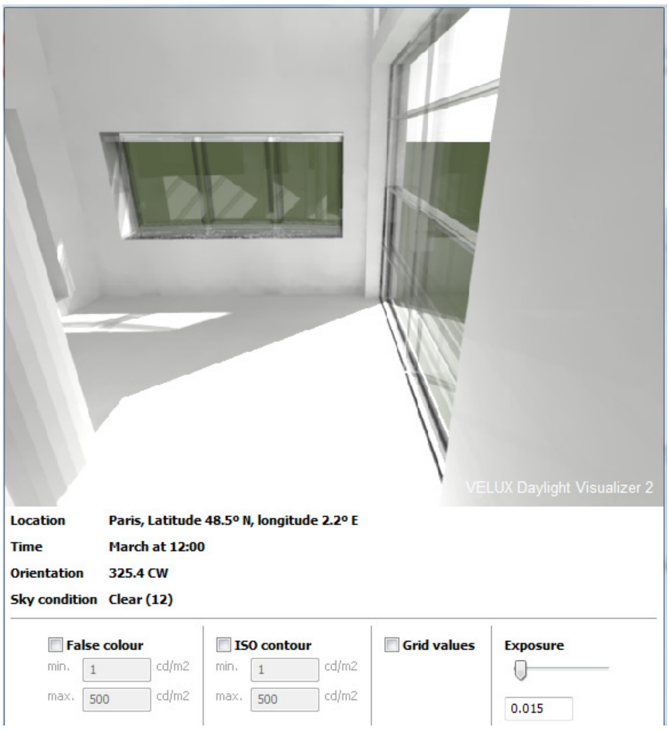

Figure 29 Visualization of daylight after rendering in Velux Daylight Visualizer 2. (picture extracted from Velux Daylight Visualizer 2)

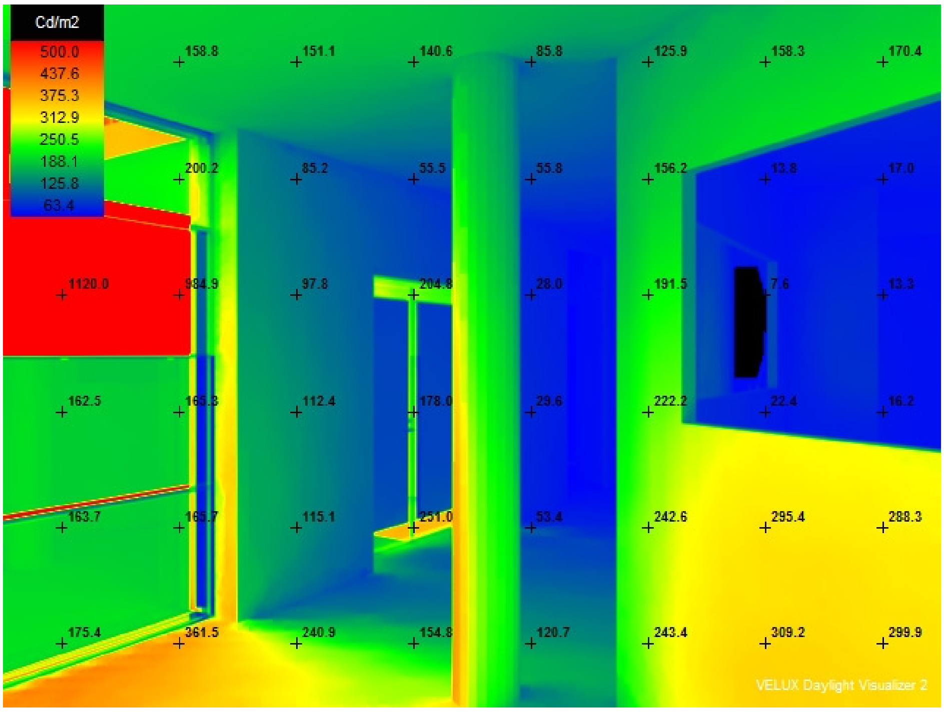

Figure 30 the rendering shows the luminance [Cd/m^2] as false colour and with a grid showing values at specific points. (picture extracted from Velux Daylight Visualizer 2)

Regarding the rendered result, is only presented visually with the option to save it as an image file, either as jpg, png or as exr. By that it is hardly integrated with Revit on a two-way basis, possibly the image file is storable in Revit but other than that the returning information link is equal to zero and the loop of information stops here and if the Revit model is later revised an export once again has to be performed.

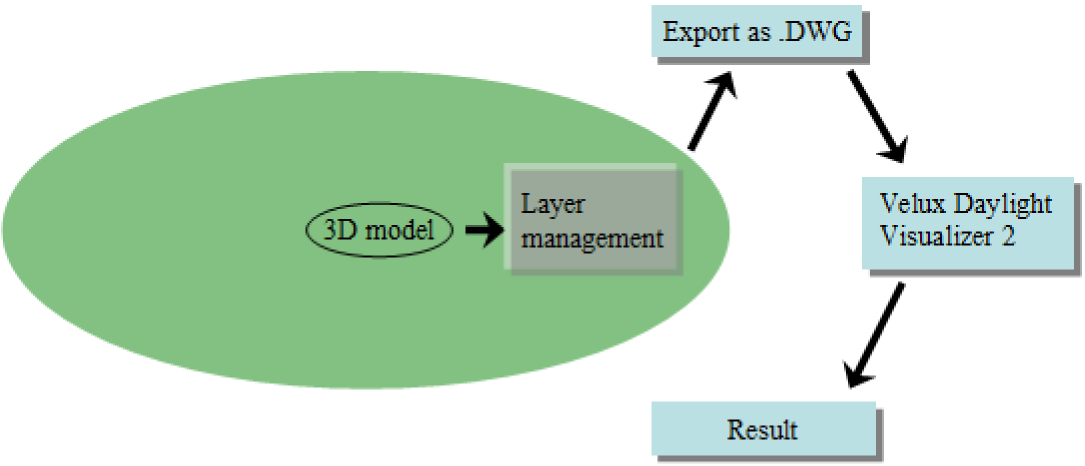

Figure 31 the prescribed procedure and loop of information when exporting information from Revit to Velux Daylight Visualizer 2. The result, in shape of an image file, is not integrated with the Revit environment but stored externally. (by author)

3.3.2 Sunlight

The concept of daylight and sunlight goes hand in hand, as mentioned in the above paragraph. As daylight in most cases is desirable to a high extent at the interior, the sunlight, or more precisely the heat generated by the sunlight is desired to keep at a minimum within the building envelope since it mostly contributes to an increased cooling demand, for office and commercial buildings mainly speaking. The solar radiation heat gain into the building is a dynamic and rather complex procedure. (Pilkington)

The heat of the sun is transported through the air by radiation, when it hits the construction, let's say a window, some of it is directly transmitted through to the interior, the rest is either absorbed or reflected back. Part of the absorbed heat will later enter the interior as secondary heat due to conduction and convection. When determining the energy usage of a building the solar radiation constitutes a significant part, especially these days with a growing trend of bigger glazed exterior areas in the building envelope and thus tools which handle this phenomenon are desirable. (Pilkington)

Autodesk Solar Radiation Technology Preview

The main argument for analyzing this software is that it is an integrated feature in the Revit environment.

It is used to understand and quantify the solar radiation on various surfaces in the Revit 3D model. It visualizes the impact of solar radiation on construction faces or at an entire district of buildings in the shape of colorization of the selected faces, see Figure 32. (Autodesk Labs)

Note that as the title implies, this is just a technology preview, a limited term release edited by Autodesk with the purpose to investigate the usability through feedback from potential users. In other words there is a great opportunity to affect the outcome of this software.

In the current version, there are some limitations regarding the application handiness;

- Simulation can only be performed in 3D views.
- It only handles mass geometries, which means that the Revit model is supposed to be modelled as a mass geometry from the beginning.
- It does not handle reflection from the ground.
- Solar radiation through translucent or transparent surfaces is not considered in calculations.

For more documented issues see the "Read Me" text file in Appendix A.

Basically, the function of this software is to simulate the effect of the sun on exterior areas. An advantage is that it is integrated as an “add-in” in Revit MEP 2011 which enables it to use the “sun-path” feature in Revit, see Figure 32, which simulates the movement and impact of the sun during the year and according to site location. This is an effective method to visualize the shadow behaviour of specific environments throughout days and years. This ability of the software is useful in cases of optimizing the placing of solar collectors etc.

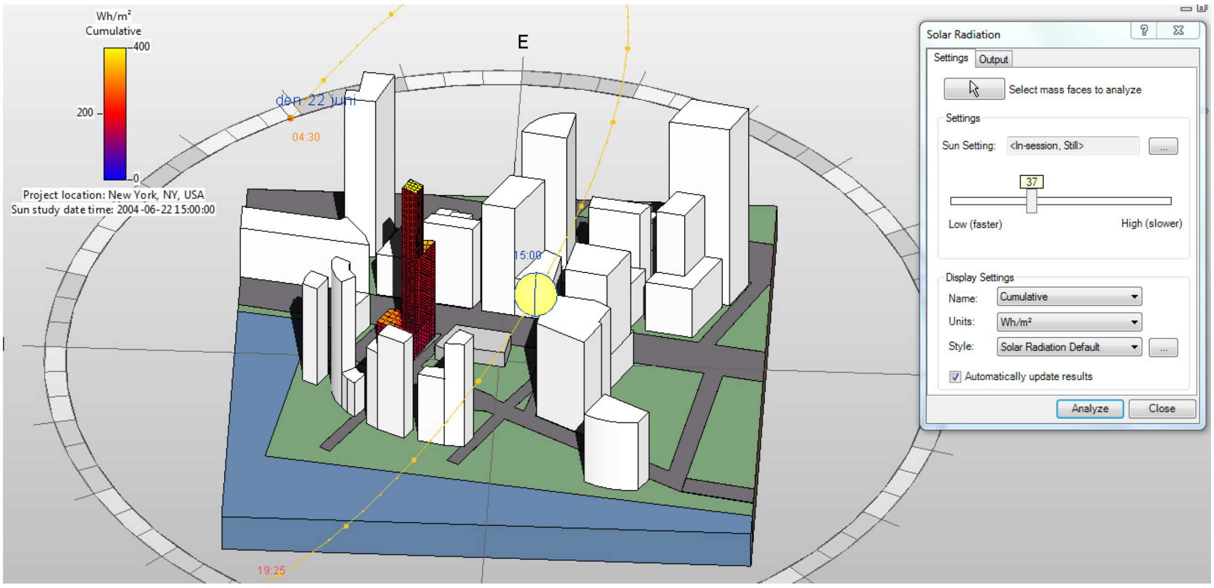

Figure 32 an overview of the add-in Autodesk Solar Radiation Technology Preview, here with sun-path and shadow functions activated. (picture extracted from the “Autodesk Solar Radiation Technology Preview”)

To summarize what is stated above this tool can, in the current shape, merely be used in the early design phase in order to compare the outcome of simulations when considering impact of such parameters as location, orientation and surrounding environment, which also is the intention of the software. Since it only generates the impact of the solar radiation on the exterior faces of a construction it is to little gain in the actual HVAC design process regarding the delivery of reliable and exact results able to use when determining total energy usage of a building. The main reason for this is the lacking ability to simulate the radiation through windows.

Another feature which brings down the software is the restriction to only model with masses in Revit, this is seldom the case when actually modeling in Revit. There is no simple method in Revit to transform model based geometry into a mass geometry in order to carry out the solar radiation simulation. It is doable though, by a workaround for this specific matter.

Workaround from model-to-mass geometry

1. Remove all of the glass from the model (as Revit will read this as a solid as a result of this process)
2. Export model as a SAT-file.
3. Create an "In-Place Mass".
4. Import the SAT-file through the "Insert/Import CAD" button

In this way no editing in the model can be performed but solar readings can be performed off the SAT-file. (Augi, Solar radiation)

It is important to keep in mind the purpose of the software though, it has not been the intention to develop a precise tool for the more detailed phases of a project. In this case it simply does not converge with the criteria in this report of how software should behave in order to be a useful tool later on in the HVAC design process. Nevertheless it is still evaluated based on those grounds.

Regarding the result management, the rendering can be saved to the Revit model as a specific rendering view in the project browser. It can then be added to a sheet or exported as an image file for use in presentations etc.

The practical procedure is summarized in figures below. Figure 33 describes the work flow when the original model is based on model geometry, as in most cases. Figure 34 describes the workflow when the original model is based on mass geometry.

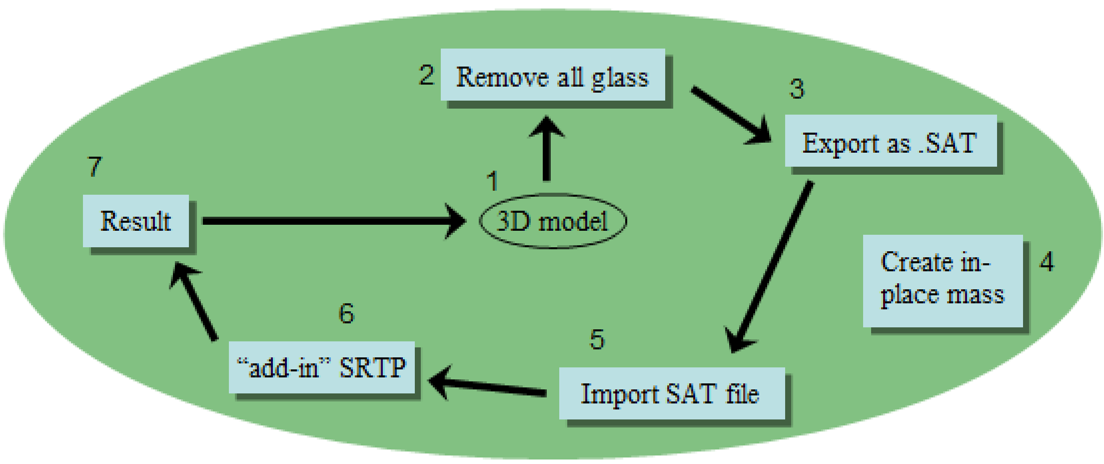

Figure 33 the prescribed procedure when originally working with model based geometry in Revit. The steps are numbered in order to make the procedure easier to follow. Step 4, the creation of the in-place mass is performed independently in Revit. (by author)

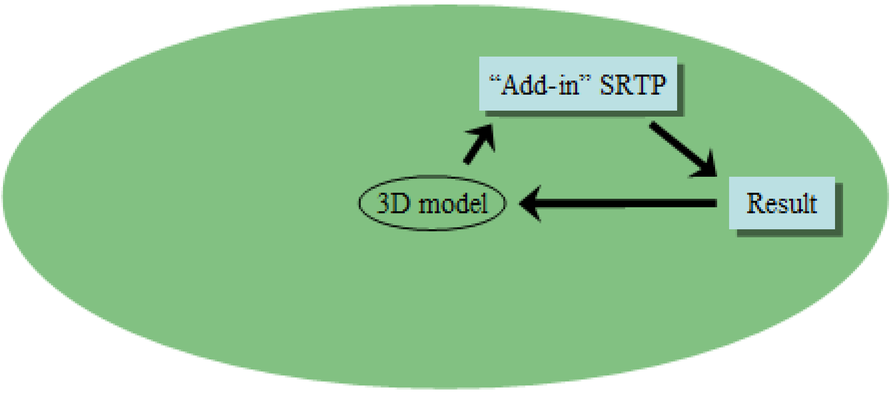

Figure 34 the prescribed procedure when originally working with mass based geometry in Revit. (by author)

3.3.3 Heating and cooling analysis within Revit MEP

Within the Revit MEP environment a feature exists with the purpose to perform analysis of the heating and cooling loads in the current model, presenting the heating and cooling demand in the building. The feature is totally integrated with Revit and is accessed from the “Analyze” tag in the menu, see Figure 35.

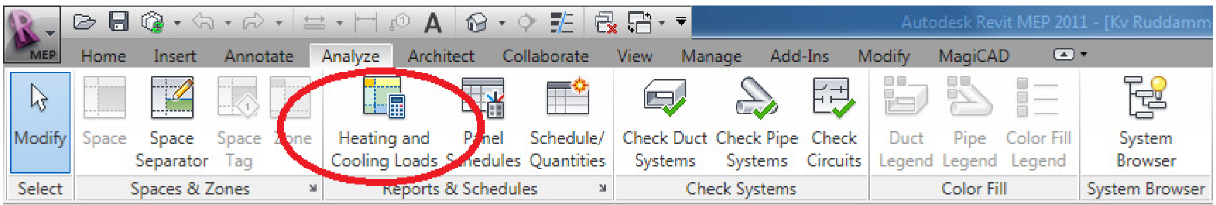

Figure 35 access to the feature ”Heating and Cooling Loads” in Revit MEP. (picture extracted from Revit MEP 2011)

The first crucial step towards the heating and cooling loads analysis is to accurately define areas throughout the building. These areas are divided into spaces and zones. Spaces are subordinate to zones and a specific space is needed for each area that wishes to maintain an individual climate, independently of surrounding environment. By this, each object placed within a space knows its belongingness.

A zone is a larger area which contains one or more spaces and is defined as the area/volume which is served by one single system. (Revit MEP User Assistance)

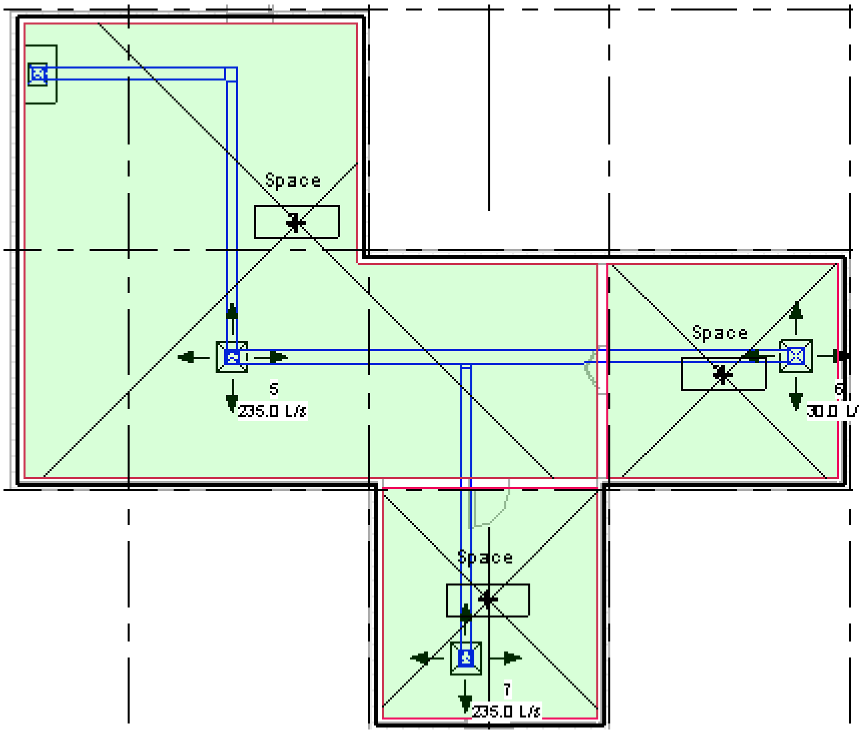

Figure 36 a zone composed by three spaces. (picture extracted from Revit MEP 2011)

Once the spaces and areas in the building are defined the model is ready for the heating and cooling loads analysis. Clicking the icon presented in Figure 35 opens the settings menu, both for the building in general and more detailed on a space level. A variety of settings is accessible, such as location, operation, building service, building construction, infiltration level, amount of people, temperature set points, air changes per hour etc. Remarkable is that the materials and U-values already specified in the model does not follow to the analysis, they have to be redefined from a drop-down menu with already defined structure compositions, see Figure 37, for each construction part and each space in the building. The materials and measures are not, at this time, adapted to the Swedish market, hence it can be difficult finding an exact match to the real construction part. However, it is possible to create construction part compositions with materials and corresponding U-values in the XML file in Revit. This procedure enables an exact match to reality, it may be a tedious process but since they are storable it is an initial one-time procedure and after a while a representative material database will be gathered.

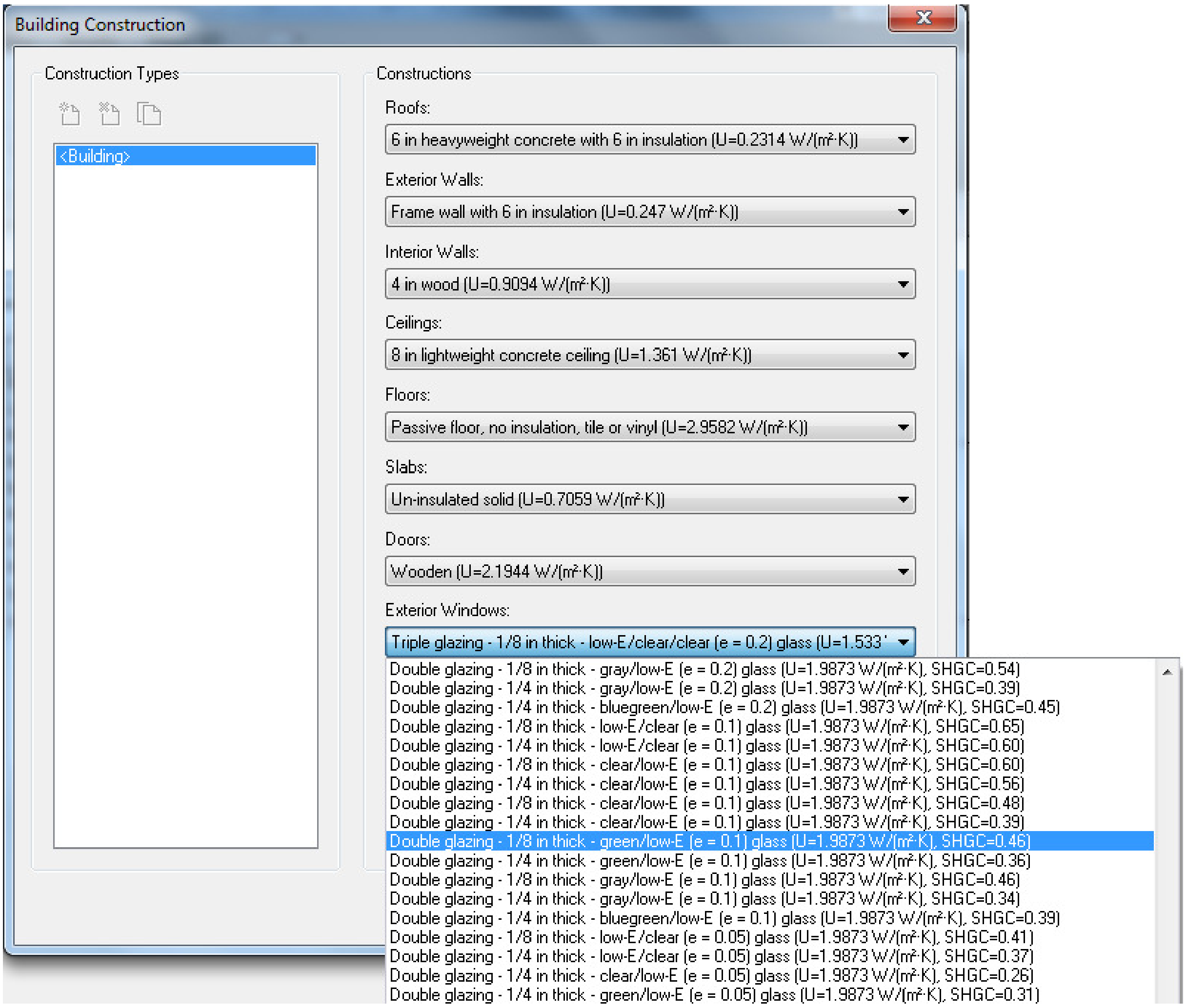

Figure 37 the settings menu for the choice of material for each construction part. The materials to choose are predefined in a drop-down menu. This has to be done for each space and zone. (picture extracted from Revit MEP 2011)

As stated above, a number of adjustments can be made regarding input parameters which affect the calculation output. However, in order to evaluate the result it is of great interest which calculation method is used and how it treats the input data.

According to Kyle Bernhardt[9], the calculation method used in heating and cooling loads analysis in Revit MEP is the "ASHRAE Radiant Time Series" method.

Briefly summarized it is a simplified calculation method derived from the "Heat Balance" method, which simply splits hourly conductive heat gains into convective and radiative parts. The splitting is performed using values from a standardized chart. A more thorough review of the calculation method is found in Appendix B.

[9] Kyle Bernhardt, Product Manager of BIM Simulation and Emerging Technologies at Autodesk, Inc.

Anyway, the conclusion of the analysis of the calculation method are that it raises questions of how the program in reality handles radiation of the sun, variable temperatures and wheather it requires cooling. It is rather unclear to me how VAV-systems are treated by the program. These speculations are further confirmed by Max Tillberg and by the research report published by Mingxian Cui[10].

Although it is a simplified calculation method with limited capability it still offers solutions for the above described limitations, how the program actually treats these issues though, are to me unknown.

After the appropriate settings are made a calculation is performed, which results are gathered and visualized in a load report accessible from the project browser, see Figure 38. Some of the input data is also available and manageable from the properties window when selecting a space.

Project Summary

Location and Weather	
Project	Project Name
Address	
Calculation Time	den 17 november 2010 10:45
Report Type	Standard
Latitude	57.70°
Longitude	11.99°
Summer Dry Bulb	27 °C
Summer Wet Bulb	19 °C
Winter Dry Bulb	-15 °C
Mean Daily Range	-10 °C

Building Summary

Inputs	
Building Type	Office
Area (m²)	111
Volume (m³)	443.60
Calculated Results	
Peak Cooling Total Load (W)	**4,524**
Peak Cooling Month and Hour	July 14:00
Peak Cooling Sensible Load (W)	4,215
Peak Cooling Latent Load (W)	309
Maximum Cooling Capacity (W)	4,151
Peak Cooling Airflow (L/s)	334.1
Peak Heating Load (W)	**3,331**
Peak Heating Airflow (L/s)	166.1
Checksums	
Cooling Load Density (W/m²)	40.79

Figure 38 a cutting out of the load report generated by the heating and cooling loads analysis in Revit MEP. (picture extracted from Revit MEP 2011)

[10] Mingxian Cui & Tingyao Chen. (2009) *A revised Radiant Time Series (RTS) method for intermittent cooling load calculation* (July 2009). Research report.

As summarization this is a welcome feature, especially the tight integration in Revit. The restrictions of the calculation method limit the range of use though. It is important for users when adopting the feature to be aware of the capabilities and limitations in order to get trust worthy information out of the software. As for now it seem to be a feature mostly intended to use in early stages of the planning, for the comparison of different scenarios rather than delivering accurate and reliable results used in the detailed design process. Figure 39 summarizes the mode of operation when performing energy analysis in the "Heating and Cooling Loads" feature in Revit MEP.

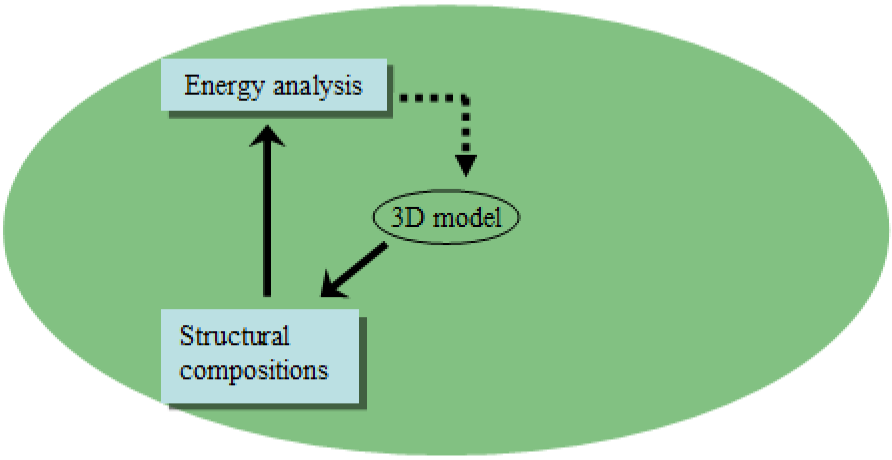

Figure 39 the mode of operation when performing energy analysis with the internal feature "Heating and cooling loads" in Revit MEP. The crosshatched arrow symbolises the questionable outcome of the analysis and the fact that only parts of the result is manageable, most of the result is gathered in the load report and available only as readable information. (by author)

3.3.4 IDA Indoor Climate and Energy

Regarding information transfer from Revit to IDA ICE, it has to go via the IFC file format. Through this the geometry and the object information is transferrable on a one-way basis, this means that results produced in IDA ICE is not able to implement back to the Revit environment, also if the original Revit model is modified after export has been carried out to IDA ICE the model has to be re-exported. At the current date no transport is possible via the gbXML file format, although the possibilities for this are being explored. (Hans Johnsson[11])

[11] Hans Johnsson, Equa Simulation AB, personal communication by telephone 2010-12-17.

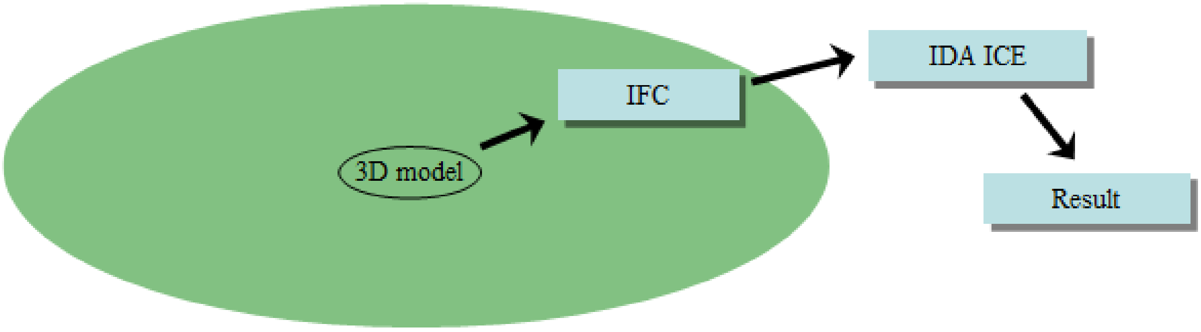

Figure 40 the mode of operation when exporting a Revit model into IDA ICE. The result is not able to implement back into Revit. (by author)

3.3.5 VIP-Energy

At the current date no standard procedure is available for transport of information between Revit and VIP-Energy. Neither the IFC or gbXML file formats are possible medias. A work-around though is to use the ArchiCAD plug-in EcoDesign and by that import Revit models into VIP-Energy. The transport from Revit to ArchiCAD can either be by dwg, dxf or IFC. EcoDesign communicates with VIP-Energy by the use of VIP-Energy's file format VUT.

Althogh, CAD-Q is in the process of developing a plug-in for Revit called QTools, which amongst others offers a direct export function between Revit and VIP-Energy, by the use of the file format VUT. (Mats-Ola Rasmusson[12])

Figure 41 shows the necessary approach when exporting a Revit model into VIP-Energy.

[12] Mats-Ola Rasmusson, Structural Design Software in Sweden AB, personal communication by telephone 2010-12-17.

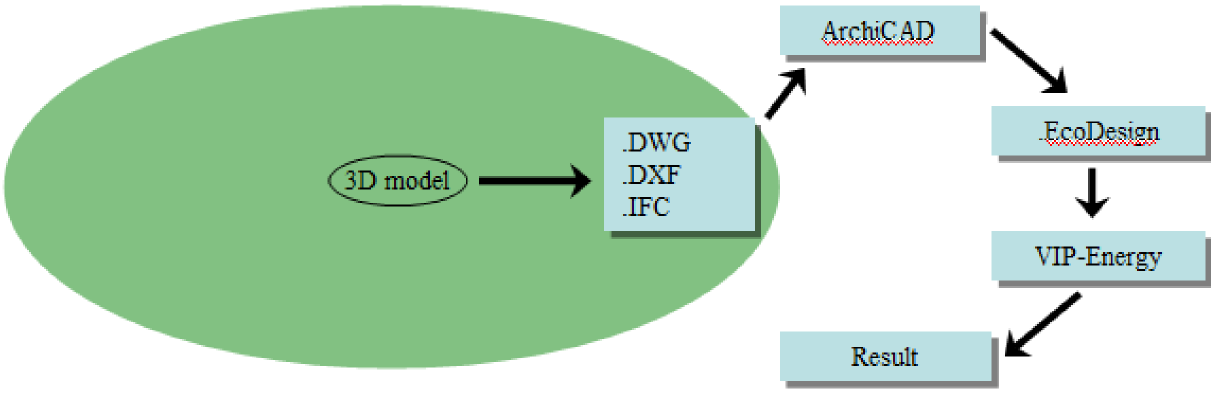

Figure 41 the mode of operation when exporting a Revit model into VIP-Energy. The result is not able to implement back into Revit. (by author)

3.4 Specifications

For this part the focus is solely on which documents can be established by the use of Revit MEP. Specifications are carried out with varying accuracy depending on stage in the design process. Of major relevancy however, are the specifications carried out during the final stage of the design process, such as definitive product lists, schedules and blueprints.

Revit MEP possesses rather sophisticated features developed for these specific tasks, which will be analysed next.

3.4.1 Schedule/Quantities in Revit MEP

In Revit MEP this feature is called "Schedules/Quantities" and is accessed from the menu in the "Analyze" tag, see Figure 42.

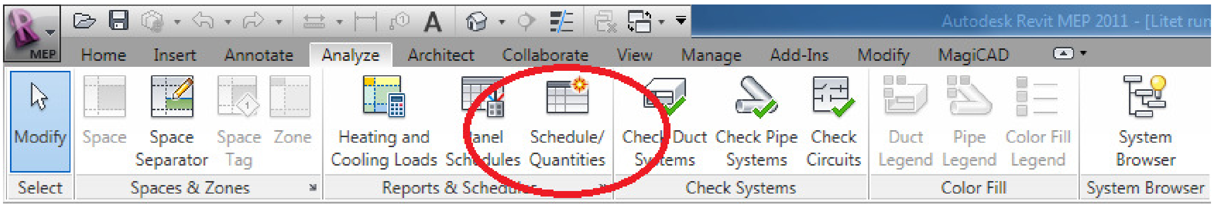

Figure 42 access to the feature "schedule/Quantities" in the Revit MEP menu system. (picture extracted from Revit MEP 2011)

This feature enables users to generate accurate lists and schedules directly synced with the object defined information in the model created in Revit. The first step when creating schedules is to select the category of focus for the specific schedule, for example a schedule listing the spaces of the project, see Figure 43. The spaces will now constitute the rows in the schedule.

The next step is to select which parameters to be included in the schedule, the columns of the schedule. The parameters are selected from a list and then added to the schedule. The order of the parameters in the schedule can be managed from here. There is also an option to create new parameters and add to the schedule, see Figure 43.

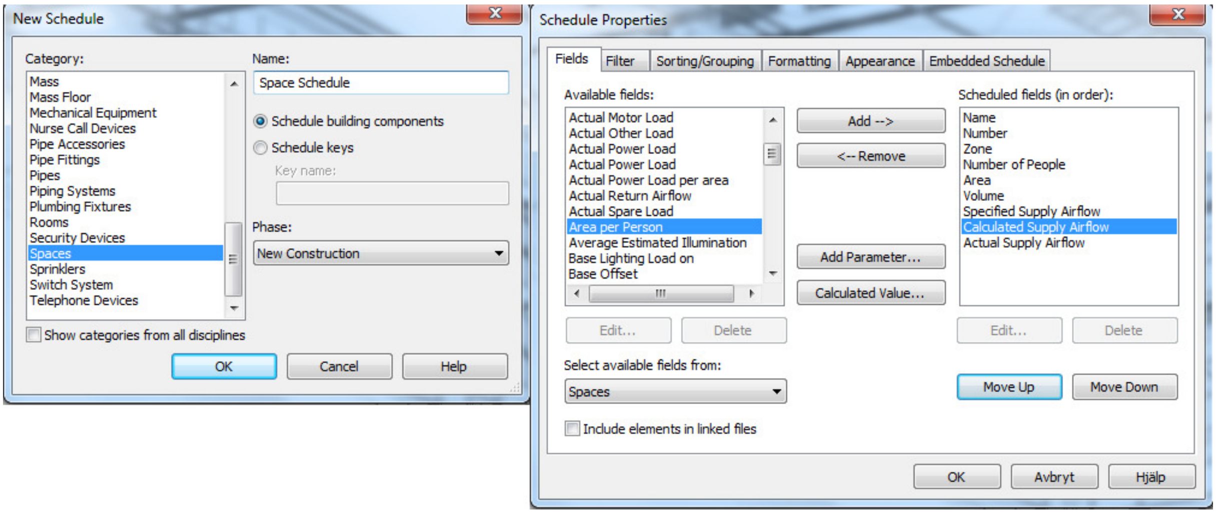

Figure 43 the left figure shows the first step when creating schedules, the category choice. The right figure shows the next step when selecting parameters to be included in the schedule. Here the left list constitutes available parameters and the list to the right shows the selected parameters. In the middle there is the alternative to create new parameters with the "Add Parameter" button. (picture extracted from Revit MEP 2011)

There is also an option to design manual formulas with involved parameters, see "Calculated Value" in Figure 43. Either by adding, multiplying etc. a value to a chosen parameter or to combine parameters in the formula. For example a parameter can be created which by a formula calculates and in the schedule shows the difference in airflow between the specified supply airflow and the actual supply airflow, see Figure 44.

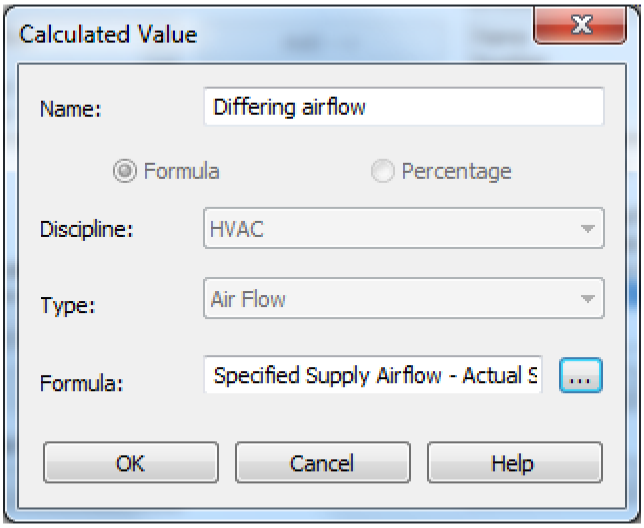

Figure 44 a new parameter is created which in the schedule is called differing airflow, which by a simple manually established formula calculates and shows the difference in airflow between the specified supply airflow and the actual supply airflow. (picture extracted from Revit MEP 2011)

By clicking the OK button in the "Schedule Properties" window in Figure 43 these actions will result in a space schedule, listing the values for the selected parameters for each space in the model, see Figure 45.

Space Schedule 2

Name	Number	Zone	Area	Number of People	Area per Person	Volume	Actual Supply Airflow	Calculated Supply Airflow	Specified Supply Airflow	Differing airflow
Space	1	Default	327 m²	11.451625	29 m²	1187.68 m³	0.0 L/s	1049.6 L/s	1049.6 L/s	1049.6 L/s
Space	2	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	3	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	4	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	5	Default	22 m²	0.777303	29 m²	64.63 m³	0.0 L/s	51.2 L/s	51.2 L/s	51.2 L/s
Space	6	Default	8 m²	0.275731	29 m²	22.93 m³	0.0 L/s	15.1 L/s	15.1 L/s	15.1 L/s
Space	7	Default	41 m²	1.435733	29 m²	119.37 m³	0.0 L/s	93.7 L/s	93.7 L/s	93.7 L/s
Space	8	Default	5 m²	0.184829	29 m²	15.37 m³	0.0 L/s	11.2 L/s	11.2 L/s	11.2 L/s
Space	9	Default	15 m²	0.53758	29 m²	44.70 m³	0.0 L/s	36.3 L/s	36.3 L/s	36.3 L/s
Space	10	Default	15 m²	0.534033	29 m²	44.40 m³	0.0 L/s	29.3 L/s	29.3 L/s	29.3 L/s
Space	11	Default	10 m²	0.33951	29 m²	28.23 m³	0.0 L/s	18.6 L/s	18.6 L/s	18.6 L/s
Space	12	Default	1 m²	0.03108	29 m²	2.58 m³	0.0 L/s	1.7 L/s	1.7 L/s	1.7 L/s
Space	13	Default	5 m²	0.181666	29 m²	15.10 m³	0.0 L/s	10.0 L/s	10.0 L/s	10.0 L/s
Space	14	Default	32 m²	1.104857	29 m²	91.86 m³	0.0 L/s	139.6 L/s	139.6 L/s	139.6 L/s
Space	15	Default	127 m²	4.434436	29 m²	368.69 m³	200.0 L/s	638.3 L/s	638.3 L/s	438.3 L/s
Space	16	Default	19 m²	0.671355	29 m²	55.82 m³	0.0 L/s	39.9 L/s	39.9 L/s	39.9 L/s
Space	17	Default	38 m²	1.347047	29 m²	112.00 m³	0.0 L/s	80.4 L/s	80.4 L/s	80.4 L/s
Space	18	Default	7 m²	0.247714	29 m²	20.60 m³	0.0 L/s	13.6 L/s	13.6 L/s	13.6 L/s
Space	19	Default	14 m²	0.479095	29 m²	39.83 m³	0.0 L/s	29.3 L/s	29.3 L/s	29.3 L/s
Space	20	Default	13 m²	0.459274	29 m²	38.19 m³	0.0 L/s	28.1 L/s	28.1 L/s	28.1 L/s
Space	21	Default	2 m²	0.07334	29 m²	6.10 m³	0.0 L/s	4.7 L/s	4.7 L/s	4.7 L/s
Space	22	Default	4 m²	0.14198	29 m²	11.80 m³	0.0 L/s	7.8 L/s	7.8 L/s	7.8 L/s
Space	23	Default	89 m²	5	18 m²	260.34 m³	200.0 L/s	302.2 L/s	302.2 L/s	102.2 L/s
Space	24	Default	48 m²	1.679662	29 m²	139.65 m³	50.0 L/s	152.2 L/s	152.2 L/s	102.2 L/s
Space	25	Default	97 m²	3.399129	29 m²	282.61 m³	200.0 L/s	306.6 L/s	306.6 L/s	106.6 L/s
Space	26	Default	48 m²	1.679662	29 m²	139.65 m³	100.0 L/s	152.2 L/s	152.2 L/s	52.2 L/s
Space	27	Default	47 m²	1.65092	29 m²	137.26 m³	100.0 L/s	149.8 L/s	149.8 L/s	49.8 L/s
Space	28	Default	19 m²	0.671355	29 m²	55.82 m³	0.0 L/s	65.8 L/s	65.8 L/s	65.8 L/s
Space	29	Default	41 m²	1.430521	29 m²	118.94 m³	0.0 L/s	249.9 L/s	249.9 L/s	249.9 L/s
Space	30	Default	147 m²	5.14362	29 m²	427.66 m³	240.0 L/s	588.3 L/s	588.3 L/s	348.3 L/s
Space	31	Default	137 m²	4.811782	29 m²	400.07 m³	0.0 L/s	685.5 L/s	685.5 L/s	685.5 L/s
Space	32	Default	19 m²	0.662115	29 m²	55.05 m³	0.0 L/s	63.7 L/s	63.7 L/s	63.7 L/s
Space	33	Default	57 m²	1.999388	29 m²	166.23 m³	0.0 L/s	345.3 L/s	345.3 L/s	345.3 L/s
Space	34	Default	17 m²	0.608229	29 m²	50.57 m³	0.0 L/s	35.6 L/s	35.6 L/s	35.6 L/s
Space	35	Default	41 m²	1.427883	29 m²	118.72 m³	0.0 L/s	406.2 L/s	406.2 L/s	406.2 L/s
Space	36	Default	50 m²	1.752952	29 m²	145.75 m³	0.0 L/s	217.1 L/s	217.1 L/s	217.1 L/s
Space	37	Default	7 m²	0.258372	29 m²	21.48 m³	0.0 L/s	26.3 L/s	26.3 L/s	26.3 L/s

Figure 45 a schedule showing parameter values for each space in the model. The column to the far right lists the, by a manually computed formula, difference in airflow between the specified supply airflow and the actual supply airflow. (picture extracted from Revit MEP 2011)

The schedules are totally integrated with the model i.e. a change in the model will instantly make impact in the schedule as well as a change in the schedule makes an impact in the model. In excess, there is a feature which allows performance control of the schedule parameters. If a value do not fulfil certain criteria it is possible to make them automatically highlighted in the schedule by assigning demands. For example restrictions to the maximum actual supply airflow and maximum tolerances for the differing airflow, see Figure 46.

Note that the purpose with the schedules in these examples is solely to demonstrate the possibilities with the "Schedule/Quantities" feature, not to deliver accurate or realistic parameter values.

Space Schedule 2										
Name	Number	Zone	Area	Number of People	Area per Person	Volume	Actual Supply Airflow	Calculated Supply Airflow	Specified Supply Airflow	Differing airflow
Space	1	Default	327 m²	11.451625	29 m²	1187.68 m³	0.0 L/s	1049.6 L/s	1049.6 L/s	1049.6 L/s
Space	2	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	3	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	4	Default	Not Placed	0	Not Computed	Not Placed	0.0 L/s	Not Computed	0.0 L/s	0.0 L/s
Space	5	Default	22 m²	0.777303	29 m²	64.63 m³	0.0 L/s	51.2 L/s	51.2 L/s	51.2 L/s
Space	6	Default	8 m²	0.275731	29 m²	22.93 m³	0.0 L/s	15.1 L/s	15.1 L/s	15.1 L/s
Space	7	Default	41 m²	1.435733	29 m²	119.37 m³	0.0 L/s	93.7 L/s	93.7 L/s	93.7 L/s
Space	8	Default	5 m²	0.184829	29 m²	15.37 m³	0.0 L/s	11.2 L/s	11.2 L/s	11.2 L/s
Space	9	Default	15 m²	0.53758	29 m²	44.70 m³	0.0 L/s	36.3 L/s	36.3 L/s	36.3 L/s
Space	10	Default	15 m²	0.534033	29 m²	44.40 m³	0.0 L/s	29.3 L/s	29.3 L/s	29.3 L/s
Space	11	Default	10 m²	0.33951	29 m²	28.23 m³	0.0 L/s	18.6 L/s	18.6 L/s	18.6 L/s
Space	12	Default	1 m²	0.03108	29 m²	2.58 m³	0.0 L/s	1.7 L/s	1.7 L/s	1.7 L/s
Space	13	Default	5 m²	0.181666	29 m²	15.10 m³	0.0 L/s	10.0 L/s	10.0 L/s	10.0 L/s
Space	14	Default	32 m²	1.104857	29 m²	91.86 m³	0.0 L/s	139.6 L/s	139.6 L/s	139.6 L/s
Space	15	Default	127 m²	4.434436	29 m²	368.69 m³	200.0 L/s	638.3 L/s	638.3 L/s	438.3 L/s
Space	16	Default	19 m²	0.671355	29 m²	55.82 m³	0.0 L/s	39.9 L/s	39.9 L/s	39.9 L/s
Space	17	Default	38 m²	1.347047	29 m²	112.00 m³	0.0 L/s	80.4 L/s	80.4 L/s	80.4 L/s
Space	18	Default	7 m²	0.247714	29 m²	20.60 m³	0.0 L/s	13.6 L/s	13.6 L/s	13.6 L/s
Space	19	Default	14 m²	0.479095	29 m²	39.83 m³	0.0 L/s	29.3 L/s	29.3 L/s	29.3 L/s
Space	20	Default	13 m²	0.459274	29 m²	38.19 m³	0.0 L/s	28.1 L/s	28.1 L/s	28.1 L/s
Space	21	Default	2 m²	0.07334	29 m²	6.10 m³	0.0 L/s	4.7 L/s	4.7 L/s	4.7 L/s
Space	22	Default	4 m²	0.14198	29 m²	11.80 m³	0.0 L/s	7.8 L/s	7.8 L/s	7.8 L/s
Space	23	Default	89 m²	5	18 m²	260.34 m³	200.0 L/s	302.2 L/s	302.2 L/s	102.2 L/s
Space	24	Default	48 m²	1.679662	29 m²	139.65 m³	50.0 L/s	152.2 L/s	152.2 L/s	102.2 L/s
Space	25	Default	97 m²	3.399129	29 m²	282.61 m³	200.0 L/s	306.6 L/s	306.6 L/s	106.6 L/s
Space	26	Default	48 m²	1.679662	29 m²	139.65 m³	100.0 L/s	152.2 L/s	152.2 L/s	52.2 L/s
Space	27	Default	47 m²	1.65092	29 m²	137.26 m³	100.0 L/s	149.8 L/s	149.8 L/s	49.8 L/s
Space	28	Default	19 m²	0.671355	29 m²	55.82 m³	0.0 L/s	65.8 L/s	65.8 L/s	65.8 L/s
Space	29	Default	41 m²	1.430521	29 m²	118.94 m³	0.0 L/s	249.9 L/s	249.9 L/s	249.9 L/s
Space	30	Default	147 m²	5.14362	29 m²	427.66 m³	240.0 L/s	588.3 L/s	588.3 L/s	348.3 L/s
Space	31	Default	137 m²	4.811782	29 m²	400.07 m³	0.0 L/s	685.5 L/s	685.5 L/s	685.5 L/s
Space	32	Default	19 m²	0.662115	29 m²	55.05 m³	0.0 L/s	63.7 L/s	63.7 L/s	63.7 L/s
Space	33	Default	57 m²	1.999388	29 m²	166.23 m³	0.0 L/s	345.3 L/s	345.3 L/s	345.3 L/s
Space	34	Default	17 m²	0.608229	29 m²	50.57 m³	0.0 L/s	35.6 L/s	35.6 L/s	35.6 L/s
Space	35	Default	41 m²	1.427883	29 m²	118.72 m³	0.0 L/s	406.2 L/s	406.2 L/s	406.2 L/s
Space	36	Default	50 m²	1.752952	29 m²	145.75 m³	0.0 L/s	217.1 L/s	217.1 L/s	217.1 L/s
Space	37	Default	7 m²	0.258372	29 m²	21.48 m³	0.0 L/s	26.3 L/s	26.3 L/s	26.3 L/s

Figure 46 the same space schedule as in Figure 45 but in this schedule spaces which do not fulfil manually established criteria are highlighted with colours. The criteria established for the actual supply airflow is that all actual supply airflows exceeding 200 l/s will be highlighted as red. The criteria established for the differing airflow is that all differing airflows exceeding 100 l/s will be highlighted as green. (picture extracted from Revit MEP 2011)

The schedules are stored in the project browser, easy accessible along with the load reports and other views. The schedules can be printed, but first after being attached to a sheet.

The next important feature to analyze is the production of blueprints, called sheets in Revit.

3.4.2 Sheets in Revit MEP

The sheet management in Revit MEP is indeed important to analyze, although this area will only be treated briefly in this report.

The process of generating sheets in Revit MEP is rather smooth, either from the project browser or via the menu. Once a sheet is created the views which should be included in the sheet is simply dragged from the project browser into the sheet, size and position is then manageable in the sheet view, see Figure 47.

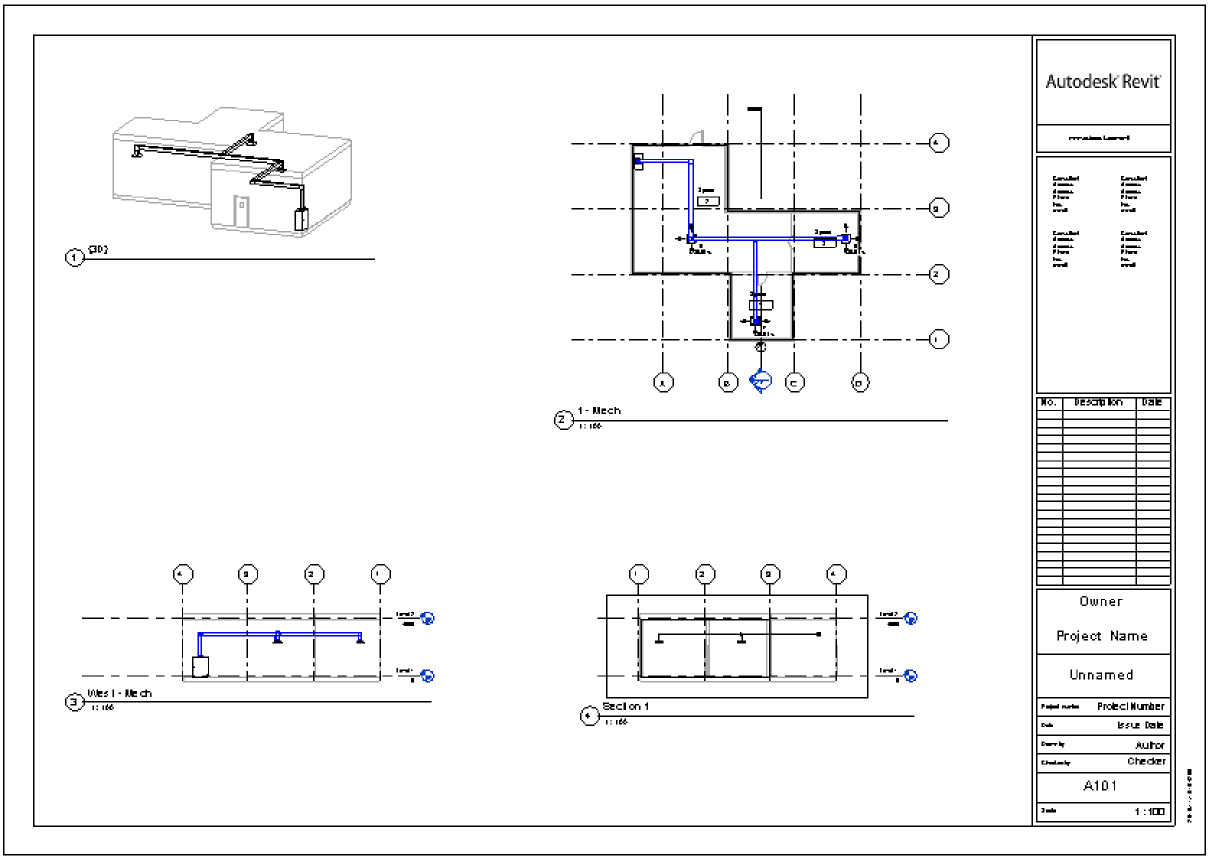

Figure 47 sheet generated in Revit MEP. The sheet shows in chronological order the views; 3D, Floor plan: 1-Mech, Elevation: West Mech and Section. Note that the sheet label is not according to Swedish standards. (picture extracted from Revit MEP 2011)

How the different views are visualized in the sheet depends on the individual setting in each view, details such as view scale, detail level, visible area etc. are all dependent of the original view.

In Revit MEP there is no template for a Swedish sheet standard layout. Basically what has to be done is to customize the sheet label manually in Revit. That procedure will not be described in this report, however a thorough "walk-through" is provided in "Revit MEP 2010 Grundkurs".

4 Revit as a tool in the HVAC design process

As previous chapters provide a very brief sort of compilation of the capability of Revit MEP, this chapter puts the concerned parts in a context regarding the HVAC design process. The HVAC design process is not linear, due to uncertainties, modifications and varying level of simulation accuracy etc. a number of phases in the HVAC design process can be defined.

The aim in this chapter is to evaluate to which extent and in which phases Revit MEP can contribute to rationalize the HVAC design process, with the tools and features available today.

4.1 The HVAC design process

The actual appearance of the design process varies from case to case, where choice of tendering procedure is an important factor. Hence the design process is a complex procedure, difficult to accurately standardize as one. In this report however, the process analyzed will be referred to as a standard procedure, which reflects a possible mode of operation, see Figure 48 below. This resembles the work chain from planning to final documentation, although in some projects the HVAC contractor will only be concerned in parts of it.

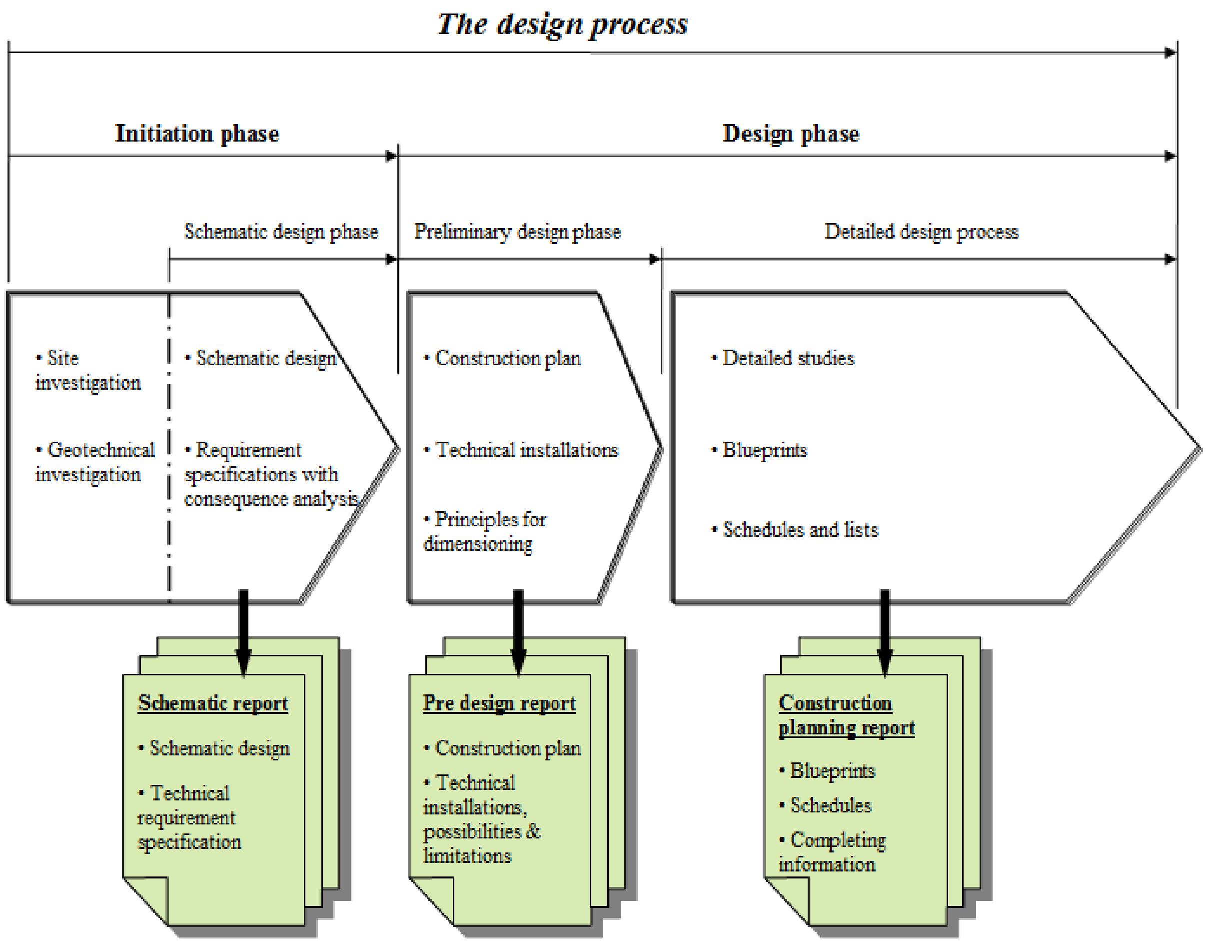

Figure 48 the "standard" design process referred to in this report. (picture edited by author. Original picture by Wannheden, 2000)

As can be seen in Figure 48 the design process can be divided into an initiation phase and a design phase. This is a basic break-down of the process, where the aim of the initiation phase is to end the formulation of demands while in the design phase solutions which fulfill the demands are presented. (Wannheden, 2000)

These phases can in turn be further divided and will be reviewed next.

4.1.1 Initiation phase

The first part of the initiation phase concerns first and foremost the establishment of demands, regarding operation, statutory concerns etc. made by the client, which will later fall into site- and geotechnical investigations. This is subject for other disciplines, the concern for the HVAC designer in the initiation phase is primarily in the next step, the *schematic design.* The main task in this phase is to establish the technical requirement specifications with a concentration on settling the function demands. (Wannheden, 2000)

Regarding the settling of the function demands, *room books* is the traditional method when documenting the demands for each area. In this stage a selection of type spaces is represented, which presents data relevant for the sizing of the building and the technical installations. (Wannheden, 2000)

In this stage such calculations and simulations can be performed with the purpose to provide early estimates on energy usage etc. by comparing simple layouts.

The information output expected from the HVAC designer from this phase is summarized in a technical report, consisting of the following information (Wannheden, 2000);

- Technical requirement specifications
- Room books

The initiation phase then results in a *schematic report* (see Figure 48) which compiles the demands the building shall fulfill. Also, a *schematic cost estimation* should here be assembled, with the accuracy of +/- 15 %, see Figure 48. (Wannheden, 2000)

4.1.2 Design phase

As can be seen in Figure 48 the design phase is divided further into a preliminary design phase and a detailed design phase.

- Preliminary design phase

- Detailed design phase

Preliminary design phase

The preliminary design phase is the initiating part of the design phase, here the principal layout is studied in order to establish framing, plan arrangement and the main structural design. Regarding HVAC, this is the stage where layout and distribution of the technical systems are established with respect to area need for technical areas, PI-diagrams, shafts and horizontal branches etc. The dimensioning data and criteria, which are to be fulfilled in the forthcoming detailed design, are established here. (Wannheden, 2000)

In order to determine the reference size and storey height critical sections need to be studied. Such parts can be crossovers and narrow spaces where installations and construction parts must get well together in a limited space. (Wannheden, 2000)

This is the stage where the technical systems are analyzed to the extent that they doubtlessly fulfill the demands stated in the previous *schematic report*. This is also the stage where elementary calculations and simulations are performed in order to analyze and optimize the performance of the chosen technical systems. The analyses should be elaborate to such extent that the following process, the *detailed design phase*, can be entirely focused on the study of details and on the formulation of the final *construction planning report*, see Figure 48. (Wannheden, 2000)

The preliminary design phase results in a *pre design report,* which provides a description of the building and its technical systems along with the premises which constitutes the choice of systems. (Wannheden, 2000)

The information output expected from the HVAC designer from this phase is summarized in a technical report, consisting of the following information;

- Solutions for the technical installations, along with flow charts and sizing criteria.
- Description of the sound requirements and criteria, often with included drawings of the sound distribution.
- Description of the fire protection requirements, often with included drawings.
- Preliminary dimensioning values showing the energy usage of heating, cooling and electricity.
- Preliminary calculations showing the yearly cost of usage, maintenance and service.
- A casual LCC of the technical systems.

A *preliminary cost estimation*, based on the establishments made, should be assembled in this stage. The accuracy of the estimation in this stage should be about +/- 10 %. (Wannheden, 2000)

Detailed design phase

When the detailed design phase is entered upon, issues such as choice of technical systems, solutions of the technical installations, area demands and critical sections which influence the performance and structural layout of the building should already be declared.

The detailed design is the most extensive phase in the overall design process. The main focus is on sizing and other dimensioning routines, definitive choice of products, coordination of all technical installations and more accurate simulations.

The detailed design process results in a tendering document, which is in the shape of a *construction planning report,* see Figure 48. These are the final documents produced by the HVAC designer, where documents such as blueprints, lists and schedules are generated. The final cost estimation is also established in this stage, with a tolerable accuracy of +/- 5 %. (Wannheden, 2000)

4.2 Key terms and parameters

In order to evaluate Revit MEP as a tool in the HVAC design process, the design process described above is fractioned into concrete terms which will be assigned to their respective position in the design process. With these terms once tied to their proper belonging in the process Revit MEP will be evaluated according to its beneficial for each term. The intention is to suggest a suitable HVAC design workflow with Revit MEP in focus and as the take-off point.

The specified key terms of interest in this report are;

1. Room books
2. PI-diagrams
3. Sizing
4. Choice of products
5. Clash control

6. Simulations and calculations
7. Schedules
8. Blueprints

These terms are established in collaboration with Mattias Torberntsson[13] and Max Tillberg.

Further on in the report when referring to these terms their corresponding figures, from one to eight, in the list above will be used. Due to the constant refining procedure throughout the process some of the terms will appear in several stages.

4.3 Possible workflow in the HVAC design process of an office building

The evaluation process consists of analyzing the different components which constitutes the HVAC design process, tie them to the appropriate phase and finally evaluate whether Revit MEP or other software is best suited for the task. The different components which constitute the design process are the key terms specified in chapter 4.2, which will be properly tied to the design process, see Figure 49.

[13] Mattias Torberntsson, Bengt Dahlgren AB.

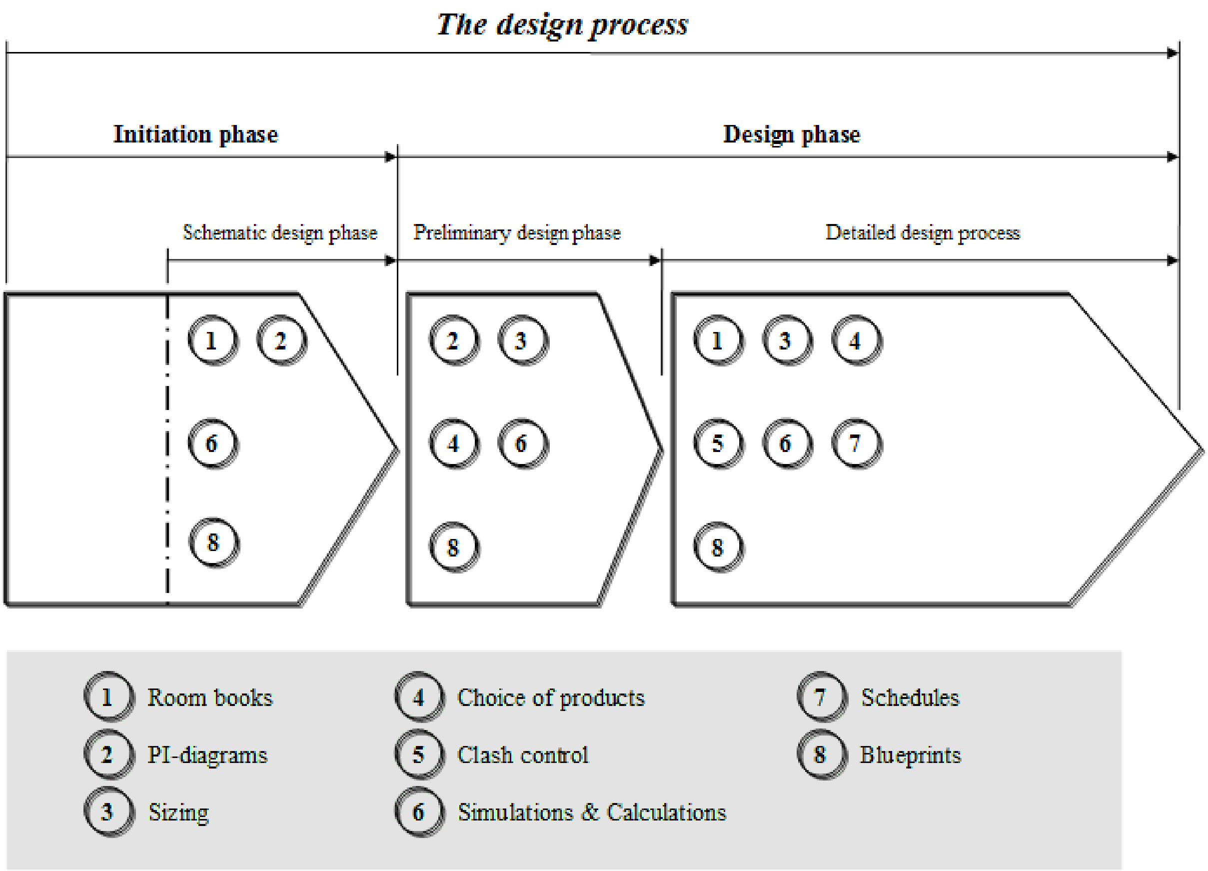

Figure 49 the key terms tied to the appropriate phases in the design process. Some of the terms appear several times due to the constant refining procedure throughout the process. (picture edited by author. Original picture by Wannheden, 2000)

Next follows brief reviews of each key term and evaluation of Revit MEP as an appropriate tool. The evaluation is among other things based on the facts stated in chapter 3.

4.3.1 Room books

The producing of room books is a fundamental part of the design process but actually it is not the HVAC designer's responsibility to create these. Although it is the client or the architect who creates the room books there are necessary HVAC information regarding the room function demands that should be documented in these. The norm of today is to perform the room books in some kind of word-processing program or Microsoft Excel.

In theory, since Revit MEP possess a rather developed feature for the producing of lists and schedules, room books could possibly be made in Revit MEP. The main issue is that Revit MEP only creates schedules of already defined objects from the 3D model. The first encounter with room books is early in the design process, in the schematic design phase, in this early stage the relevant objects and information are seldom defined in the 3D model.

Thereby the conclusion is that Revit MEP is not a suitable tool for this key term.

4.3.2 PI-diagrams

The PI-diagrams are performed on an early basis in the design process, either in the schematic or in the preliminary design phase, see Figure 49. At the present date the PI-diagrams are performed in AutoCad, which probably is the best suited tool for this task due to the line and layer oriented nature of the software as a contrary to the 3D modeling strategy of Revit MEP, although PI-diagrams surely can be performed with Revit MEP. Due to above statement, this task has not been analysed any further.

Thereby the conclusion is that Revit MEP is not the optimum tool for this key term but that it surely can be done with Revit MEP.

4.3.3 Sizing

The concept of sizing is a wide term consisting of several procedures, see chapter 3.2.3, where the sizing of ducts and the sound dimensioning are handled. MagiCad is the tool mostly used for these tasks and mainly for circular ducts and for pipes, in case of rectangular ducts MagiCad suggests flow optimized cross-sections which often is space demanding, in areas where space is “hard currency”. (Mattias Torberntsson, 2010-11-26). In any case, in Revit MEP the sizing feature can be performed either in the internal feature or in the MagiCad “add-in”. For more information about the sizing feature in Revit MEP and the MagiCad “add-in” read chapter 3.2.3.

The conclusion is that Revit MEP is a tool capable of performing this task, either by the internal function or by the use of the MagiCad “add-in”. Both of them has limitations and it should be up to the user to evaluate the accuracy and thereby the credibility of them.

4.3.4 Choice of products

Also regarding the choice of products there is more than one alternative in Revit MEP. Either the internal feature or the MagiCad “add-in” is capable of performing this task. The down-side with the internal feature is that it is not yet very adapted the Swedish market. In Figure 49 this key term appears in two phases, in the preliminary design phase where the general technical systems are established and also later in the detailed design phase where the objects and products are decided upon on an instance level.

The conclusion for this key term is that the MagiCad “add-in” in Revit MEP is most suitable for the task.

4.3.5 Clash detection

Clash detections are performed in projects with the purpose to detect interferences between disciplines, normally a global interference check is performed in the later part of the project such as the detailed design phase. If all other disciplines are using Revit as modeling platform, the clash detection can preferably be performed within Revit. Otherwise other software is recommended, for example Navisworks.

The feature which handles clash controls in Revit MEP, described in chapter 3.2.4, enables smooth continuous clash detection throughout the design process by successively linking in other disciplines and run the interference check.

The conclusion is that, with Revit as the theme software used by all disciplines involved for this task throughout the project, Revit MEP is a highly suitable tool for this specific task. However if varying software platforms are used then other tools are recommended.

4.3.6 Simulations and calculations

The ideal scenario for the HVAC designer is to be part of a project from the start or at least at an early date in order to stamp the authority and make the necessary estimations, which to a considerable degree will characterize the continuation of the project. The later the HVAC designer enters the project the less influence he posses and to a greater overall cost of the project, see Figure 50.

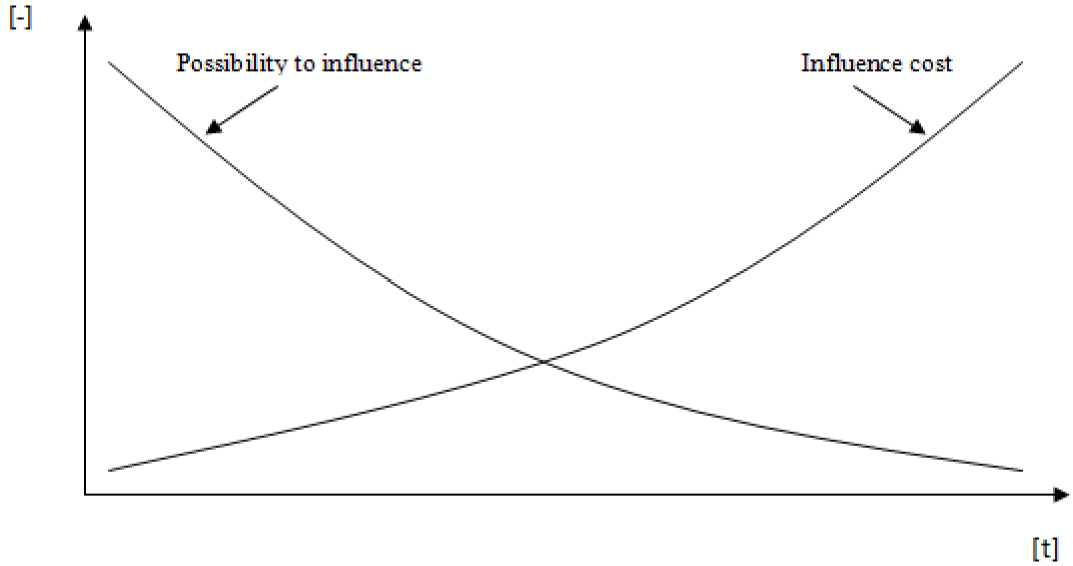

Figure 50 diagram showing the relation between the possibility to influence the project and the corresponding cost to influence the project. (theoretical picture made by author)

Hence, the desire is to be able to be involved in the early stage of a project. This fact is taken into consideration when evaluating Revit MEP as a tool in HVAC design process.

In order to influence the performance and layout of a building basic simulations and calculations is a required step. A necessary measure in order for these simulations and calculations to be carried out is to define a number of essential parameters, these parameters (established in collaboration with Max Tillberg) and how they can be expressed are listed below;

- **Geometry** The exterior shape of the building as well as the interior layout. Relative sizes of varying surfaces etc.
- **Operation** The purpose of the building. Office, residential etc. but also internal activity such as occupancy schemes, amount of people, internal loads etc.
- **Structure** Heavy or light framework, infiltration, materials etc.
- **Demands** Requirements regarding building performance, climate control, comfort etc.
- **HVAC** Choice of technical installation, FTX etc.
- **Location** Geographical placement and orientation.

The complexity of the simulations varies depending of the desired outcome, three examples are given below;

- Geometry optimization
- Heating analysis
- Cooling and energy analysis

The amount of known parameters needed increases along with the arrow.

These have an ascending level of simulation complexity with the geometry optimization as the simplest. The amount of known parameters needed follows accordingly the complexity of the simulation.

In the early stage of a project, often only the approximate shape of the building and the location are known parameters. Theses facts are often enough to perform basic solar and daylight studies and with the outcome of these simulations the geometry of the building can in an early stage be optimized regarding shape, orientation, amount of glazed area in different directions, material propositions etc.

However, for more complex simulations, such as energy analysis, there is a need for more parameters to be known. Although, by experience and the use of statistics, in many cases some of the parameters can be locked and thereby regarded as known, also in the early stage. This is greatly dependable of the type of building the simulations are intended for though, see Table 1 below. (Max Tillberg)

	Operation	Geometry	Structure	Demands	HVAC	Location
Residential	ok	ok	ok	ok	ok	ok
School	ok	ok	ok	ok	ok	ok
Hospital	(ok)	ok	ok	(ok)		ok
Office		ok	ok		ok	ok
Mall		ok	ok			ok
Sports hall		ok	ok			ok
Indoor bath complex		ok	ok			ok

Table 1 Parameters able to lock for different building types, in early stages. The column showing the operation relates to such interior activity as occupancy schemes, amount of people, internal loads etc.

In this chapter an office building will be regarded when analyzing Revit MEP as a simulation tool in the HVAC design process. When studying Table 1 and more specifically the row containing the office, the parameters operation and demands are not locked. A more describing explanation to this is simply the methodology of the workflow in the design process. The HVAC designer can not set the regulations for the operation to be and demand that the operation should be adapted to the functionality of the HVAC technical system, on the contrary the HVAC technical system should be adapted to the operation and in the early stage of a project it might be clear that it is an office building but the details of the sub-ordered internal activity is in most cases relatively unknown. The same reasoning goes for the demand parameter, the HVAC designer's duty is to adapt the technical installations in order for the building to fulfil the demands regarding performance, climate control, comfort etc., and in the early stage these are often not definitive. (Max Tillberg)

In different phases of the design process different simulations and calculations are relevant or possible to perform.

In the *schematic design phase*, most relevant is the simulations which study the impact of the sun, in this report called solar radiation studies. As stated above, there is a desire to be able to perform energy calculations already in this early stage although it is in contradiction to the amount of known input data. However, Revit MEP claims to be able to perform energy estimations in this early stage. By this also energy calculations will be regarded as interesting in this phase.

Simulations and calculations studied in the *schematic design phase,* see Figure 51;

- Solar radiation studies
- Energy calculations (very rough)

In the *preliminary design phase,* the simulations and calculations studied are, see Figure 51;

- Heating (for a major part of the building)
- Cooling (for type rooms)
- Energy calculations (rough)
- U-mean value calculation
- Total airflow calculation

In the *detailed design phase*, the simulations and calculations studied are, see Figure 51;

- Heating (detailed calculations)
- Cooling (detailed calculations)
- Energy calculations (detailed and final calculations)

- Mean U-value calculation (detailed and final calculations)
- Total airflow calculation (detailed and final calculations)
- Daylight simulations
- Air movement

Established in collaboration with Max Tillberg.

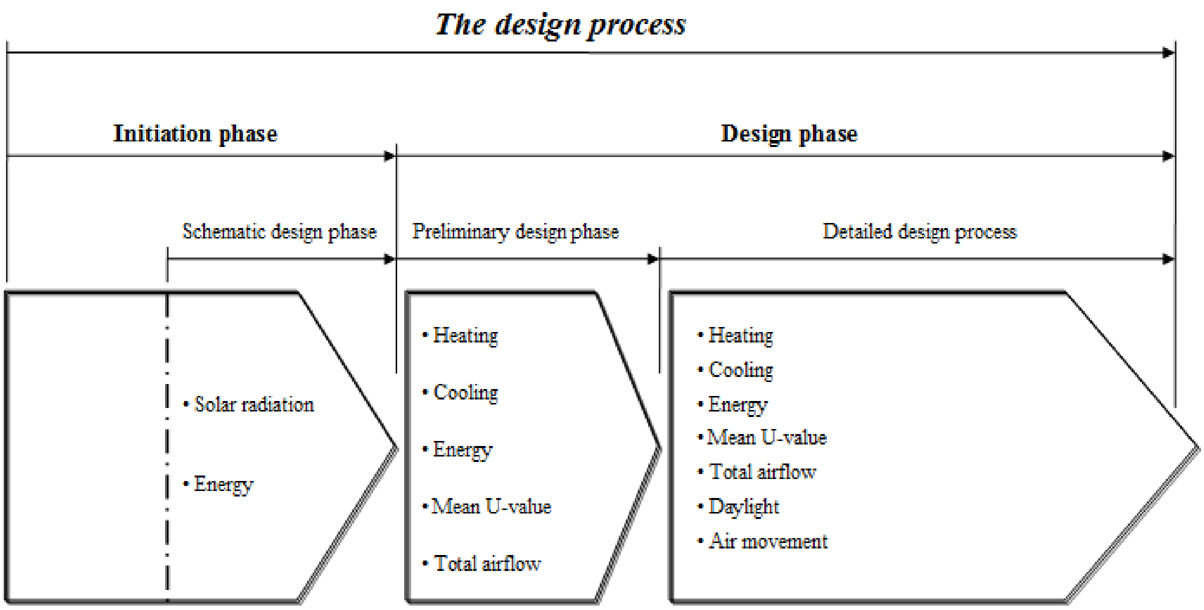

Figure 51 relevant simulations and calculations in each phase of the design process. Some of them occur in several phases, this is due to the constant refining procedure throughout the process, whereas more information is gathered more accurate simulations and calculations can be performed. In the figure also air movement simulations is present, this part however is not treated in this report. (picture edited by author. Original picture by Wannheden, 2000)

Of the simulations and calculations listed in Figure 51, if only focusing on the actual capability, i.e. disregarding the credibility of the result, some of them can be performed with Revit MEP while for some there probably is other software better suited for the specific task.

Next the listed simulations and calculations in Figure 51 will be reviewed and the usability of Revit MEP will be evaluated.

Solar radiation

As stated above early solar studies are performed with the purpose to optimize the shape, orientation, glazing etc. of the building. In Revit MEP solar studies can be performed with the use of "add-ins", either by the use of the Autodesk Solar Radiation Technology Preview (ASRTP) described in chapter 3.3.2 or by the use of another Autodesk technology preview called Project Vasari. The ASRTP has expired at this moment and the expiration date of Project Vasari is set to May 2011. Hence, the actual outcome of these technology previews is yet to be seen. There are other software's on the market suited for this specific task, such as EcoTect software's, but these previews are the ones with the tightest integration with Revit.

As for the result, the credibility of it will have to be up to individual judgement but a more thorough review of ASRTP is provided in chapter 3.3.2.

The conclusions in this report of ASRTP is that it is a tool with limitations regarding the usability in the HVAC design process and it is indeed a tool suited for early estimations but for more accurate simulations further on in the design process it is not reliable enough.

Heating

In this report the heating is regarding the dimensioning of the heating system due to transmission losses. For this task Revit MEP can contribute with its internal load calculation feature "Heating and cooling loads", reviewed in chapter 3.3.3. With the appropriate settings, such as radiators for example, Revit MEP should with this feature be able to perform this kind of transmission loss calculation, at least in the preliminary design phase. In the load report generated by the analysis the transmission losses are listed for each building component, see Figure 52.

Components	Cooling		Heating	
	Loads (W)	Percentage of Total	Loads (W)	Percentage of Total
Wall	463	10.23%	2,078	62.37%
Window	460	10.16%	93	2.80%
Door	14	0.31%	156	4.67%
Roof	241	5.34%	1,005	30.16%
Skylight	0	0.00%	0	0.00%
Partition	0	0.00%	0	0.00%
Infiltration	0	0.00%	0	0.00%
Ventilation	0	0.00%	0	0.00%
Lighting	1,137	25.13%		
Power	1,551	34.28%		
People	658	14.55%		
Plenum	0	0.00%		
Fan Heat	0	0.00%		
Reheat	0	0.00%		
Total	4,524	100%	3,331	100%

Figure 52 the transmission losses generated by the "Heating and Cooling Loads" analysis feature in Revit MEP. (picture extracted from Revit MEP 2011)

The MagiCad application in Revit MEP does not contain any feature for this purpose, if MagiCad is to be used for this purpose an export via IFC to MagiCad Room is necessary (Johan Sörensson[14])

Otherwise calculation methods performed by hand are to recommend.

Thereby the conclusion in this report is that Revit MEP is capable of calculating the transmission losses through the building components. However it should be up to each user to independently evaluate the result since the calculation method is rather concealed.

Cooling and Energy

The most essential simulations and calculations in the HVAC design process are the ones treating the cooling demand and the energy consumption, much more complex than the solar radiation and the heating and involving, besides these two, parameters such as internal loads, air infiltration, building structure etc. Traditionally these tasks are performed initially in the preliminary design phase and then refined and finalized in the detailed design process, see Figure 51. In order to produce reliable results these parameters must be known or at least able to "lock", as explained above.

Interesting is that Revit MEP, with its internal feature "Heating and Cooling Loads", somewhat claims to be able to perform cooling and energy analyses already in a very early stage. As described in chapter 3.3.3. the calculation method used is to simple for the performing of accurate and detailed simulations in the later phases of the design process, it can possibly be used in the early stage, such as the schematic design phase, as a kind of rough estimation and as a hint of how to optimize such parameters as building shape, orientation, glazing, materials etc.

The contradiction for this kind of reasoning is that in the "Heating and Cooling Loads" analysis in Revit MEP all of the parameters involved in these kinds of analyses have to be properly set in order to carry out the analysis, partly visualized in Figure 37. In the early stage some parameters simply can not be properly set, as explained in Table 1. The outcome is that Revit MEP performs analyses on dubious grounds. With this in mind, the lack of calculation transparency should also be respected. The fact that the assumptions and simplifications made are concealed further increase the insecurity of the result.

The conclusion in this report is that for cooling and energy analysis Revit MEP could possibly be used in the early stage, such as in the schematic design phase, with the purpose of providing early estimates of energy consumption but mostly for comparing designs and thereby optimizing the building as described above. For cooling and energy simulations

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[14] Johan Sörensson, CADCOM AB, personal communication by telephone 2010-12-07.

further on in the design process where more accurate and reliable results are required, Revit MEP is not recommended.

Other software's on the market adapted for the purpose are IDA Indoor Climate and Energy, VIP+, IES Apache et al. (Max Tillberg)

Mean U-value calculation

The mean U-value calculation is a rather simple procedure. If the compositions of the building components are known, and thereby the U-values, it is only a question of adding areas and U-values, taking thermal bridges into consideration and divide by the envelope area, see Equation 1.

$$U_m = \frac{\sum U_i \times A_i + \sum \psi_i \times l_i + \sum X_i \times n_i}{A_{env}} \qquad \textit{(Equation 1)}$$

Equation 1 the methodology when calculating the mean U-value of the building. (Swedisol)

Where:

U_m = Mean U-value [W/m^{2}K]

U_i = Individual U-Value of construction part [W/m^{2}K]

A_i = Individual area of construction part [m^2]

Ψ_i = Linear thermal bridge [W/m^{2}K]

l_i = Distribution of linear thermal bridge [m]

X_i = Point-shaped thermal bridge [W/m^{2}K]

n_i = Amount of point-shaped thermal bridges [-]

Revit MEP should be capable of this kind of calculations since the area and U-value information is resident in the 3D model. The most obvious mode of operation for the solving of this task in Revit MEP would be to use the schedule feature in combination with some manual formula management. Unfortunately, according to my research, it seems like Revit MEP is incapable of performing this task. There seems to be no way to match specific areas to corresponding U-values, actually it seems like any kind of U-value calculating is excluded other than in the “Heating and Cooling Loads” analysis.

The fact that Revit MEP is not a suitable tool for this task is also confirmed by Fredrik Berg, CityDATA Future Cad in Sweden AB.

Thereby the conclusion in this report is that Revit MEP is not a tool suited for this kind of operation.

Total airflow

This task is divided into three main areas to analyze, first of all if it is possible to get the total air flow of a system and also the concept of “*sammanlagring*”, the Swedish expression for the case when consideration is taken to the fact that the system is not dimensioned for the total theoretical airflow due to the probability that all air terminal devices are running on max at the same time. This enables the system to be under-dimensioned, preferentially by a factor less then one.

In Revit MEP it is possible to get the total airflow, either from the project browser or by the schedule feature. It is also possible in the schedule feature, by adding an extra parameter for the under-dimensioned value where the original flow is multiplied with a factor less than one, to calculate the under-dimensioned value, see Figure 53. The schedule has to be filtered in order to show the flow for each system, otherwise supply air and extract air will be summed together.

Air Terminal Schedule			
magiProductC	System Name	Flow	Sammanlagring
DVHA-160	Supply Air 1	50.0 L/s	30.0 L/s
DVHA-160	Supply Air 1	50.0 L/s	30.0 L/s
DVHA-160	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
VFKA-250	Supply Air 1	50.0 L/s	30.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
COLIBRI C	Supply Air 1	30.0 L/s	18.0 L/s
Grand total: 51		2390.0 L/s	1434.0 L/s

Figure 53 schedule showing the airflows of the air terminal devices. The column named flow shows the original supply air flow and the column named sammanlagring shows the original supply air flow multiplied with a factor 0,6. The bottom row shows the total amount of devices, the total original supply airflow and the total under-dimensioned air flow. (picture extracted from Revit MEP 2011)

The next step is to analyze if the under-dimensioned value can be tied to calculations, for instance the calculation of pressure drop.

Unfortunately it seems like the under-dimensioned value presented in the schedule in Figure 53 is for visualization only. However there is a work-around in order to get the under-dimensioned value as the current air flow in calculations. By editing the family properties of the air terminal devices the dimensional air flow used in calculations can be arranged. In order to arrange this dimensional air flow two new parameters has to be added, one representing the total air flow in the system and the other parameter as a coefficient. In order for the under-dimensioned air flow to represent the value used in calculations the two created parameters will be assigned to the dimensional flow field as total air flow times the coefficient. Note that this is a procedure necessary for each type of family involved. (Håkan Wikemar[15])

For a more thorough guide see Appendix C.

In addition to this it is desirable to use the under-dimensioned value for selected parts of the system, such as in the main branches while it desirable to use the original value for the air terminal devices.

[15] Håkan Wikemar, AEC AB, personal communication by telephone 2010-12-09.

There seem to be no smooth mode of operation for alternating of air flows used in calculations. The option seems to be to manually perform the above described procedure each time and by turns activate and deactivate the created parameters.

Thereby the conclusion is somewhat double-edged, the total air flow and the under-dimensioned air flow can both be scheduled and used in calculations. The question is if it is a reasonable procedure in the design process, also the reliability of the result is uncertain since it not seems possible, on a likely level, to adapt the dimensional value to different regions in the system. However it is a positive feature and a step in the right direction. As before, users have to independently evaluate the reliability of the outcome when using this feature in Revit MEP.

Regarding the MagiCad-application in Revit MEP there is no way to calculate with some kind of “sammanlagrat”, or under-dimensioned, air flow. (Johan Sörensson, 2010-12-07)

Daylight

Daylight studies are performed mainly in the detailed design phase with the purpose to analyze the amount of daylight entering at different sections of the building. In Revit MEP there is no internal feature intended for this operation, in order to carry out these kind of simulations the Revit model has to be exported to an external software developed for this specific task, for instance Velux Daylight Visualizer 2 which is treated in chapter 3.3.2.

Thereby the conclusion in this report is that Revit MEP is not a tool capable of performing daylight studies, however the geometry can be exported to external software’s in order for this task to be carried out.

Summarization of Revit MEP as a simulation and calculation tool in the HVAC design process

This part of the chapter will put the evaluation of Revit MEP as a simulation and calculation tool in context to the HVAC design process and visualize it by the use of Figure 51 above. The simulations and calculations able to perform with Revit MEP is highlighted with a *green* colour, the ones able to perform with Revit but with questionable outcome is highlighted *yellow*, the ones requiring some kind of export is highlighted *light blue* and those not suited for Revit are *not highlighted* at all, this is visualized in Figure 54.

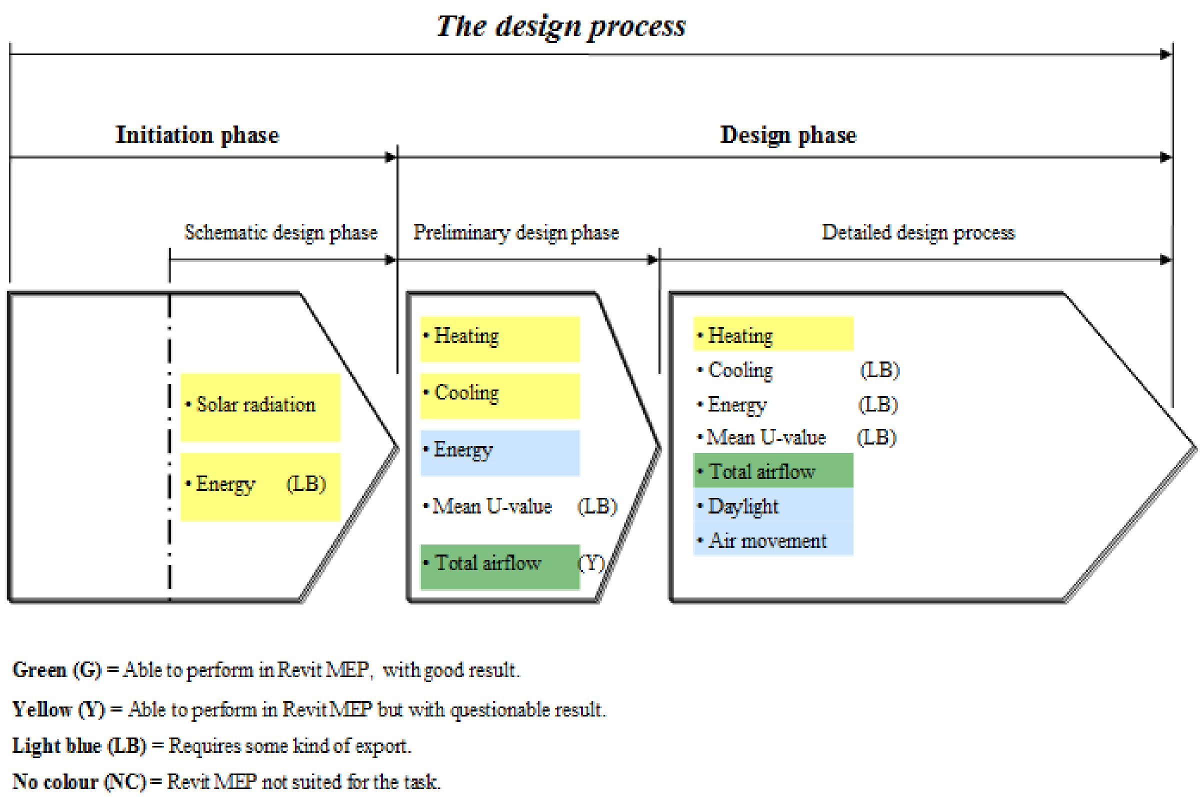


Figure 54 summarization of the evaluation of Revit MEP as a simulation and calculation tool in the HVAC design process. Due to the complexity and varying accuracy of simulations throughout the process in combination with the user knowledge of the software and the intended use some evaluations are complemented, letters within brackets. I.e. two alternatives are suggested. (picture edited by author. Original picture by Wannheden, 2000)

The conclusion of Revit MEP as a simulation and calculation tool in the HVAC design process is that its major contribution is in the early design phase where very rough estimations are performed. Later on in the design process where more accurate results are needed Revit MEP is not a very suitable tool, partly due to the simplified calculation method and partly due to the lack of transparency regarding the calculations.

4.3.7 Schedules

As described in chapter 3.4.1, Revit MEP possesses a rather rationalized feature regarding the producing of schedules and quantities lists.

Further analyses will have to reveal possible down-sides with the feature but the conclusion in this report is that the feature in Revit MEP should be used for this specific task.

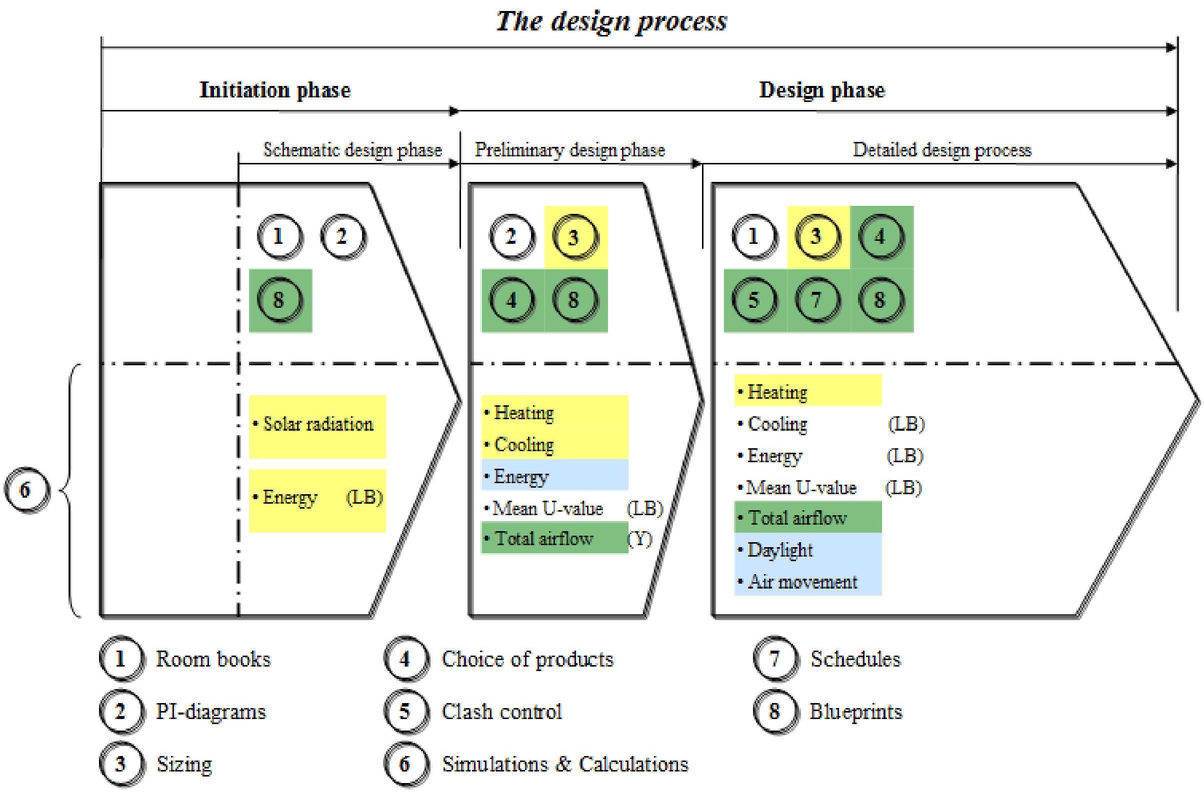
4.3.8 Blueprints

As described in chapter 3.4.2, Revit MEP possesses a rather rationalized feature regarding the producing of blueprints, called sheets in Revit.

Further analyses will have to reveal possible down-sides with the feature but the conclusion in this report is that the feature in Revit MEP should be used for this specific task.

4.4 Summarization of Revit MEP as a tool in the HVAC design process

This chapter will put the rest of the evaluation of Revit MEP as tool in context to the HVAC design process, along with the simulation and calculation part evaluated in chapter 4.3.6.1. The total evaluation is visualized in Figure 55.



Green (G) = Able to perform in Revit MEP, with good result.
Yellow (Y) = Able to perform in Revit MEP but with questionable result.
Light blue (LB) = Requires some kind of export.
No colour (NC) = Revit MEP not suited for the task.

Figure 55 summarization of the evaluation of Revit MEP as a tool in the HVAC design process. The lower part of the figure consists of the previously performed simulation and calculation evaluation. (picture edited by author. Original picture by Wannheden, 2000)

By this the final conclusion of Revit MEP as a tool in the HVAC design process is that it for other tasks than simulation and calculation is a rather rationalized and well suited tool, throughout the HVAC design process. However, the simulation and calculation task is the weak link in Revit MEP, regarding this task Revit MEP could possibly contribute in the early stage with rough estimations. It is in the highest degree important to be aware of that simplifications are made in the calculation method, although it is hard to pin-point them due to the lack of transparency regarding calculations.

5 DISCUSSION

The closing argumentation in this report consists of three subject areas:

- Conclusion and discussion
- Vision of adaptation with Revit MEP
- Need for future research

5.1 Conclusion and discussion

First of all it shall be mentioned that following statements in this chapter, if nothing else is indicated, are based on my outermost subjective reflectances and speculations, which are gathered from literature and various conversations with people related to the industry and relevant software's, but primarily from my personal knowledge about the software, gained from the acquaintance with Revit MEP gathered throughout the master's thesis.

The evaluation of Revit MEP as a tool in the HVAC design process performed in this report shows that the introduction of Revit MEP does not revolutionize the HVAC designer's mode of operation in the HVAC design process. On the question if it rationalizes the mode of operation the answer is ambiguous. For the non-simulative and calculative part of the HVAC design process Revit MEP does contribute in a positive manner and actually eases the mode of operation, mainly regarding modeling, revision of model, scheduling etc.

In order for Revit MEP to be a competitive and really useful tool for the HVAC designer there is a need for it to deliver a complete package which can contribute positively throughout the design process, to approach this scenario there is a need to further evolve the simulation and calculation part. The actual presence of some features does not necessarily mean that they should be used or even are useful in all cases, even if they appear to be capable of treating the problem. The Revit MEP feature "Heating and Cooling Loads" analysis is such a feature. It is clearly a feature which **possibly** can be used in the early design stage in order to optimize parameters such as orientation of the building and amount of glazed areas in different directions etc. It is n not clearly stated that the feature is limited to the early design stage, on the contrary it provides settings on a level which easily could persuade less informed users to believe it as a provider of accurate information about cooling and energy consumption designated in the detailed design phase.

As far as I see it, since Revit MEP is a software developed more or less for the HVAC industry it should also contribute throughout the entire HVAC design process, the HVAC design process does not end with estimations in the early stage. It should be possible to produce accurate results in the detailed design phase as well as rough estimations in the early design phase in order to be a truly useful simulation tool. This is not the situation today.

The ideal scenario would be if Revit provided an internal feature for each procedure performed in the HVAC design process, preferably the ones represented in Figure 55, with the possibility to adapt the accuracy of the calculation depending on current phase in the process.

Another disappointing detail regarding Revit MEP as a tool to achieve BIM, is that information defined in the 3D model has to be redefined in the energy analysis feature. This may seem as a minor detail but with a variety of type rooms with varying material compositions it is a time consuming effort, this detail should be subject for development. This further denotes the "Heating and cooling Loads" as a feature merely for the early stage of the design phase.

The expression above in this text regarding that Revit MEP should be able to contribute in all procedures throughout the HVAC design process is a desire, however it should be mentioned that this is in the strive for the ultimate HVAC designer tool. Although it may be a somewhat unrealistic vision as it would influence the very core of the calculation engine in Revit MEP, it would require a radical upgrade of the calculation method used today. A critical and limiting factor for this scenario to become reality is probably the computer performance available today and in the near future.

Autodesk continuously releases new features and "add-ins" in order to rationalize Revit MEP as a tool for the HVAC engineer and this is indeed welcome, however as long as they keep the actual calculation procedures hidden the simulation and calculation features will remain relatively uninteresting.

In text above, criticism has been addressed to the simulation and calculation features in Revit MEP but the fact is that this is actually the only area where criticism is legislative. For most of the remaining procedures in Figure 55 Revit MEP contributes to rationalize the HVAC design process. Such areas where Revit as a total really shines are first and foremost the object oriented 3D modeling strategy which to a great deal simplifies the mode of operation regarding modifications in the model and as a spin-off to this the scheduling and blueprint features are highly developed and represents Revit brilliantly as a tool to move towards BIM in the building industry. Minor flaws may figure also in these features but the foundation is laid and with the appropriate adjustments it is a very competitive tool.

Another interesting spin-off effect of the tight integration in work flow between disciplines, which is enabled due to the BIM approach, with the use of Revit is the concern of copyright and ownership, both regarding models and more specific constructions parts in models. It is not obvious who has the right to make modifications in models and model parts. This subject is not treated in this report but it is doubtlessly a matter that has to be encountered.

The final conclusion is that Revit is a tool that contributes to rationalize the building process in many aspects; modeling, modifications, scheduling, producing of blueprints etc. Although these are procedures common for each of the Revit editions. Significative for Revit MEP are the simulation and calculation features and unfortunately these do not contribute very much to the rationalization of the HVAC design process.

Regarding the transfer of information between Revit and third party software, the geometry is in most cases transferrable. However information and result management on a two-way basis is rare, except in the add-ins created by Autodesk which are representative for the ideal behavior of information exchange when working with Revit MEP.

It will be of great interest to follow the development in the future as more of the third party software's will be integrated with Revit and as Autodesk continuously releases new features and probably the aim expressed above will be approached. Every step towards this is welcome and with a tight cooperation between Autodesk and the HVAC engineer's in the development of new features it is possible to move towards these desires.

5.2 Vision of adaptation with Revit MEP

The concept of BIM is in most aspects an up-to-the-minute topic. There are expectations within the building industry that Revit is the tool to achieve this concept. However, in order for Revit to be a useful tool in the HVAC design process and contribute to a more effective mode of operation, it needs to ease the procedure regarding the HVAC design process.

Listed below are some essential features and the desire is that Revit MEP should be able to accomplish these in order to be a competitive tool and rationalize the HVAC design process.

This list is compiled in collaboration with Max Tillberg at Bengt Dahlgren AB.

Application handiness:

- The main function and desire with the program should be to use existing information in different operations, i.e. no need to redefine already defined information.

    - U-values and structure compositions defined in 3D model is "re-used" in simulations and calculations.

- Not depending on export in a physical way in order to perform calculations and simulations, i.e. integrated use of third party software without leaving Revit.

  - Tighter integration of third party software's in the Revit environment and more effective features developed by Autodesk.

- The information and result should be clear and easy accessible, both in a detailed and in a more general case.

  - Information management on a two-way basis.

- When it is necessary, there should be a smooth operation regarding import/export of IFC and Green Building XML. Revit should be capable of handling the same amount/degree of information as is possible to be transported via IFC and gbXML.

- Revit as an information reservoir, with the ability to store desirable information but also the option to add posts with optional content.

- Quality assurance

  - Signature

  - Check lists

Transparency:

The desire is to be able to overview and influence the calculation process. From a responsibility point of view and in order to secure the quality this is important. In order for a simulation and calculation tool in Revit MEP to even be an alternative the two points below are of the outermost importance.

- Where, in which software is the calculation performed?

- What happens in the calculation process?

  - Which calculation model is used?

  - Which parameters are considered?

Flexibility:

- Integration, preferably on a two-way basis, with relevant third party calculation and simulation software. This means the result generated from outside software should be able to implement back into Revit.

- The possibility to influence and “manipulate” the result from the calculation process. For example, Revit automatically adapts, or proposes, a fitting system to current demand.
- It should ease the overall process when it comes to modification of the model.

Visualizing

- A desired function in Revit MEP is the capability of the program to visualize results from calculations or simulations in some kind of colour scale with representative values. In this way the result is easy accessible for all parts, especially when used in presentations.
- Revit MEP alarms the user of modifications which should cause an upgrade of the calculation.

5.3 Need for future research

The introduction of Revit and the inevitable BIM approach of it is in a global aspect positive as it enhances the cooperation between disciplines and overall simplifies the mode of operation. At least this is the official persuasion, it might sound nothing but beneficial on all instances in theory but in practice several concerns are arising.

A major concern is the copyright and ownership issue. The owner of the actual model might be solvable but as an effect of the tight integration in the modeling procedure a modification will have a direct effect on not just your own model but also on other disciplines involved and their models and calculations. This reveals the issue with who actually has the right to make modifications in models used by several disciplines and how this is treated.

A good example representing this issue is the question of who is responsible for a window. Windows are composed by a variety of materials with corresponding properties whereas the responsibility of each of these properties is assigned to different disciplines. But who is responsible for the actual window?

Another issue is the work flow between disciplines throughout the project. What is the optimum mode of operation? Which is the optimum procedure when varying software platforms are utilized?

These are not issues with an obvious answer, hence it would be an interesting follow-up to this report.

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Revit MEP User Assistance, internal help feature in Revit MEP.

Personal contact (E-mail, telephone, interview etc.):

Camilla Pettersson, Swegon AB.

David Malmgren, Chief Executive at CADCOM AB.

Fredrik Berg, Building/Technical Chief at CityData Future CAD in Sweden AB.

Hans Johnsson, Equa Simulation AB.

Håkan Wikemar, AEC AB.

Johan Sörensson, CADCOM AB

Johannes Dursun, Sweco AB

Kai Bingström, Lindab AB

Mats-Ola Rasmusson, Structural Design Software in Sweden AB.

Mattias Torberntsson, Bengt Dahlgren AB.

Max Tillberg, Bengt Dahlgren AB.

APPENDIX A – README FOR THE "ASRTP" FOR REVIT 2011

This text is authored by Autodesk and accompanies the software "Autodesk Solar Radiation Technology Preview" as a textfile.

"Limited Term Release

This technology preview is a limited term release to seek customer feedback on its performance and expires on November 5th 2010.

We look forward to receiving your comments at labs.revit.ecotect@autodesk.com. Please visit Ecotect Analysis and Revit product pages for updates and more information.

To uninstall the add-in:

> For Windows XP, go to Start > Settings > Control Panel > Add and Remove Programs.
> From the list select *Autodesk Solar Radiation Technology Preview for Revit 2011* and click "Remove".
>
> For Windows Vista and Windows 7, go to Windows > Control Panel > Programs and Features.
> From the list select *Autodesk Solar Radiation Technology Preview for Revit 2011* and click "Remove".

Components of Solar Radiation

This technology preview calculates and displays *incident solar radiation* on selected conceptual mass faces of Revit models, given the geometry of the model, project location and date/time range. Within incident solar radiation, the *direct* component represents the direct effect of the sun and *diffuse* component is made up from reflections off clouds, moisture and other particulates within the sky. Solar radiation calculations in this technology preview do not include reflections from ground or other elements of the built environment. Furthermore, solar radiation through translucent or transparent surfaces is not considered in calculations.

Calculations for incident solar radiation uses hourly recordings of direct beam and diffuse *horizontal* solar radiation values taken from loaded weather file data. The application automatically obtains weather station data closest to the project location over the Internet.

The application creates calculation points on selected conceptual mass faces. The quantity and locations of calculation points depend on the precision setting. Using a shading mask calculated from every visible geometry in the active view, incident solar radiation on each calculation point is determined and displayed on selected faces using the selected analysis display style.

This technology preview provides fast solar radiation analysis implementing several geometry optimization techniques and taking advantage of multiple core processors.

This technology preview is also a showcase for Revit 2011 APIs: Selection API, Analysis Visualization Framework API, and Dynamic Update API.

Known Issues

- You should save your Revit project before using this technology preview to protect against inadvertent changes and unforeseen problems that might arise.
- Solar radiation analysis cannot be performed on linked masses.
- Imported mass faces are included in solar radiation analysis even when the import category is made invisible. To workaround, delete the imported faces in the model before analysis.
- Selecting faces from multiple 3D views of the same document is not allowed.
- While in selection mode, box selection clears all existing selected faces.
- Gridlines in analysis results do not directly correspond to analysis locations. To see analysis locations, use an analysis display style of text marker type.
- Undo does not clear analysis results. If you need to clean analysis results, select it in Revit view and click the Delete button.
- Analysis legend may disappear after multiple analyses are performed on different selected faces. One workaround is to change display units to another unit and back to the original unit.
- Analysis results may disappear after a mass is modified and an analysis is performed again. A workaround is to click on Analyze button to refresh analysis results.
- When a mass is modified, analysis results update only on active view. If you have other views with analysis results, you will need to activate other views and click on analyze on the Solar Radiation dialog to update those views.
- Analysis results sometimes do not get shown on Revit MEP.

Showing analysis results may affect how shadows are displayed. You may need to refresh the active Revit view to see shadows properly."

Appendix B – The ASHRAE "Radiant Time Series" calculation method

Calculation method – ASHRAE Radiant Time Series (RTS)

The calculation method used in Revit for heating and cooling loads is, according to Kyle Bernhardt, the ASHRAE "Radiant Time Series Method". It is a method suited for the American standards of how to perform climate analysis. It is a simplified method derived directly from the "Heat Balance Method". It relies on a 24-term "response factor series" to generate conductive heat gain and on a 24-term "radiant time series" to convert instantaneous radiant heat gain into cooling loads. (Spitler, 1997)

The method has been developed to offer a non-iterative but still rigorous calculation procedure which takes into consideration each component's contribution to the total cooling load. (Atlanta, Ga. : The Society, 2005)

Assumptions and principles

The basis for the RTS derivation from the "Heat Balance Method" for the design of cooling loads is the assumption of steady-periodic conditions, i.e. the design day's weather, occupancy and heat gain conditions are identical to those for prior days with a repetitive identical 24 hour load cycle basis.

In cooling load calculations, consideration is taken to two time–delaying effects resident in building heat transfer processes:

- Delay of conductive heat gain through opaque massive exterior surfaces (walls, roofs or floors).
- Delay of radiative heat gain converted into cooling loads.

Exterior construction parts conduct heat due to a difference in temperature between interior and exterior environment. Also, solar energy is absorbed by exterior surfaces and transferred by conduction to the interior environment. However, due to material properties such as mass and thermal capacity of the construction part (wall or roof), there is a significant time delay for the heat input at the exterior surface to become heat gain at the interior surface.

Heat energy is transferred to the room by a combination of convection and radiation, where the convective part is directly treated as a cooling load. The radiative part though, must first be absorbed by the interior design and later transferred by convection from this to the room air, in order to become a cooling load. (Atlanta, Ga. : The Society, 2005)

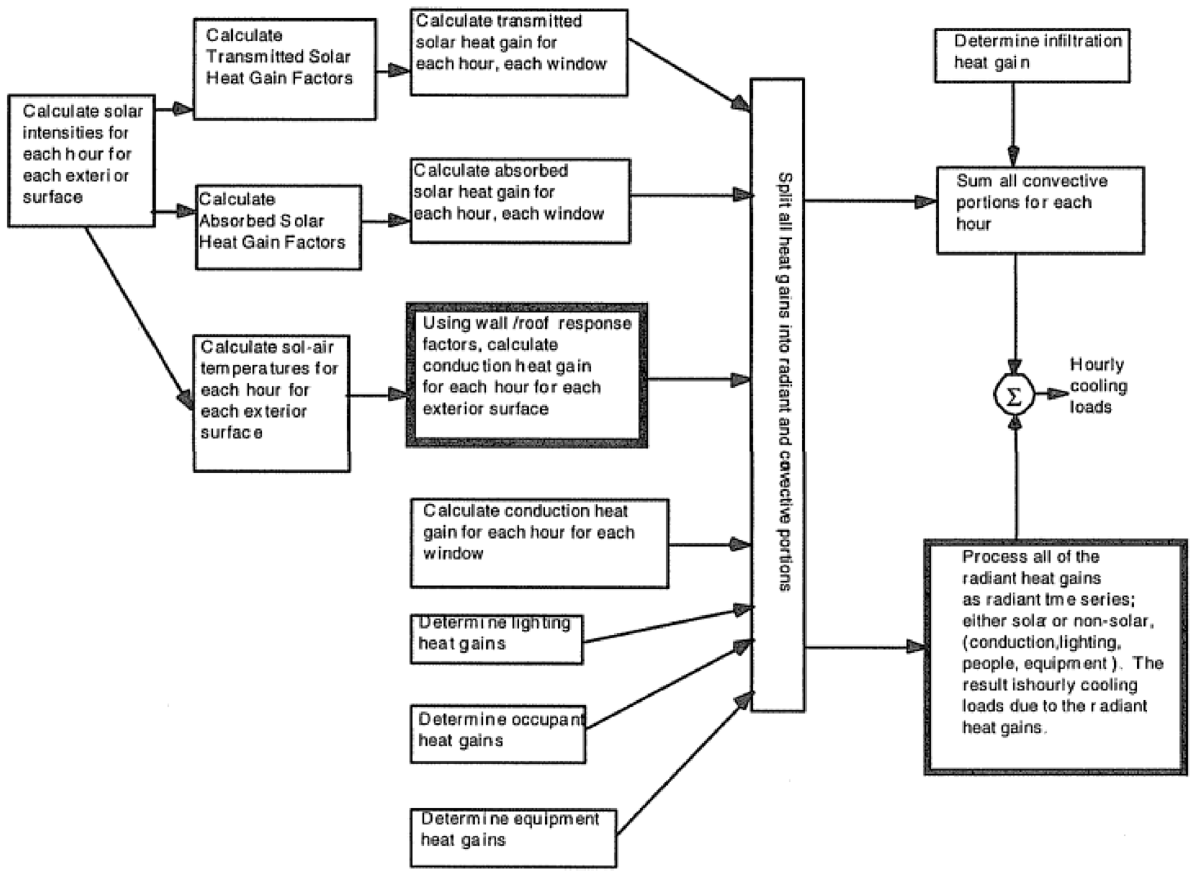

Figure 56 **the principle of the "Radiant Time Series Method". (Spitler, 1997)**

The RTS calculation procedure

The most interesting part in this method and what differs from previous methods is the procedure in the two bold boxes and the splitting procedure in Figure 56.

- Computation of conductive heat gain
- Splitting of all heat gains into radiant and convective portions
- Conversion of radiant heat gains into cooling loads

Basically, radiant time series and wall/roof response factors are decided by the "ASHRAE Cooling and Heating Load Calculation Manual (McQuiston and Spitler, 1992). Two sets of response factors (walls and roofs), two sets of radiant time series (internal loads and solar), sol-air temperatures and solar heat gains must be calculated. The response factors and the radiant time factors are used to calculate the cooling load for the current hour on the basis of current and past heat gains. (Spitler, 1997)

Radiant time factors and conduction time factors reflect the percentage of an earlier heat gain that becomes cooling load during the current hour. Each radiant or conduction time series must equal a total of 100 percent. (Atlanta, Ga. : The Society, 2005)

A summarized calculation procedure where these response factors are included follows below;

- Calculate hourly conductive heat gains using response factors.
- Split hourly conductive heat gains into radiative and convective parts.
- Compute hourly solar heat gains using the standard ASHRAE procedure (MqQuiston and Spitler, 1992).
- Sum hourly internal heat gains into radiative and convective parts.
- Convert radiative part of internal heat gains into hourly cooling loads using radiant time factors.
- Convert solar heat gains into hourly cooling loads using radiant time factors.
- Sum the convective part of conductive and internal heat gains with hourly cooling load from radiative portions and solar heat gains.

In order to get the actual heat gain through exterior surfaces the sol-air temperature is of importance. The sol-air temperature is the outdoor air temperature that, in the absence of all radiation generates the same rate of heat entry into the exterior surface as the combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings and convective heat exchange with outdoor air. This is derived from the following equations:

$$\frac{q}{A} = \alpha E_t + h_0(t_0 - t_s) - \varepsilon \Delta R$$

Where:

α = absorptance of surface for solar radiation, [-]

E_t = total solar radiation incident on surface, [Btu/h*ft^2]

h_0 = coefficient of heat transfer by long wave radiation and convection at outer surface, [Btu/h*ft*°F]

t_a = outdoor air temperature, [°F]

t_s = surface temperature, [°F]

ε = hemispherical emittance of surface, [-]

ΔR = diff. between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temp., [Btu/h*ft^2]

The rate of the heat transfer can be expressed in terms of the sol-air temperature, t_e.

$$\frac{q}{A} = h_0(t_e - t_s)$$

And finally,

$$t_e = t_0 + \frac{\alpha E_t}{h_0} - \frac{\varepsilon \Delta R}{h_0}$$

In order to compute the conductive heat gain the response factor formulation is used, which gives a time series solution to the transient, one-dimensional conductive heat transfer problem. (Spitler, 1997)

$$q_\theta = A * \sum_{j=0}^{23} Y_{Pj} * (t_{e,\theta - j\delta} - t_{rc})$$

Where;

q_θ = hourly conductive heat gain for the surface [W];

A = surface area [m^2];

Y_{pj} = j:th response factor;

$t_{e,\theta - j\delta}$ = sol-air temperature j hours ago [°C];

t_{rc} = presumed constant room air temperature [°C];

Next step is to split the conductive heat gain into radiative and convective parts, see Figure 57. This is a simplification used instead of simultaneously solving for the instantaneous convective and radiative heat transfer from each surface. After splitting, the two heat gain parts can be converted into cooling loads, the convective part can without any further imposition instantly be regarded as a cooling load. The radiative part however, is absorbed by the thermal mass and then transferred to the zone via convection, this process creates a time lag and a dampening effect. (Spitler, 1997)

Heat Gain Type	Recommended Radiative Fraction	Recommended Convective Fraction	Comments
Occupants	0.7	0.3	Rudoy and Duran (1975)
Lighting Suspended fluorescent-unvented Recessed fluorescent -vented to return air Recessed fluorescent -vented to supply and return air Incandescent	 0.67 0.59 0.19 0.71	 0.33 0.41 0.81 0.29	York and Cappielo (1981), pp. II.83-84
Equipment	0.2-0.8	0.8-0.2	ASHRAE TC 4.1 has ongoing research aimed at evaluating the radiative/convective split for various types of equipment typically found in offices, hospitals, etc. In the meantime, use higher values of radiation fractions for equipment with higher surface temperatures. Use lower values of radiation fractions for fan-cooled equipment, e.g., computers.
Conductive heat gain through walls	0.63	0.37	The values presented here are based on standard ASHRAE surface conductances for vertical walls with horizontal heat flow and $\varepsilon = 0.9$ and for ceilings with heat flow downward and $\varepsilon = 0.9$. The computer program used to generate radiant time factors may also be used to generate better estimates of the radiative/convective split for walls and roofs.
Conductive heat gain through roofs	0.84	0.16	
Transmitted solar radiation	1	0	
Absorbed (by fenestration) solar radiation	0.63	0.37	Same approximation as for conductive heat gain through walls.

Figure 57 Splitting guideline for converting conductive heat gain into radiative and convective heat gain.

Regarding the radiative part the radiant time series method converts the radiant part of hourly heat gains into hourly cooling loads using radiant time series. These factors calculate the cooling load for the current hour on the basis of current and past heat gains. (Spitler,1997)

$$Q_\theta = r_0 * q_\theta + r_1 * q_{\theta-\delta} + r_2 * q_{\theta-2\delta} + \ldots + r_{23} * q_{\theta-23\delta}$$

Where;

Q_θ = cooling load (Q) for the current hour (θ), [W];

q_θ = heat gain for the current hour, [W];

$q_{\theta - n\delta}$ = heat gain *n* hours ago;

r_0, r_1, etc = radiant time factors

For detailed information about the procedure for generating wall/roof response factors and radiant time factors see Spitler, J.D., Fischer, D.E., Pedersen, C.O. (1997). *The Radiant Time Series Cooling Load Procedure.*

Conclusion of RTS

The RTS method is a simplified method, not substantially more complex than a hand made calculation procedure. Significant simplifications are made in contrast to more realistic computational procedures.

- The assumption of steady-periodic conditions – the climate information is repetitive on a 24 hour basis. This is not the accurate way according to Swedish approach.
- The method selects the hour with the peak load for the design of the air-conditioning system. This will render in an over sized HVAC system.
- The implication of the sol-air temperature is a substitute for the real treatment of the outdoor radiation. The method is incapable of dealing with radiation in a realistic manner.
- The method relies on estimated radiative/convective splits, instead of simultaneously solving for the instantaneous convective and radiative heat transfer from each surface.

This chain of simplifications is a source for generation of misleading results. It seems like the inbuilt feature "Heating and Cooling Loads Analysis" in Revit MEP is more suitable for making comparisons of the impact when changing parameters like orientation or amount of glass area etc. rather than delivering dependable results to use when dimensioning a system.

In the ASHRAE: Handbook fundamentals 2005 it is stated explicitly that the RTS method generates misleading results in particular cases such as large glazing areas with lightweight exterior envelope. (Atlanta, Ga. : The Society, 2005)

This is a problem since in the new housing estate large glazing areas is the norm rather than the exception.

The RTS method is based on the assumption of continuous operation of the air-conditioning system with constant air space temperature, due to this it is incapable of correctly handling intermittent operation such as turning off the air-conditioning system during night-time. The use of the RTS method could result in largely underestimated design cooling loads. Today most non-residential buildings are intermittent operated. Engineer's usually takes this into consideration by increasing the cooling load by 10 percent. (Mingxian, 2009)

The question is, amongst others, how matters like this are considered in Revit MEP.

APPENDIX C – CREATING NEW PARAMETERS IN FAMILY

The procedure described in this appendix is developed in collaboration with Håkan Wikemar[16].

The analogy when setting the under-dimensioned air flow (sammanlagrat luftflöde) as the dimensioning air flow used in calculations in Revit MEP is that on a family level add new parameters, one representing the maximum air flow and one representing a coefficient smaller than one. The aim is to multiply these two in the field of the dimensional flow used in calculations.

The first step is to right click on an air handling device in the 3D model and choose "Edit Family", see Figure 58.

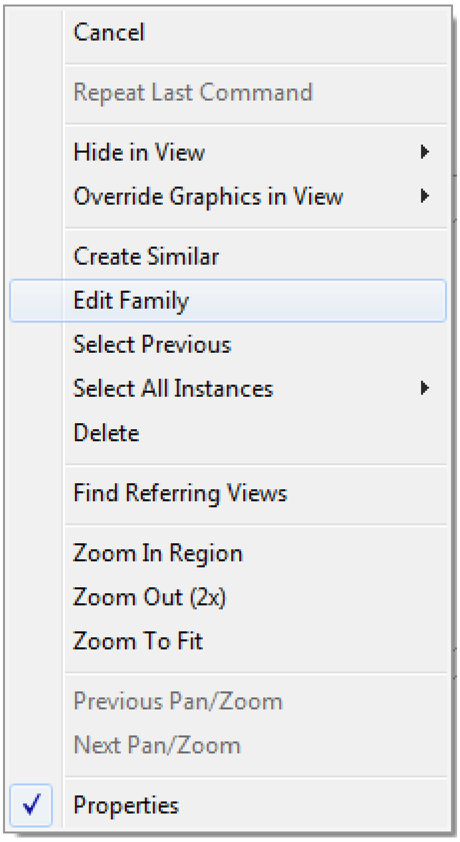

Figure 58 The first step when setting the under-dimensioned air flow as the one used in calculations is to right click on an air handling device and choose "Edit family". (picture extracted from Revit MEP 2011)

[16] Håkan Wikemar, AEC AB.

The next step is to click on the “Family Types” button in the Home menu under the tag properties, see Figure 59.

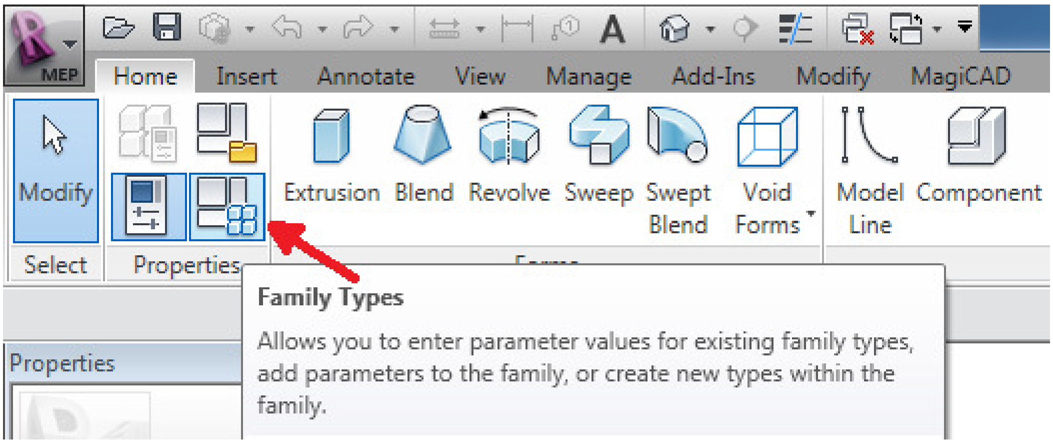

Figure 59 **the second step is to click the ”Family Types” button in the menu. (picture extracted from Revit MEP 2011)**

This opens up the family types window where the governing parameters are accessed, see Figure 60.

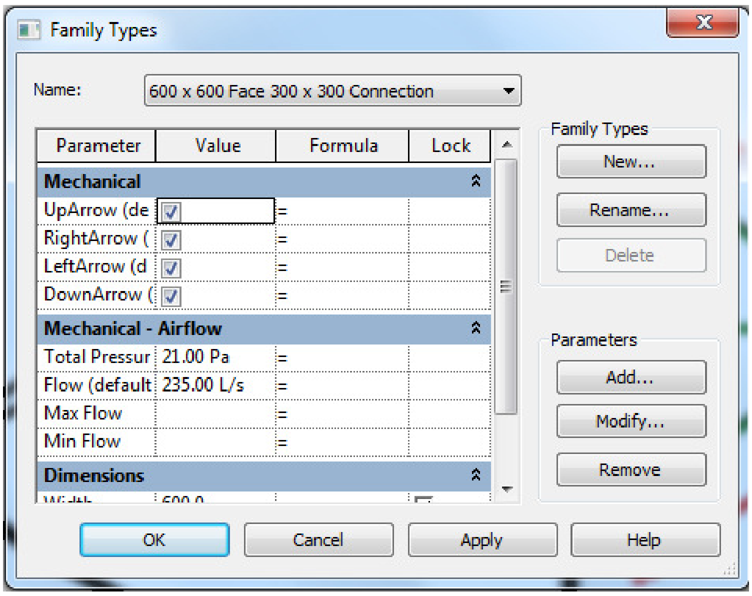

Figure 60 **the governing parameter for the air flow used in calculations is the parameter ”Flow”. This is the original setup before the new parameters are added. (picture extracted from Revit MEP 2011)**

The next step is to add the new parameters, this is done by clicking the “Add…” button for parameters in Figure 60. In the next window “Parameter Properties” Shared Parameter has to be choosen, then click “Select”.

In the next window “Shared Parameters” the “Edit” button shall be chosen. This opens a new window called “Edit Shared Parameters”, in here the “New…” button in the Parameters field shall be chosen.

This new window ”Parameter properties” is where the actual parameters are created. Note that it is different disciplines and types of parameters for the max flow and the coefficient, this is visualized in

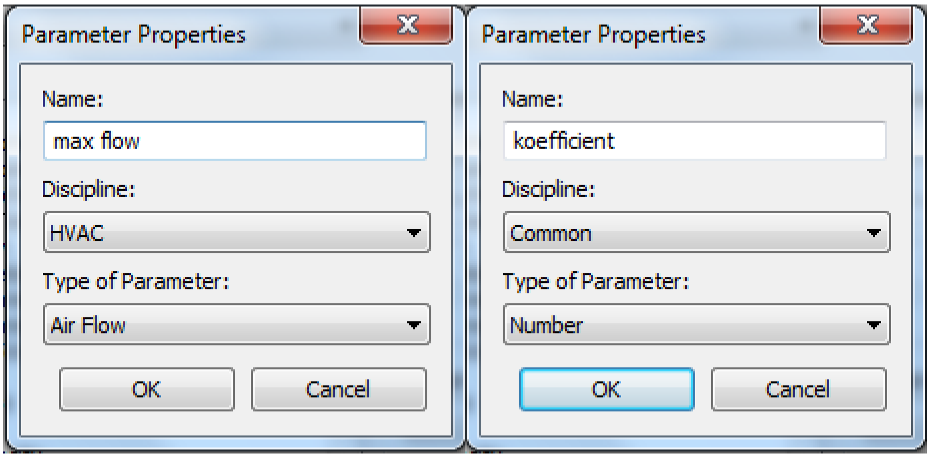

Figure 61 this is where the actual parameters are created. Here they are given names, sorted due to discipline and type of parameter is decided. Here the differences between the two parameters are compared. (picture extracted from Revit MEP 2011)

The next step is simply to add them to the family types window by clicking ok a few times and select them properly. The new “Family Types” window now looks like in Figure 62.

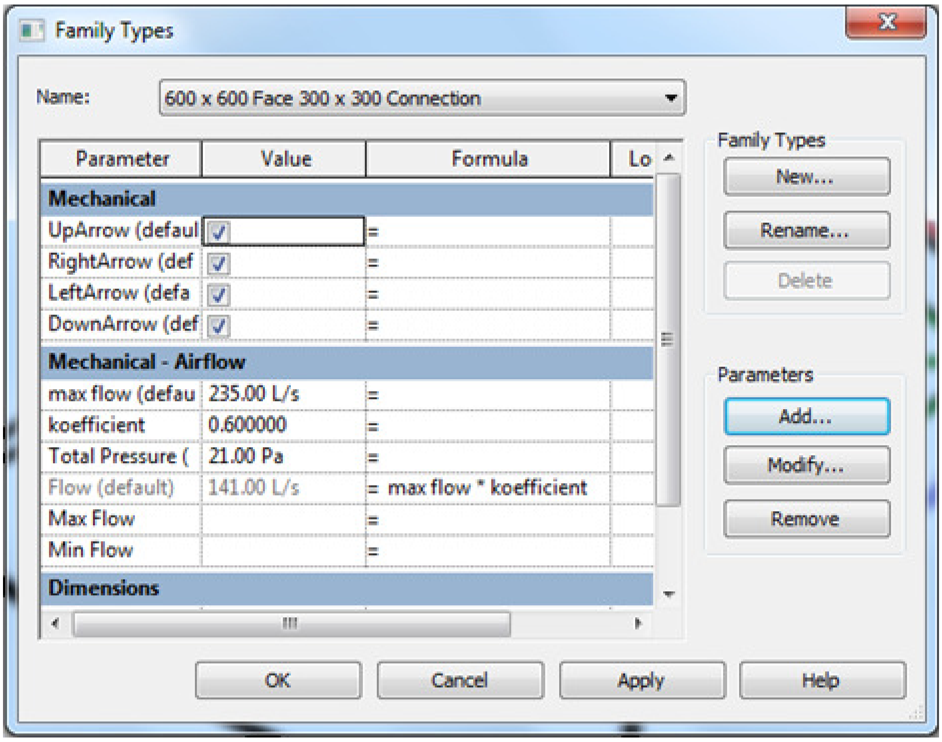

Figure 62 the new parameters ”max flow” and “koefficient” are added. The field used in calculations is “Flow”, here a manual formula is typed in which calculates the under-dimensioned air flow and uses it in calculations. (picture extracted from Revit MEP 2011)