BIM-integrated Design tool for in-line recommended ventilation rates with Demand Controlled Ventilation strategy

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ABSTRACT

Use of Demand Controlled ventilation (DCV) can potentially save more than 50% of energy use for ventilation purposes compared to constant air volume (CAV) ventilation. Correct and updated calculation of preset minimum (V_{min}) and maximum (V_{max}) airflow rates are important to maximize energy saving and to ensure good indoor quality. Furthermore, earlier studies have shown that controlling units' ability to actually handle V_{min} is lacking and causes instability in the DCV systems

State of the art study of leading Norwegian consulting firms documented that use of advanced Spreadsheet-sheets is the common approach for calculation ventilation rates, where the main focus is on V_{max}. This even if use of BIM (Building Information Modeling) is common in this kind of firms.

Based on this knowledge, we have developed a BIM-integrated Design tool for calculation of ventilation rates. This tool defines a method for using specific data for each space within the model as basis for the calculations. By running different scripts, recommended ventilation rates are easily calculated. The tool can save hours of work and ensure correct values in line with changes done during the design phase. The tool has a built-in check of the VAV-dampers ability to control air flow rates from V_{mix} to V_{max}. This will increase the focus on V_{min}, and implemented recommendations are new research-based values. The tool also includes first recommendations on ventilation rates based on CO2 calculations. These calculations will be further developed.

KEYWORDS

BIM, tool, ventilation rates, demand controlled ventilation

1 INTRODUCTION

Demand Controlled ventilation (DCV) has emerged as a dominant ventilation strategy for non-residential building in Norway. DCV has been shown to potentially save more than 50% of energy use for ventilation purposes compared to constant air volume (CAV) ventilation, in the numerous buildings having rooms that are unoccupied for significant part of the operation hours (Mysen, Berntsen, Nafstad, & Schild, 2005) where ventilation rates for unoccupied rooms can be significantly reduced (Halvardsson, 2012).

To achieve the potential energy saving without compromising indoor air quality, correct specification of minimum (V_{min}) and maximum (V_{max}) airflow rates are important. Furthermore, components in the DCV system that are actually able to regulate between minimum and maximum airflow rates without causing instability must be installed.

Norway is a vanguard nation in terms of BIM, taking international leadership in building SMART, and introducing BIM to the Norwegian building sector as early as 2006-2008. Large property owners like Statsbygg have demanded use of BIM modelling since 2010 and the largest consultant firms base their work on use of BIM coordinators (Bråthen, Flyen, Moland, Moum, & Skinnarland, 2016). Nevertheless, calculation of ventilation rates seems to be rather manual and outside the BIM world.

BEST VENT is a Norwegian research project for developing BEST demand-controlled VENTilation strategies to maximize air quality in occupied spaces and minimize energy use in empty spaces. The object of the tool development is design of optimal maximum and minimum ventilation rates as well as DCV dampers, integrated with the BIM tool

2 STATE OF THE ART

2.1 Existing tools in use – focus group discussions

The focus group interview method is well-suited for exploring attitudes and arguments (Morgan, 1997). Selected persons from front running companies were gathered; three consultant firms, one building owner and one contracting firm (real estate developer); to discuss existing practice on calculation tools for ventilation rates, barriers against digitalization and needs for tool development. The participants then addressed the same questions in inhouse expert workshops. For the second round of focus group interviews, discussions were based on collected tools and practice.

The results showed that the existing practice is mostly based on advanced spreadsheets. The sheets reflected minimum requirements for design conditions given in the Norwegian building codes based on internationally agreed recommendations. Some versions include ventilation rates for cooling demands. Calculations were based on floor area, use of materials, design person load and polluting processes in each room. Input data were manually collected from architect drawings and space programming information at an early stage of the project.

Only one of the companies had started testing calculation of ventilation rates based on the Revit model by introducing Dynamo scripts.

The manually practice was reported as time consuming with high risks of later changes in the space program not being reflected in the ventilation rates.

The tools were designed for calculation of maximum rates, there were no focus on minimum rates and suitable dimensions of DCV dampers enabling good regulations. However, the tools normally included calculation of ventilation rates for cooling.

2.2 Identified barriers

Identified barriers for not using BIM integrated tools are:

- No official tool/method is established on the marked
- The advanced use of BIM tools is often done by dedicated users or young and newly educated candidates. Senior staff are often used to 3D modelling but often they have only limited familiarity with all features of newer design tools.
- Programming skills are lacking or limited, and even use of existing scripts can seem difficult.
- Fear of doing something wrong. If the users don't fully understand the procedure, they might refuse to use it.

2.3 Identified gaps and desired changes

Identified desired changes are summed up in the table below. Through the discussions, we experienced that saving time is a benefit of great value for the designers. Digitalisation saves time from time consuming and maybe boring and repeating operations. More time is then left for the skilled evaluation and decision process, often referred to as more fun. Being able to present in-line values seems to be added value and feeling of professional pride. Calculation of ventilation rates based on the model, enables easy updating to correct values after redesign at a later stage.

The practice of calculating minimum ventilation rates, is by this study of tools identified as lacking or missing. Increase focus on minimum ventilation rates is needed as well as control of chosen dampers. will regulate according to demand. for a well-functioning and stabile ventilation system.

Table 1: Identified gaps and desired changes

Today's situation	*Desired change*
Use of separate calculation tools	Calculations within the BIM model
Based on drawing details early design phase	Based on in-line model spaces
Time consuming - hours	Quick – within seconds
Transfer on information manually	No manual transfer of data. Based on data within the BIM model (spaces)
High risk of errors in transfer	Low error risk
Information divided in several tools	All information in one tool – from 3D to 4D
Calculating maximum values Minimum values lacking or missing	Calculating max and min values
No control of suitable choice of damper dimension	Control of suitable damper dimension

Poor regulation and design caused by wrong damper dimension

3 METHODS

3.1 Modelling of output criteria

Based on the state of the art results, following requirement specification was developed for the output:

- The tool should present output in a format recognisable and logic compared to existing tools.
- Both Vmax and Vmin values are calculated.
- Standard calculations and BEST VENT alternative calculations are presented
- User interface should enable user to select values based on calculated values
- Selected values are returned to the BIM model.
- The tool will not include ventilation rates for cooling.
- Control of damper suitability. Control list suitable for building owners. This list return max and min values for each room, as well as a documented control of suitable damper size. This to ensure proper regulation of chosen dampers according to demand for a well-functioning and stabile ventilation system.

3.2 Modelling of input criteria

- The calculations are based on updated input values for each space from the BIM model
- The maximum rates are based on standard calculations for occupied rooms, summarizing ventilation rates needed for material emissions, number of people present and activity, and if applicable – process related ventilation.
- The minimum rates are based on standard calculations for empty rooms, which refer to emission rates for materials.
- For further development, the aim is to look further into calculations based on CO_2 production, and variety in gender and age.
- Damper control is based on chosen damper dimension and air rate. Then duct velocity is calculated to ensure valid values within the dampers operating range.
- The development of the tool is connected to the research project BEST VENT. As results from the research experiments are ready, the calculations will be updated accordingly. Calculating of ventilation rates connected to material emissions and ventilation rates based on CO_2 emissions are in focus.

3.3 BIM integration

The tool should be based on Revit, which is the most used modelling tool in Norway. To perform the calculations, the integrated support tool Dynamo should be used to develop different scripts needed. Calculated values should be returned to the Space and visible at the BIM drawings.

3.4 Calculation methodology – Scripts

When the best practice spreadsheet tools is integrated in BIM, standard spreadsheet calculations are no longer available. Calculations are performed by use of Scripts in the Dynamo tool available for Revit. The developed tool is based on use of Schedules ("Spreadsheet in Revit") and Scripts:

- Collecting space values, like floor area, number of people etc
- Insert standard values for ventilation rates per floor area and persons
- Calculation of ventilation rates
- Returning values to the BIM model.
- Calculation of damper dimension and control
- Establish control scheme for damper suitability

Additionally, prepared for advanced BEST VENT calculations:

- Categories parameters, for calculations of ventilation rates based on CO_2

3.5 Real-case testing

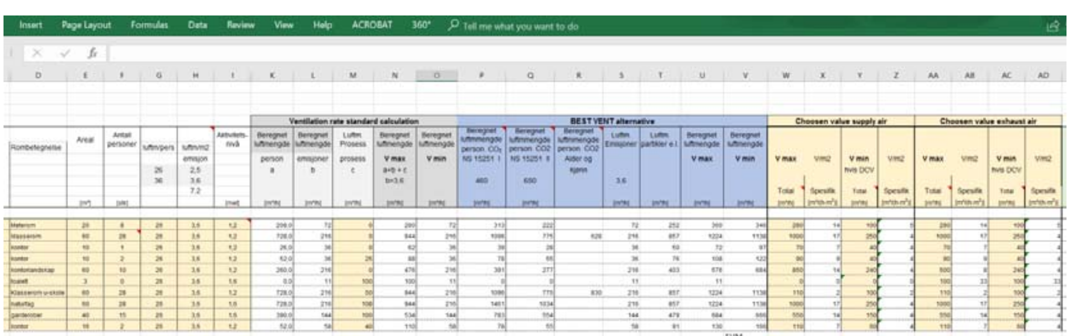
Pre-testing was performed in the development period. Collaborating partners, from the initial used frontrunning companies, were presented to the tool by scripts and demonstrating videos. Smaller on-going building projects are then chosen for testing by real users. Noted reactions after first ½ year testing is reported.

4 RESULTS

4.1 Best practice Spreadsheet tool

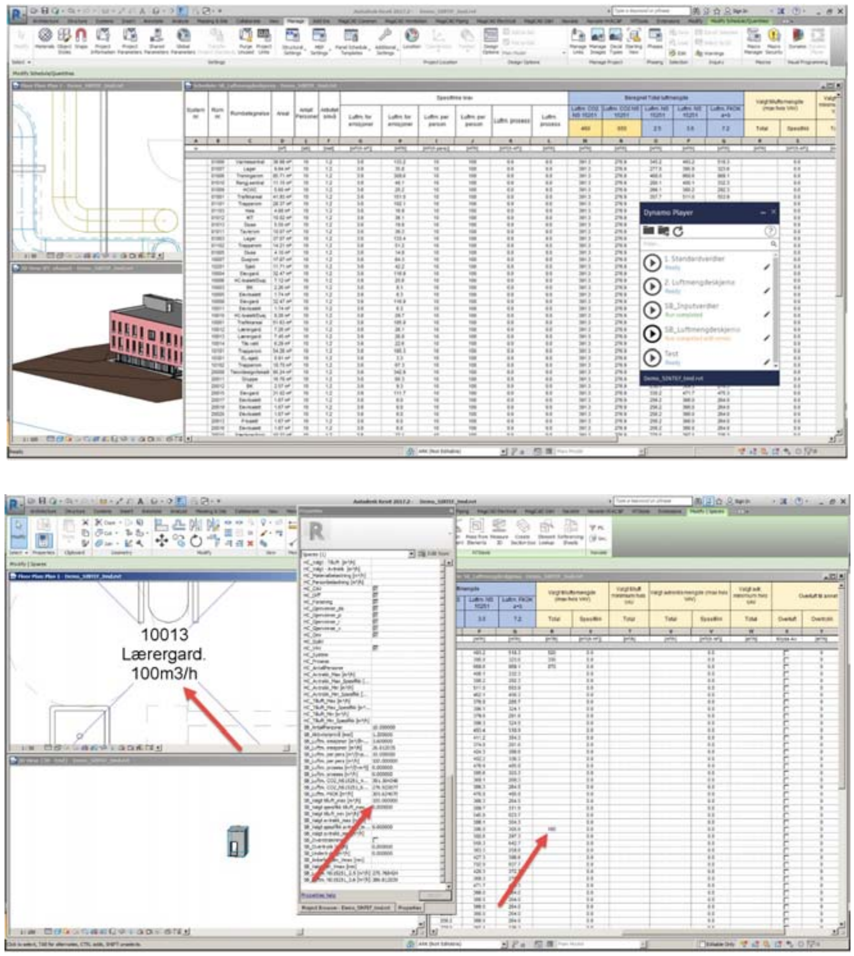
The figure 4.1 below shows the spreadsheet developed based on today's best practice and identified needs. There are two set of calculations, the standard calculation, based on international recommendations and Building Codes (grey), and the alternative BEST VENT calculation (blue). The latter include lower ventilation rates for material emissions, based on research results. It is also including a preliminary calculation of ventilation rates based on CO_2 productions from occupants. The designer can compare and choose the minimum and maximum value for both supply air and exhaust air, included transferred air (yellow).

Figure 4.1. Spreadsheet sheet developed based on best practice and developed BEST VENT 0,9 alternative calculation.



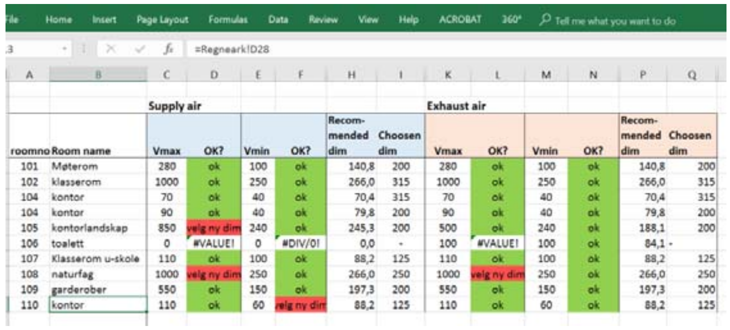
Included in Revit, the result is presented in figure 4.2 as the different Scripts have been run through Dynamo. Chosen maximum values will be returned to the BIM model and visible at drawings.

Fiugure 4.2 a) Calculations using Scripts and b) returning values to drawings



Developed scheme for control of proper damper function is presented in figure 4.3. blue columns represent supply air and red columns exhaust air. Recommended dimension is calculated based on duct air speed, and control of damper based on damper properties for measurements and regulation.

Figure 4.3. Example of scheme for control of proper damper function.

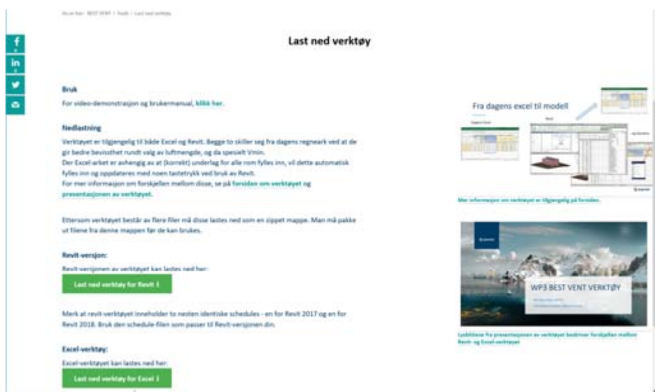


roomno	Room name	Supply air Vmax	OK?	Vmin	OK?	Recom-mended dim	Choosen dim	Exhaust air Vmax	OK?	Vmin	OK?	Recom-mended dim	Choosen dim
101	Møterom	280	ok	100	ok	140,8	200	280	ok	100	ok	140,8	200
102	klasserom	1000	ok	250	ok	266,0	315	1000	ok	250	ok	266,0	315
104	kontor	70	ok	40	ok	70,4	315	70	ok	40	ok	70,4	315
104	kontor	90	ok	40	ok	79,8	200	90	ok	40	ok	79,8	200
105	kontorlandskap	850	velg ny dim	240	ok	245,3	200	500	ok	240	ok	188,1	200
106	toalett	0	#VALUE!	0	#DIV/0!	0,0	-	100	#VALUE!	100	ok	84,1	-
107	Klasserom u-skole	110	ok	100	ok	88,2	125	110	ok	100	ok	88,2	125
108	naturfag	1000	velg ny dim	250	ok	266,0	250	1000	velg ny dim	250	ok	266,0	250
109	garderober	550	ok	150	ok	197,3	200	550	ok	150	ok	197,3	200
110	kontor	110	ok	60	velg ny dim	88,2	125	110	ok	60	ok	88,2	125

4.2 Online availability, user manual and support

The tool is available online (Thunshelle, 2018), both for dedicated collaborating partners and other interested users. Support like user manual, process description, demonstrating video, and Frequent Asked Questions are developed. The different Scripts are available both for Revit 2017 and Revit 2018 versions.

Figure 4.4. Online available tool and support



The tool is presented to building owners and tested by selected designers. The tool is also getting attention from the open audience. Preliminary tests fulfil the identified needs and expectations.

5 DISCUSSION

5.1 Increased focus on minimum ventilation rates

The practice of calculating minimum ventilation rates, is by this study of tools identified as lacking or missing. Use of not suitable components, poor design and regulating is earlier identified as problems in DCV-systems (Mysen, Schild et al 2014). One important purpose of the tool is then increased focus on minimum ventilation rates and ensure use of suitable dampers.

The choice of Vmin has an obvious impact on energy use. So far, there are no scientifically based guidelines for Vmin. For unoccupied rooms, this minimum demand in Norway varies typically between 0,7m/s to more than 2,0 m/s. New studies have shown that with low-emitting materials, Vmin above 1 (l/s)/m^2 have no impact on PAQ (Mysen & Holøs, 2018), and that this level can be used as design criteria. Furthermore, main focus on Vmax as design criteria results in ventilation systems suffering from instability due to poor regulation ability on Vmin (Mysen and Holøs 2018). An increased focus on Vmin in the design phase will improve choice of dimensions, quality in regulation purpose and energy savings.

5.2 Calculation of ventilation rates based on CO_2?

Ventilation rates based on numbers of people present can be discussed. Common practice is Demand Controlled Ventilation based on CO_2 emissions, temperature or a combination of these. This raise the question whether CO_2 is a reliable indicator for ventilation rates, and if the current rate of 7l/s per person is correct. New studies indicate that the CO_2 production varies between gender and age (ref paper CO2 calculations), and that differencing rates should be considered especially for school buildings (Holand & Yang, 2018). The tool is well suited to include these calculations. The tool makes this difference between standard rates and recommended rate based on CO_2 production visible by examples for increased consciousness on the matter. At the moment the tool only includes simple examples on this matter. More advanced calculations based on updated field experiment results are planned for next release.

5.3 Integrated tool

The calculations are based on updated values for each space from the BIM model. This will avoid typical problems like calculations based on too old versions of the architect drawings. The tool allows a more dynamic calculations than todays practice with calculations at an early stage, only recalculating major changes. An integrated tool will eliminate errors, give correct ventilation rates, better regulation and better indoor climate. Designers regard the tool as very useful and understandable, even if it demands use of scripts. Digitalisation of the calculation process have a huge impact on use of time resources and quality. Updated, correct results can be performed within seconds.

5.4 Documented function control.

A critical component in a DCV system is correct dimensioned DCV damper. For correct and stabile damper positioning, proper measurement of air duct velocity is needed. Too large dimension result in not detectable air velocities, fully open damper positions and instabilities in the ventilation system. On the other hand, a too small dimension results in unnecessary energy loss. An increased focus of correct choice of dimension of each DCV damper is necessary, both regarding Vmin and Vmax. The tool therefore also includes a DCV damper control. This can be used both as a control tool for the designer, and as documented function control to the building owner. With the colour system, the problems spots can be identified at a glance, even in comprehensive systems. The tool allows the user to adjust critical air duct velocity to chosen product.

The increased focus on Vmin and documented function control is welcomed especially by building owners. This function control document can be a part of a quality assurance system.

6 RECOMMENDATIONS

The tool represents a large step towards digitalisation of design of ventilation rates aligned with BIM design process. It ensures improved quality in regulation and energy use for the ventilation systems, as well as eliminating time consuming processes. The BEST VENT alternative of the tool is under development, awaiting new results from field experiments. This alternative will be further developed within the next year.

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