Dynamo
+ Revit Systems Analysis
True BIM for HVAC

Sean Fruin
Sigma AEC Solutions

Majid Makhloof
Bird Tools

Learning Objectives

- Discover how to use the new Revit’s Systems Analysis tools.
- Learn how to streamline the process of creating a Revit analytical model with Dynamo.
- Learn how to run HVAC Sizing and Energy Analysis directly inside Revit.
- Learn how to connect 2D schematics to Revit 3D elements.

Description

There is a fair amount of work and settings that need to be addressed to use Revit Systems Analysis effectively. Customizing the workflows requires an understanding of all the moving parts and some coding. This class will help you navigate Revit Systems Analysis features and show the potential for powerful computational workflows for mechanical engineers.

Speaker(s)

Sean Fruin is a Mechanical Engineer (EIT), design technologist, and innovator who has an intense fascination with automation and the exploration of computational design solutions for the AEC industry. He has had the opportunity to learn many aspects of the design industry, having worked in manufacturing, MEP designing, and General Contracting. Sean started Sigma AEC Solutions to live his dream, having the opportunity to explore and implement the latest technologies to improve efficiency and increase quality in the AEC industry.

Majid is a Mechanical Engineer and Design Technologist, with a Master of Science in Mechanical Engineering. He is an Autodesk Revit Certified Professional and a member of the Autodesk Developer Network. In January 2020, he founded Building Information Researchers and Developers OÜ, a software development company based in Estonia and providing services for the AEC sector worldwide. He specializes in BIM Management, Autodesk Revit, and AutoCAD Add-in development, both public and custom-developed, Forge web and cloud-based apps, Dynamo Zero Touch Node Packs, and mobile VR/AR applications.
Contents
Learning Objectives ......................................................................................................................... 1
Description ........................................................................................................................................ 1
Speaker(s) ......................................................................................................................................... 1
Intro .................................................................................................................................................. 3

Workflows Frameworks .................................................................................................................... 4

Revit .................................................................................................................................................. 5
Revit Families ..................................................................................................................................... 5
Revit MEP Systems ............................................................................................................................ 6
Rooms ................................................................................................................................................ 7
Space ............................................................................................................................................... 7
HVAC Zones ...................................................................................................................................... 8
Revit Drafting Views .......................................................................................................................... 6
Revit Energy Analysis .......................................................................................................................... 8
Revit Systems Analysis ....................................................................................................................... 8
Open Studio ....................................................................................................................................... 10
Energy Plus ....................................................................................................................................... 11
Dynamo ............................................................................................................................................. 11
Revit API .......................................................................................................................................... 11

Integrated Workflows ..................................................................................................................... Error! Bookmark not defined.

Workflow Intro ................................................................................................................................. Error! Bookmark not defined.
Project Template ............................................................................................................................... Error! Bookmark not defined.
Project Set Up .................................................................................................................................. Error! Bookmark not defined.
Space Set Up .................................................................................................................................... Error! Bookmark not defined.
Energy Model Set Up ........................................................................................................................ Error! Bookmark not defined.
Space Calculation ............................................................................................................................. Error! Bookmark not defined.
System Zoning .................................................................................................................................... Error! Bookmark not defined.
Schematic Diagrams Set Up .............................................................................................................. Error! Bookmark not defined.
Mechanical Systems Set Up ............................................................................................................ Error! Bookmark not defined.
Analytical System Set Up .................................................................................................................. Error! Bookmark not defined.
Building Energy Model Data Import ............................................................................................... Error! Bookmark not defined.

Errors and Debugging ..................................................................................................................... Error! Bookmark not defined.

Outro ................................................................................................................................................ 11
Intro

With exponential improvements in computer power and huge advancements in computer science, data-driven and computer science approaches have reshaped countless industries. Fueled by frustration with the status quo and ease of entry to coding with graphical programming languages, the AEC industry is starting to see this shift.

Autodesk loves showcasing Design Automation, Generative Design, and Machine Learning; these popular topics and buzz words show up in social media, conferences, and graduate papers. As early adopters start to incorporate data-driven workflows into the old manual process, the proof of concept is there. However, implementing these perfectly splendid workflows at scale across teams is difficult, leaving firms confused about how to automate their processes.

The AEC industry has seen an emergence of companies working hard to monetize design automation with simple, intuitive tools; however, these solutions are doomed to fall short of being a one-stop-shop for fully automating large portions the design process. It is incredibly challenging to assemble enough code to cover all the fine details in the countless different building codes governing the industry. As algorithms get more specialized with building types, geographical locations, and governing bodies, the tool's market gets smaller, and the program gets more complicated. For instance, the algorithms used to fully design an HVAC system for a San Francisco high rise will fail at meeting the requirements for a school in New York. With an estimated 1300 different building codes governing the US's design logic alone, firms will be doing a disservice waiting for the third-party solution that is a perfect fit for their design problems.

That brings us to the love-hate relationship with Autodesk, with a monopoly in the market and perpetually increasing subscription services of the AEC Collection suite of software. The justification of the rising costs is a complete design and documentation workflows across a construction project lifecycle, interoperability between all required software, and access to cutting edge generative design capabilities.

On the surface, Revit falls flat on delivering that promise. First, Revit has its limitations and has a very tedious user interface. New features are still designed and executed with the point-and-click mentality from its predecessor, AutoCAD. Virtually all training videos and documentation are demonstrated with manual clicking and dragging workflows. Second out of the box, the program only does basic workflows. Interoperability between tools falls short, the supplied example content is rubbish, and there are only a few simple fundamental generative design workflows. Third, as more and more features get added, Revit is becoming progressively more fragmented, scattered, and mysterious. All of this is leveling designers confused, frustrated, and defaulting back to old habits. Leading to industry-wide standard workflows where data is entered manually, PDF sheets are the project database, and the start point is virtually a blank canvas.
The solution to this problem is to get under the hood of the programs; with some programming proficiencies, the mysteries to these promising workflows are unlocked, and Autodesk’s plan is exposed. Autodesk’s business model is not to provide its customers with an easy button but rather to provide its customers with frameworks. In computer programming, a framework is a set of general functionalities that users can manipulate for customization. Autodesk’s goal is to provide customers with tools to construct their own automated workflows that can be tailored to their every need. Their tag line is "Make Anything," after all.

In this class, Dynamo and Revit's new Systems Analysis Framework will be used to investigate different automated workflows. Learn how to connect data from different frameworks and get under the hood of the Revit's MEP API to explore different HVAC System configurations, run energy models, and document the design.

**Revit MEP Building Block**

Before one can start to build customized workflows, it is critical to understand the programs’ ins and outs. Revit has an overwhelming number of tools that are built on a variety of different frameworks. Below is a list of the different frameworks, components, and concepts utilized to build the energy modeling workflows. Note, there have been many changes in the last few releases around the energy analysis workflows, and these explanations cover Revit 2021.

**BIM**

The first key concept in the integrated workflow is Building Information Modeling. The idea behind BIM is to combine a database with a scaled 3D model of building components that form the design and documentation in an easy to manage process. The database stores attribute (parameters) about each modeled building component (element) and populate the documentation (schedules, sheets). The idea behind a true MEP Building information modeling workflow is an endlessly evolving process aimed to cut down on the production time of designing and documenting the model. The model's data is used to drive engineering calculations and turn design logic into algorithms automating tasks one by one until no tasks are left, and the process is fully automated. This end goal is a stretch but is the northern light. To achieve this goal, several different frameworks in Revit, all with unique data structures, exclusive functions, and tools, need to come together. The data required and produced from the array of tools needs to be connected like a gigantic puzzle. First, all the different puzzle pieces need to be identified. Second, the data needs to be stored in a coherent structure; this is where Revit shines.

**Key Notes**
- Access to all the different team’s data is critical in a true BIM process.
- BIM is all about the "I" and identifying the information needed.
Revit

Revit is numerous BIM tools wrapped in a software package, but at its core, Revit is a database. The information in the database populates documentation like views, schedules, and sheets. As 3D Building elements, like walls, floors, and HVAC equipment, get placed in a model, parameters are applied that incorporate information about the building components. Also, when a new element is placed, a unique Id is applied to a parameter. This data structure is essentially a relational database. A relational database is a set of tables containing data in predefined categories. (Walls, Doors, Pipes, Mechanical Equipment). Each table includes one or more data parameters in columns (fire rating, size, flow rate, manufacture). Each row contains a unique instance of data for the categories defined by the columns. Relationships between items of different tables can be established using Primary and Foreign Keys. A Foreign Key is a field in a relational table that links back to another table's Primary Key column. The key to getting all data from the elements from different Revit MEP frameworks connected is establishing relationships between elements using the element ids as Primary and Foreign Keys. Shared Parameters are added to the model to create the data table and establish connections.

Key Notes
- The element Id is automatically assigned to any element placed in the Revit model.
- Some Elements and Revit tools are natively connected, while many are not.

Shared Parameters

Shared parameters are customized vessels for storing information in the Revit Projects database. A master list of shared parameters is created and stored in a text file separate from a Revit project. These data containers have particular data types, used to constrain their purpose and be used in unit-specific calculations. The critical element to standardizing shared parameters is utilizing a clear naming structure and adding the right data types for each parameter. Once a Shared Parameter is created, it can be added to most categories in a Revit project or Revit families. Parametric geometry and project documentation rely on Shared Parameters.

Key Notes
- There are other types of parameters, but Shared Parameters provided the best flexibility.
- We cheat sometimes and make the parameters unitless, so the input is not constrained.

Revit MEP Families

Families are a mixture of geometry, parameters, and formulas used to embody building components and provide a critical foundation for a Revit model by facilitating data sorting,
parametric design options, and creating an informative schedule. These graphical representations of building components are organized hierarchically to create the Revit project's database's different data tables. The family is made in the Revit Family environment and is saved as a separate file. After a Family is created or edited, it gets loaded into Revit projects. MEP system families have connectors added to the geometry; the connectors develop connections to other elements to form mechanical systems.

Key Note
- To get the most out of Revit, the default Revit families are not adequate.
- Family location points, connectors, and parameters need to be coordinated with design automation algorithms.

Revit MEP Systems

MEP systems define logical relationships between related MEP Families and let engineering flow data propagate through the elements. This data structure is known as a graph in computer science. A graph is made up of edges connected by edges and provides an excellent way to model relations between non-linear data like a Duct or Piping System. When an MEP system is created in Revit, a logical relationship between Revit Families is built, and analysis can efficiently be conducted using traversal algorithms. Creating MEP systems requires that the families have MEP Connectors that are appropriately assigned. Connectors get assigned a System Classification and direction. Families with the same connectors can be paired together. These relations can be viewed with the System Browser display.

Key Notes
- System Classification is predefined classifications within Revit.
- Connectors cannot be hidden or set parametrically on a Family
- No Physical connection between elements needs to be made to make a system.

Revit Drafting Views

Drafting Views are used to create 2D views that are unconnected to the 3D model. These views are often utilized for details and schematics. Generic Annotations with parameters can be placed in drafting view and combined with Detail Lines to create project required diagrams.
Rooms

Rooms are used to store information about the subdivision of areas within a building model to identify usage and occupancy. When a Room is placed at a point, the area covered is automatically constrained by room bounding elements like walls, floors, roofs, and ceilings. Rooms can be automatically created for enclosed and be divided by using room separation lines.

Key Notes
- Architects typically create Rooms.
- Room Bounding is a parameter found in the elements or/and link model.
- Rooms are not affected by space separation lines.

Space
Spaces are similar to Rooms but are used to store data for HVAC energy analysis. Designers have complete control over the volume of the Spaces. Like Rooms Spaces, boundaries stop at room-bounding components, such as walls, floors, ceilings, and roofs. Multiple Spaces can be added to one Room by using Space separation lines. Additionally, the "Limit Offset" parameter can be used to control the vertical extent of the volume.

Spaces also have the intelligence to know what Rooms reside within the Space. If there is no Room present within the Spaces, Space is set to "Unoccupied." If there is a Room, Spaces automatically records the Room Name and Number and is set to "Occupied."

As of Revit 2021-It is no longer necessary to place Spaces in the interior opening of a model. When the energy model is created, an analytical Space will be made in all voids. It is still best practice to place Spaces in all openings of a floor plan view even if a Room is not present, such as shafts and chases, so a Space Type can be assigned to identify the Space unoccupied.

The Space Type for new Spaces is automatically set to the default setting of Building Type. In my opinion, all Spaces should be assigned a Space Type. The Building/Space Type Settings menu controls heating and cooling load parameters like ventilation, occupancy, operation schedules, and internal heat gains and can have a significant impact on the energy model.

Key Notes
- New Set Point Parameters have been added to the Space Type in Revit 2021
New Parameter values cannot be added to the Space Type as of Revit 2021
Building Types work the same way as Space Types and is set by default to new Spaces
Many built-in parameters do not have any impact on the Energy Model

HVAC Zones
Zones were used for heating and cooling load calculations. Spaces needed to be assigned to Zones; spaces designated to the Default zone would not be included in the heating and cooling loads calculations. As of Revit, 2021-this is no longer the case with Revit Systems Analysis; Zones are irrelevant and can be ignored.

Revit Systems Analysis
System Analysis is a framework that connects Revit to Energy Plus for building energy modeling. The designer can quickly group Analytical Spaces into thermal zones using a sketch tool then apply a range of different HVAC equipment to thermal zones. Based on the selected equipment type, various options become available to assign the equipment to appropriate Air and Water loops. This workflow provides the ability to define a countless different system configuration from packaged single- and multi-zone systems with gas or electric heating and DX cooling to larger complex systems with heating and cooling coils served by hot and chilled water from central plants to radiant units that serve individual regions. Out of the box Systems Analysis supports a set of default equipment with typical high-performance systems assumptions. Two default workflows, Annual Building Energy Simulation and HVAC Systems Loads and Sizing, are included with Revit 2021. Designers have the option to create customized workflows to override the default values.

The process goes like this; a gbxml file is created that is comprised of climate data (Revit Project Location), thermal data (Analytical Space, Analytical Surfaces, and Energy Settings), and HVAC systems data (Analytical Systems). The "Workflow" converts the gbxml to an osw/. Osm Opensource Studio file that then gets transforms into a .idf file Energy Plus to run the simulation. The simulation results are tabulated in a report that can be viewed in Revit and used to populate analytical spaces parameters.

Revit Energy Analysis
Energy Analysis framework creates a gbxml schema for energy modeling directly from a Revit model at any detail level. The analytical energy model created from this framework comprises four main components, climate data, Analytical Spaces, Analytical Surfaces, and Analytical Systems. The analytical model is generated only when a new energy model is created and does not dynamically update with model changes. The geometry of the Analytical Energy Model is produced by interesting Room Bounding building components of the model with a 3D grid called a voxel. The Analytical Surfaces are created by the intersections of the building element's faces
and the voxel. The voids that are bounded by the surfaces create the Analytical Spaces. The energy model can be examined in Revit to ensure the analytical geometry closely matches the physical model using a 3D view and inherited the right information using schedules.

Energy Settings offer designers various options to ensure the model meets the design intent and control to dial in the voxel resolutions for the best results. Additionally, the designer can specify additional information such as thermal properties for the Analytical Surface and Spaces.

Click Analyze tab > Energy Optimization panel > (Energy Settings).

Climate data information is collected by assigning a geographic location to the building. The Location tool allows the site to be set using the street address, nearest major city, or the latitude and longitude.

The Weather tab offers a way to verify the Cooling and Heating Design Temperatures and the Clearness Number for the project location. These settings can also be overwritten in this tab.

Click Manage tab > Project Location panel > location.

Analytical Spaces

Analytical Spaces are volumes of air that experience heat transfer through building components and specified internal heat gains. Revit generates Analytical Spaces within enclosed volumes in the model and automatically populates data from Building Type, Rooms, or Spaces. In the Energy settings, Spaces or Rooms can be specified. Spaces are a better choice since they contain Energy Analysis parameters for better flexibility in calculating energy usage. By default, Analytical Spaces uses the Energy Analysis settings from the assigned Building Type. If a Space location point resides in the Analytical Space’s enclosed volumes, the Analytical Space parameters inherit the Space Energy Analysis parameter data.

Analytical Surfaces

Analytical Surfaces are automatically created from Walls, floors, roofs, and other building components from either a native or a linked model when the Energy model is created. The surfaces get categorized according to location and function. Thermal properties for these surfaces can be assigned in a variety of ways. Conceptual Types and Schematic Types offer a valid approximation that can be applied quickly to the entire building or surface-bound individual Analytical Spaces. It is possible to model particular thermal properties of specific surfaces or assemblies and assign materials to the elements. Analysis of Detailed Elements does not require that all elements or materials in the model contain Thermal Properties. Revit gives
Conceptual or Schematic Types to elements without detailed thermal information, allowing users to mix and match elements with known Thermal Properties and schematic elements.

Analytical Systems

Analytical Systems were added to Revit 2020.1 and are used to add HVAC Systems to the Energy Models gbxml to inform load calculations, equipment sizing, and system simulation. Analytical Systems get applied to different building regions and are configured from zone equipment, air systems, and water loops.

Zone Equipment, Air Systems, and Water Loops are added to the project by clicking their respected icons in the Systems Browser. The System Browser also displays the hierarchical relationships of the analytical system components and identifies if an element is not adequately defined with a warning icon.

All the different system components first get assigned a Type and Name in the Properties palette. Depending on the Type selected, additional options appear in the Properties palette to specify more equipment specific characteristics.

System Zones are graphic elements (line, enclosed shapes, 3D forms) used to assign Analytical Spaces to the Analytical Systems. Analytical Space that intersects the System Zone geometry is automatically assigned to that System Zone when an Energy Model is created. The System Zones then get manually set to Zone Equipment in the Properties Palette.

Key Notes

- It is not possible to select an Analytical Space and manually alter the properties.
- If analytical systems are not created, Revit uses the ideal air system for the systems analysis.

Gbxml

GBXXML is an industry-standard XML schema language format for building energy modeling interoperability. It allows disparate 3D building information models (BIM) and architectural/engineering analysis software to s information with each other.

Open Studio

Open Studio is an open-source development kit design to create and manage Energy Plus models and functions as the bridge between Revit and Energy Plus. The conversions process includes two main components Measures and Workflows. Open Studio Workflows are configuration files that describe what to run, how to run it, and finding the dependent files. Measures are sets of commands that efficiently renovate the energy model. There are three types of measures, model measures, energy plus measures, reporting measures.

When a Revit's Systems Analysis workflows are selected to run, OpenStudio runs the background's Energy Model simulation. First, the Revit project's assigned weather file, OpenStudio workflow file, OpenStudio Measures, and projects gbxml are automatically gathered, bundled into an EnergyPlus file. Next, EnergyPlus runs the simulation, followed by OpenStudio running the reporting Measures. The output is an HTML Report and populated Analytical Space Parameters.
Key Notes

- The OpenStudio file is saved outside of Revit.
- NREL Technology Performance Exchange

Energy Plus

EnergyPlus is an open-source, cross-platform, and powerful whole building energy simulation program with a broad array of features and capabilities for building performance and energy analysis. The program is Ashrea 140 compliant and works under the hood of other trusted Building Energy Modeling software like Trane Trace 3DPlus. The program reads an input text file known as IDF and writes outputs to text files. Designers do not typically interact with these files. Instead, Open Studio is used to manipulate the inputs and outputs to create different workflows.

Dynamo

Dynamo is a Visual Programming language that connects to Autodesk Revit. Dynamo allows access to Revit API, internal/external data, and model geometry. In some cases, there is not a native Dynamo node for a particular function. Python or C# can be used to build customized nodes. All this data can be connected to define relationships and execute a sequence of actions that create algorithms. Algorithms can be used for a wide array of applications, from processing data to generating, analyzing geometry, placing, and manipulating Revit Families. Design steps can be linked together to form workflows.

Revit API

An API or application programming interface is a collection of operations with a simple description of what users can use to communicate with the software. This allows users and external application developers to integrate and customize their workflows.

Customization and Data Connections

Automation

Outro

Like many workflows in the AEC Collections, the Revit Systems Analysis has a considerable setup. Manually navigating Revit to set up a model, adding weather data, levels, spaces, assigning space types, specifying construction envelopes, and defining system for the whole model is a disappointing maze that takes a considerable amount of time. This frustration can be eliminated by setting up a standard process and applying computational strategies to the design
process. The number of required user inputs can be dramatically reduced, and workflows can be executed seamlessly by presenting the end uses with design options and data needed to make design decisions. Setting up these automated workflows is difficult. There is no doubt many problems still need to be solved with many hurdles and issues that remain unresolved within the Autodesk software. However, we insist that imperfect is still immensely powerful, and if it were easy, it would just be the way. It takes talented and passionate teams. Companies need to support staff education and foster computer programming skills, embrace lateral thinking, and cut stubborn dead weight within their organizations to get the most out of their costly software. Tools. In a world that is changing exponentially, these new data-driven approaches and methodologies are not only needed but will be required to stay competitive and adaptive. We believe design tools will ultimately replace most design functions now performed by people, but people will still be needed to create the algorithms and fill in the details. So, get to programming, enhance your projects’ speed and quality, and rapidly explore design alternatives. Ultimately setting your organization’s success in the future and win more work.