



# Improving and Automating Building Model Data Exchange

March 2024

*Changing the World's Energy Future*

Nicholas Cole Crowder



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# **Improving and Automating Building Model Data Exchange**

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Digital Engineering Scientist

# Improving and Automating Building Model Data Exchange

From Architectural Design to Structural Analysis Domains

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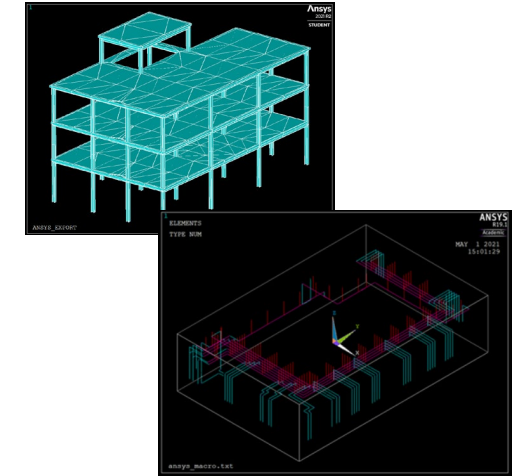
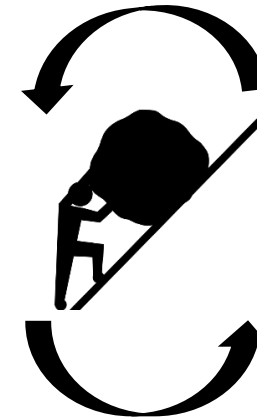
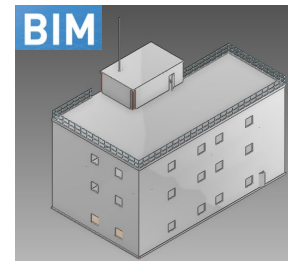


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# Background and Motivation

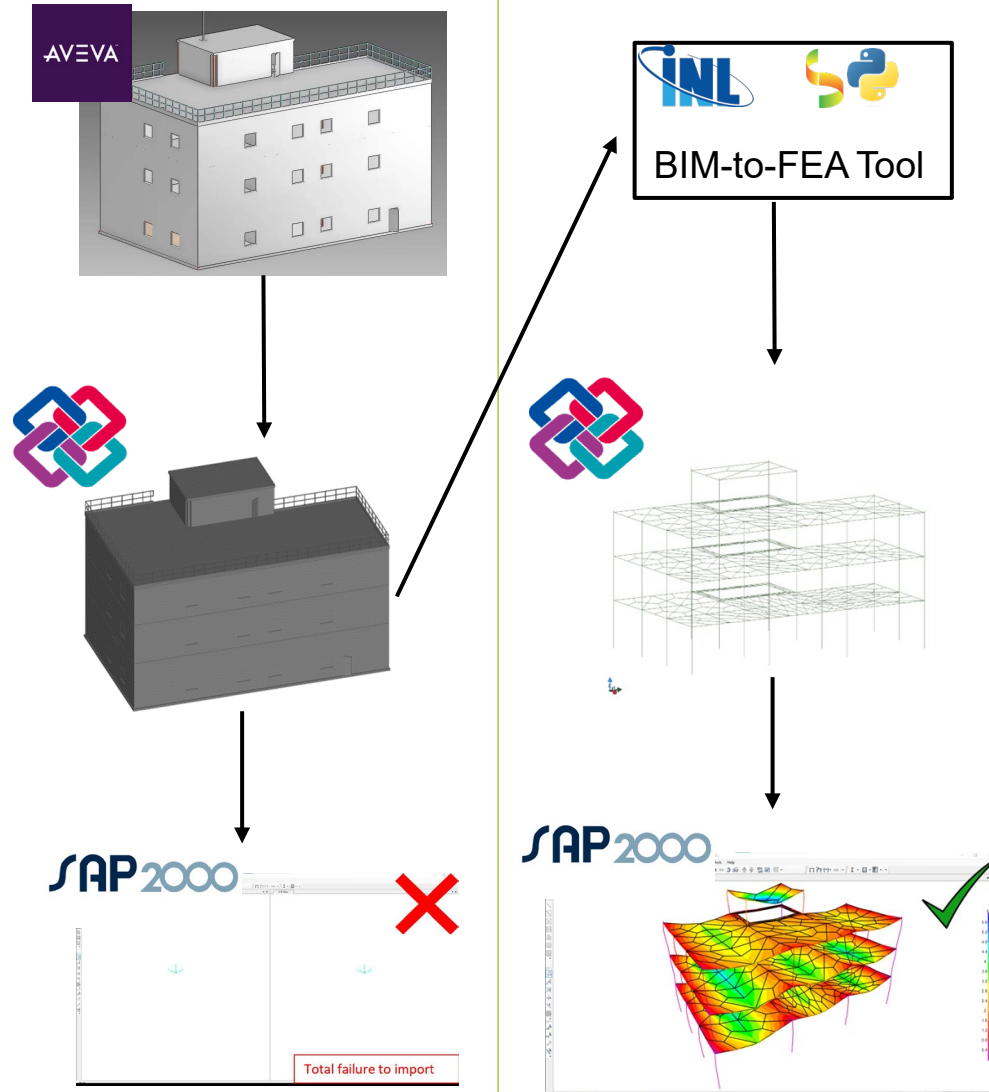


Cost overruns and schedule delays plague AEC projects. Issues arise from design changes and rework.



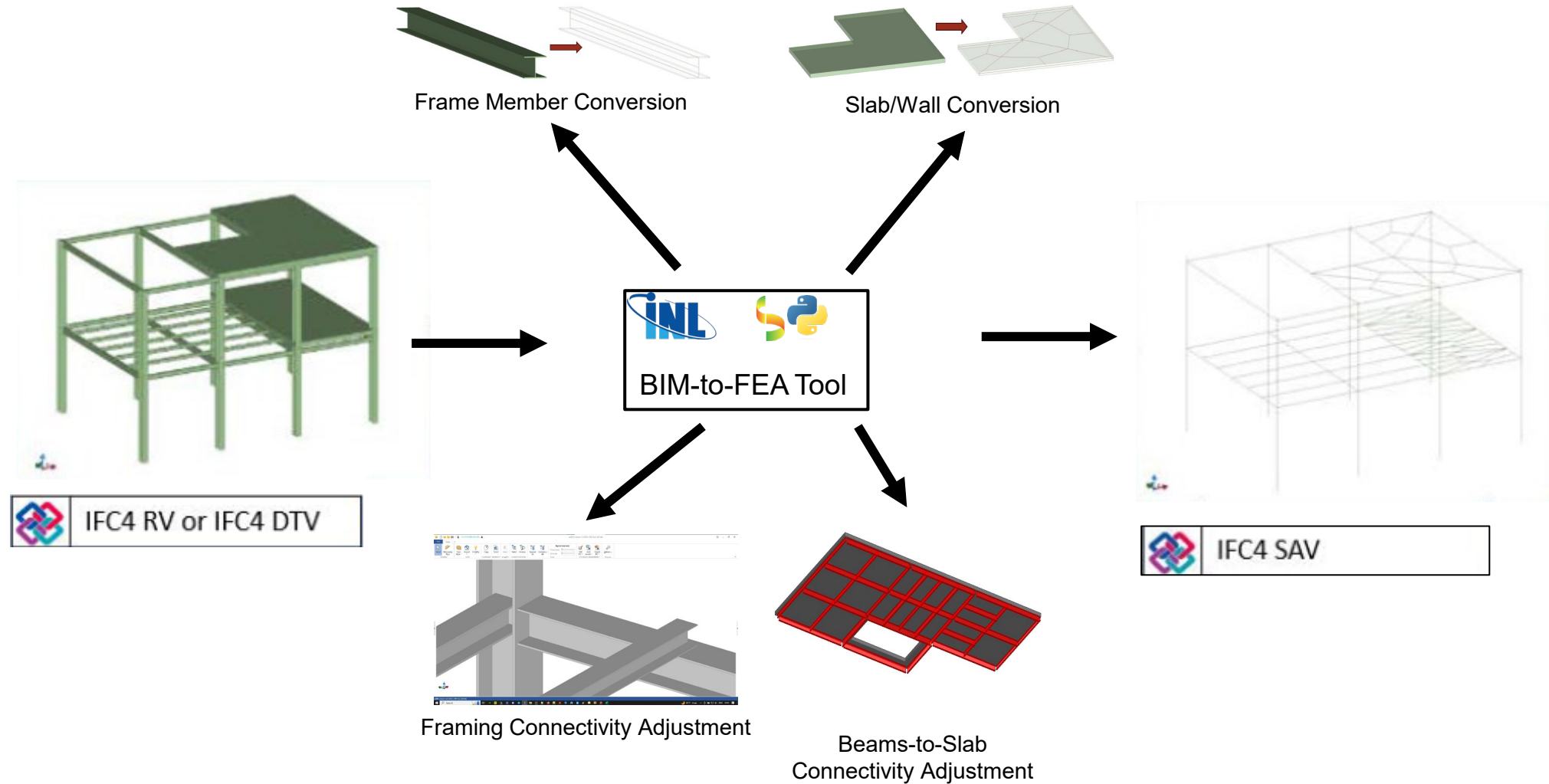
Digital engineering implementation can save on project costs. However, there are challenges with BIM software interoperability and model data exchange.

# IFC-based BIM-to-FEM Workflows – Existing Practice vs Proposed Solution



- Industry Foundation Classes (IFC)
  - Standardized digital representation of AEC objects
- Left: Existing Practice
  - IFC import to analysis software
  - Data loss; incompatibility
- Right: BIM-to-FEM Conversion Tool
  - Interprets analytical model from IFC
  - OpenBIM philosophy
  - Improvement over existing capability

# Technical Implementation of BIM-to-FEM Conversion Tool





# Frame Member Conversion

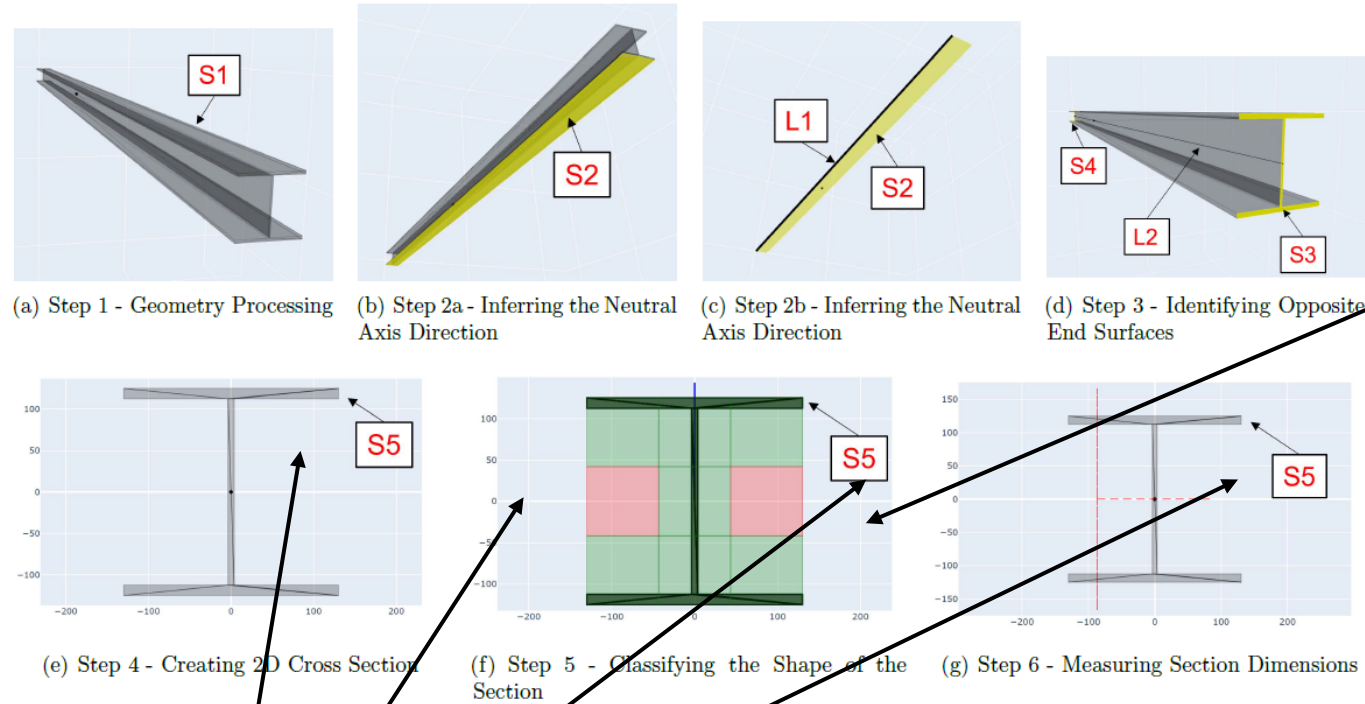


Figure IV.23: Frame Member Conversion – Steps for Obtaining Geometric and Section Information

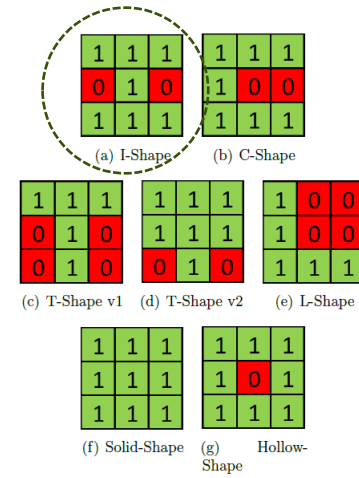
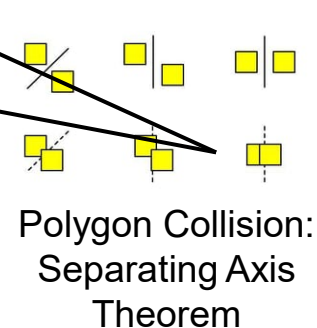
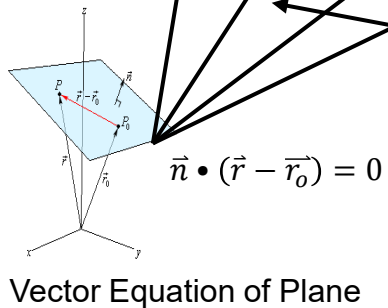
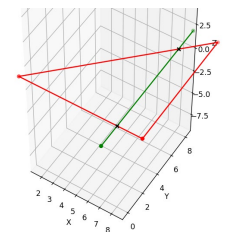
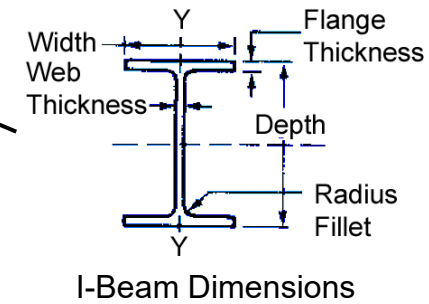


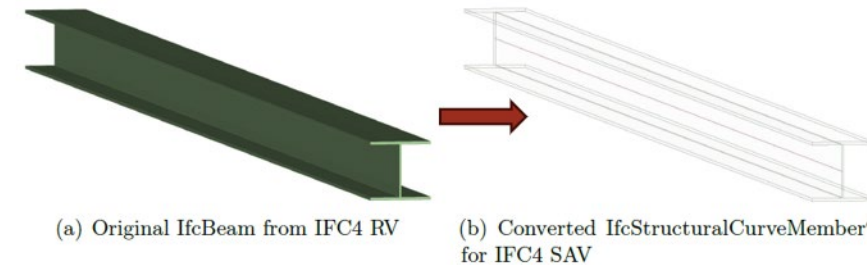
Figure IV.25: Grid Images for Common Beam Sections

$$\|x - y\| = \sum_{i=1}^d (x_i - y_i)^2$$

L2 Norm



Input/Output:

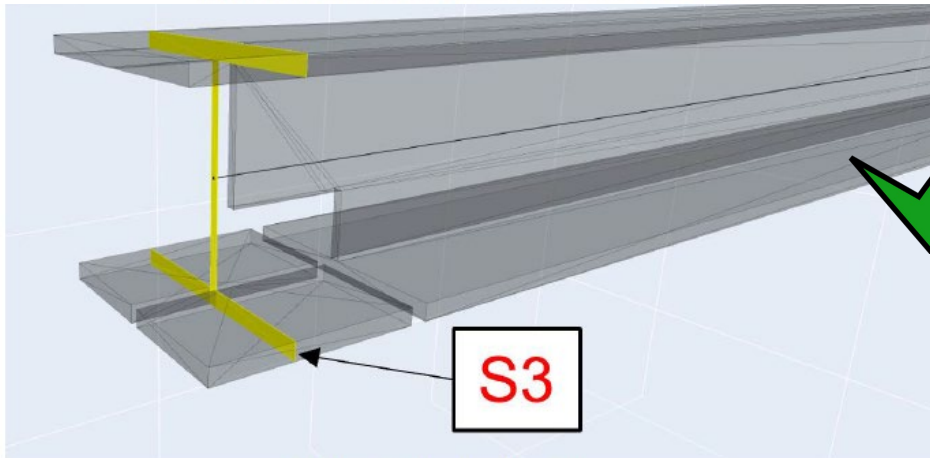




# Challenge – Complex Geometry



(a) Irregular IfcBeam from ArchiCAD SOffice IFC4 RV File



(b) Step 3 for Irregular Beam Conversion

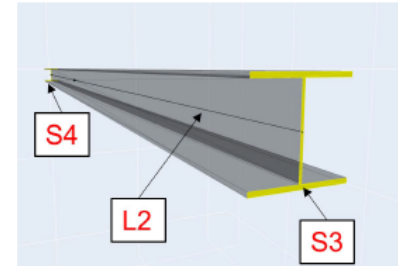
Figure IV.24: Frame Member Conversion Special Case – Irregular Beam Ends

**Problem:** How to handle complex geometry?

**Solution:** Step 3 accounts for this!

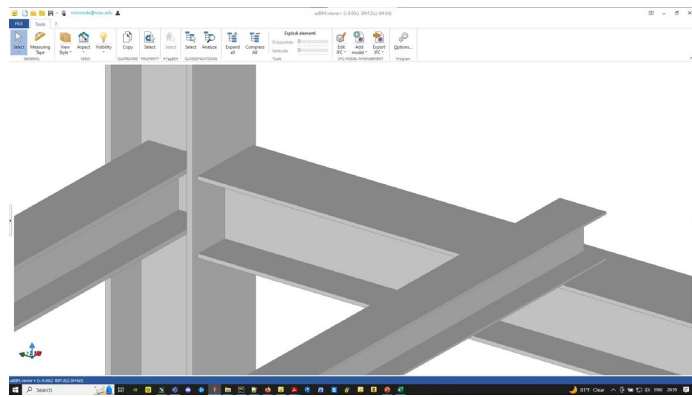
- Identifies only those polygons associated with cross-section
- Projects onto 2D surface

**Limitation:** Not applicable for curved beams.

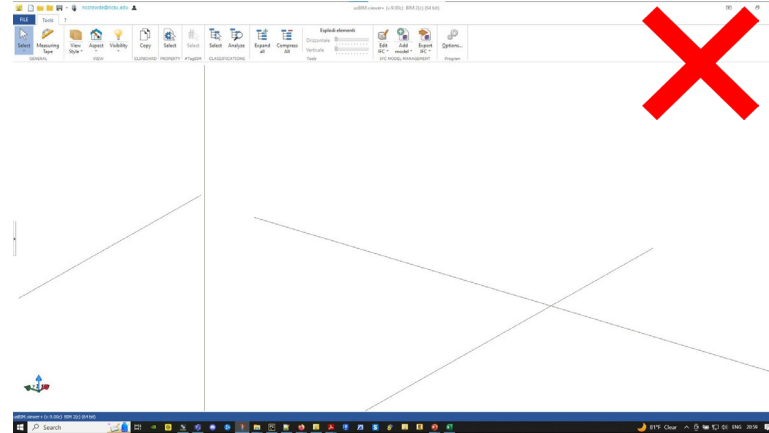


(d) Step 3 - Identifying Opposite End Surfaces

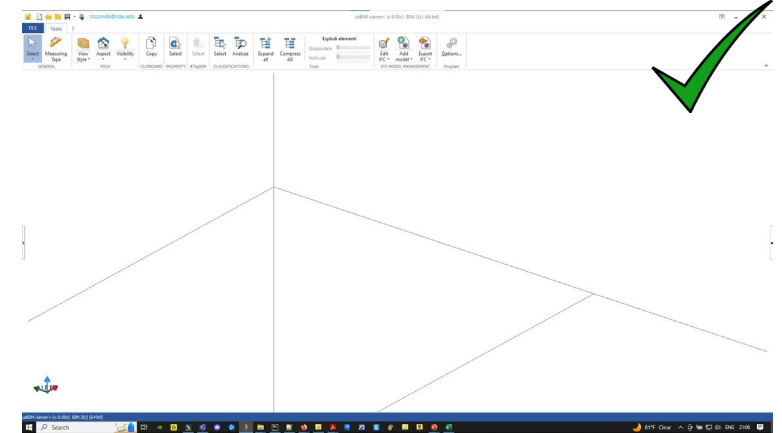
# Element Connectivity Adjustment for Frame Members



IFC4 RV – Before Frame Snapping



IFC4 SAV – Before Frame Snapping



IFC4 SAV – After Frame Snapping

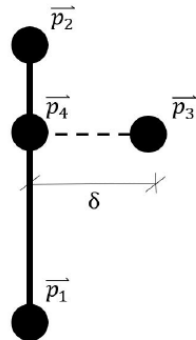


Figure IV.28: Point Snapping to Line Segment

$$\delta = \|\vec{p}_4 - \vec{p}_3\| \quad (\text{IV.2})$$

$$\vec{p}_4 = \begin{cases} \vec{p}_1 & \text{if } t < 0 \\ \vec{p}_2 & \text{if } t > \|\vec{p}_2 - \vec{p}_1\| \\ \vec{p}_1 + t\hat{p} & \text{otherwise} \end{cases} \quad (\text{IV.3})$$

$$t = (\vec{p}_3 - \vec{p}_1) \cdot \hat{p} \quad (\text{IV.4})$$

$$\hat{p} = \frac{\vec{p}_2 - \vec{p}_1}{\|\vec{p}_2 - \vec{p}_1\|} \quad (\text{IV.5})$$

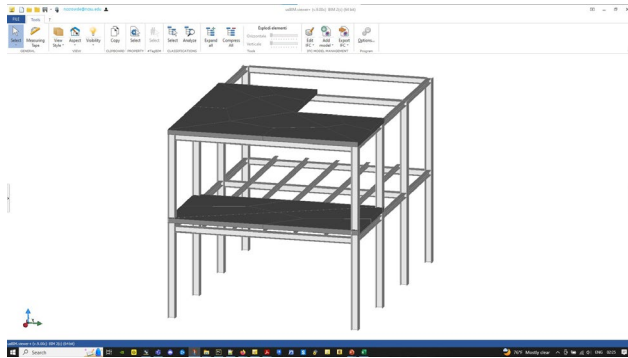
Calculate distance between members

$\delta - \delta_{allowable} \leq 0$   
Snapping Criteria

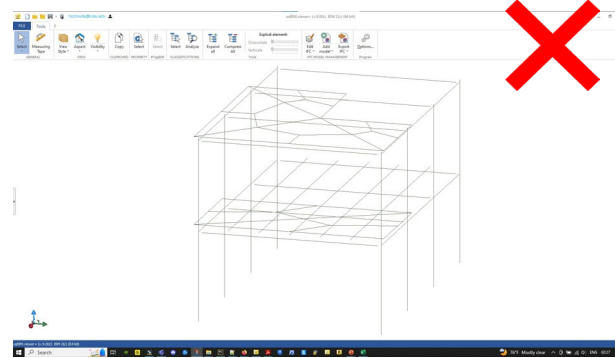
Connectivity Order:

- 1) Girders to Columns
- 2) Joists to Girders
- 3) Diagonals to Columns

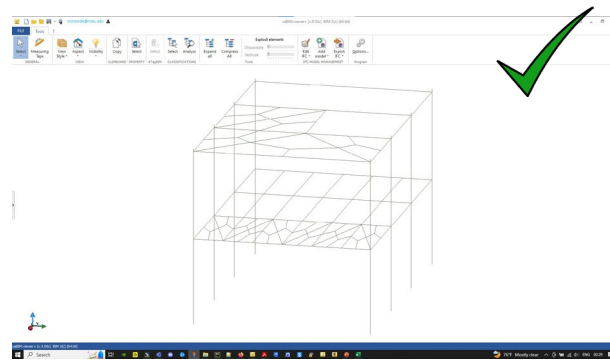
# Element Connectivity Adjustment for Slabs and Floor Beam Systems



IFC4 RV – Before Frame Snapping



IFC4 SAV – Before Frame Snapping



IFC4 SAV – After Frame Snapping

# Application of BIM-to-FEM Tool on Commercial Software



Custom Structure



Steel Construction



Building B02



S-Office



IFC

SAP2000

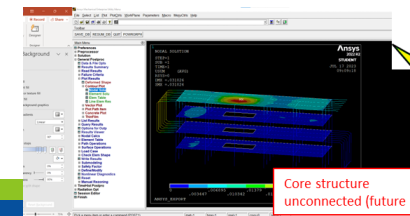
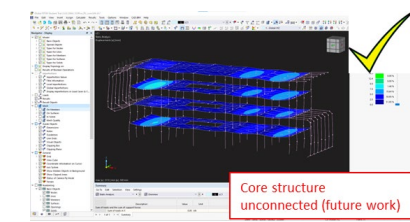
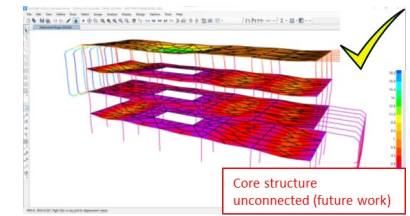
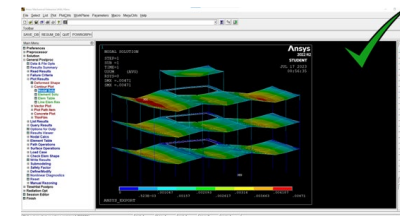
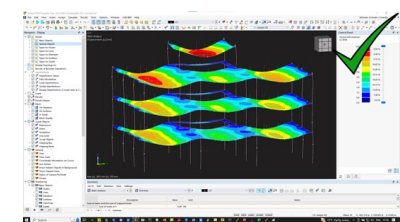
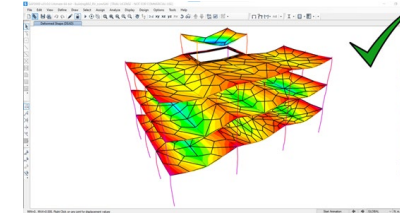
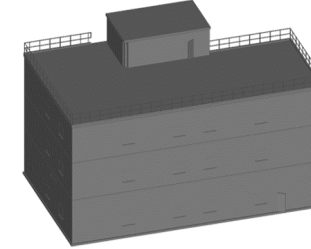
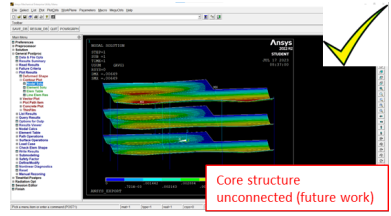
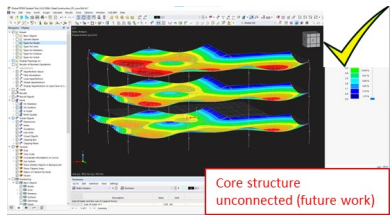
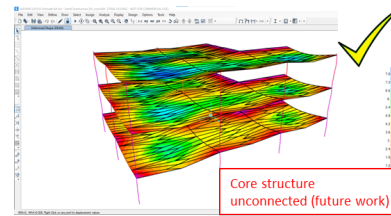
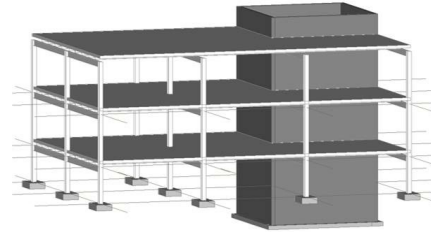
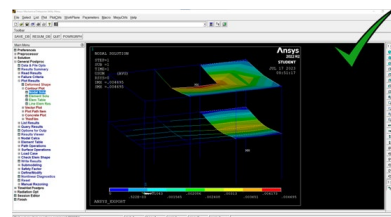
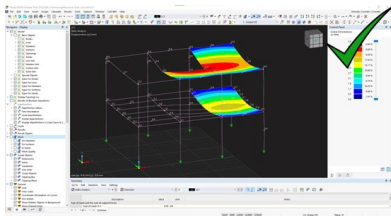
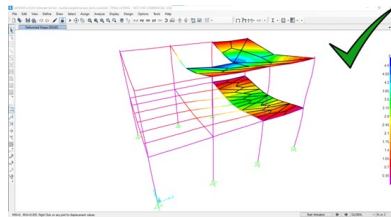
IFC Import &  
Static Analysis



IFC Import &  
Static Analysis

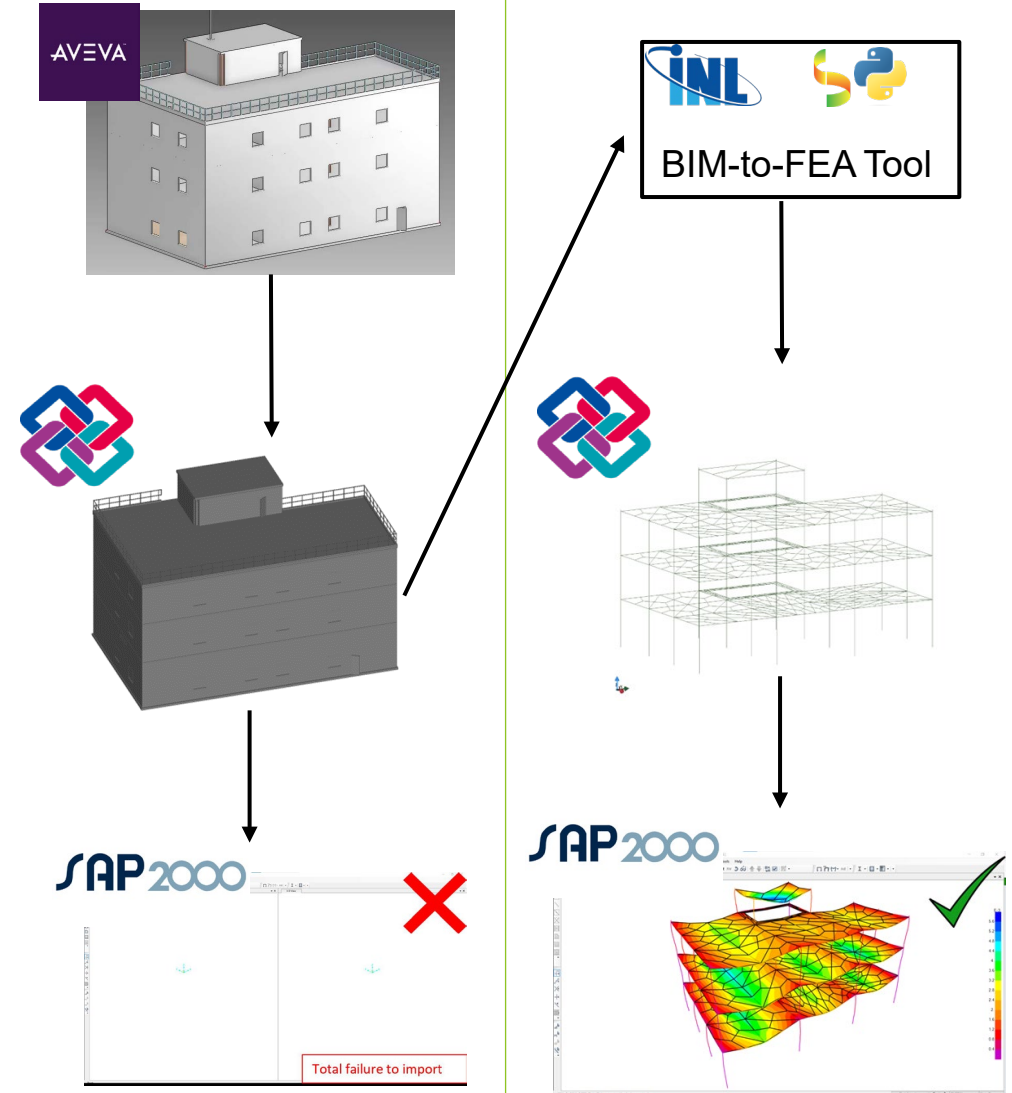


TXT Macro  
Import & Static  
Analysis



# Summary and Future Work

- Summary
  - Need for improvement in IFC-based model data exchange workflows
  - Developing BIM-to-FEA tool
  - Testing on commercial BIM software
  - Showcased significant improvement over existing practice
- Future work
  - User friendly interface
  - Integration with DeepLynx Data Warehouse
  - Generative Design-Analysis Workflows
  - Wall elements; nuclear containment structures; piping and equipment







# Idaho National Laboratory

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