BIM for Resilience:
Automated Designs to Retrofit Informal Housing

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About Build Change

Safer Buildings: 79,000
Safer People: 410,000
People Trained: 54,000
Global Challenges by Affected Population (2030)

- Climate Change: 9 billion
- Basic Healthcare Access: 4.5 billion
- Malaria: 4.5 billion
- Substandard Housing: 3 billion
- Clean Water Access: 780 million
- Trafficking/Slavery: 40 million
- HIV: 37 million
Colombia’s population: 50 million

- 77% of the population live in urban areas
- Major cities are expanding beyond capacity, creating informal neighborhoods
- Low-income families are building without technical guidelines or permits
Risk = Hazard × Vulnerability
Risk = Hazard x Vulnerability

Natural Events:
Earthquakes, hurricanes, tsunamis, landslides, floods
Risk = Hazard \times\text{Vulnerability}

**Natural Events:**
Earthquakes, hurricanes, tsunamis, landslides, floods

**Built Environment:**
Infrastructure quality, construction standards, disaster preparedness
Colombia’s National House Improvement Program

- Nationwide subsidy program led by the Ministry of Housing and Agriculture
- Aims to improve 600,000 houses in a 4-year timeframe
- Will impact more than 2 million people
- Build Change is providing technical consultancy
Previous Workflow and Limitations
Workflow of Retrofit Projects

Data Collection in Field

Engineering Calculations

Construction Package

Construction Works
Workflow of Retrofit Projects

Data Collection in Field → Engineering Calculations → Construction Package → Construction Works

9+ days
Data Collection → Engineering → Construction Package
Wall Area Percentage

\[ WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}} \]
Wall Area Percentage

$$WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}}$$
Wall Area Percentage

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Wall Area Percentage

\[
WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}}
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Actual WAP \quad \geq \quad \text{Required WAP}

Retrofit WAP_1

Retrofit WAP_2
Wall Area Percentage

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**Wall Area Percentage**

\[
WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}}
\]
Data Collection → Engineering → Construction Package

Actual WAP → Retrofit WAP$_n$
1. Existing Drawings (Plans, elevations, sections)
2. Engineering Results
3. Retrofit Drawings (Plans, elevations, sections)
4. Structural Details
5. Cost Estimate
New Scalable Workflow
How to make the workflow efficient and scalable?

- 3rd party app Integration
- New Engineering Methodology
- Automation Tools
Data Collection
Data Collection

Engineering

Construction Package

magicplan
Data Collection

- External Packages
- BC Nodes
- Python Nodes
- Revit API

Engineering

Construction Package
Data Collection

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Engineering

Construction Package

• External Packages
• BC Nodes
• Python Nodes
• Revit API

Magicplan API

Dynaweb
Data Collection

- Magicplan API
- Dynaweb
- XML

Engineering

- External Packages
- BC Nodes
- Python Nodes
- Revit API

Construction Package
- External Packages
- BC Nodes
- Python Nodes
- Revit API

Magicplan API

Dynaweb

Data Collection

Engineering

Construction Package
1. Import
1. Import
2. Process
List of plans in the workspace

Data Collection → Engineering → Construction Package

Client → Server

HTTP request → Server → HTTP response

MP Server (API)
Data Collection → Engineering → Construction Package

Client

Server

MP Server (API)

List of plans in the workspace

Ask the user to pick by name

Plan ID by User’s choice
List of plans in the workspace

Ask the user to pick by name

Plan ID by User’s choice

Plan information

Data Collection

Engineering

Construction Package

MP

Server

(API)
List of plans in the workspace → Ask the user to pick by name → Plan ID by User’s choice → Plan information → Save *.XML Locally
Plan:
- Attributes
- Floors
Plan:
- Attributes **
- Floors**:

Floor n:
- Attributes **
- floorRooms**:

"..."
Plan:
- Attributes **
- Floors**:
  - Attributes **
  - floorRooms**:
    - floorRoom n:
      - Attributes **
      - Points**
      - Windows**
      - Doors**
      - ...
    - ...
    - ...
  - ...
  - ...

Data Collection  Engineering  Construction Package
Plan:
- Attributes **
- Floors**:
  
  Floor n:
  - Attributes **
  - floorRooms**:
    
    floorRoom n:
    - Attributes **
    - Points**
    - Windows**
    - Doors**
    - ...
    - ...
  - ...
  - ...

Point/Window/Door n:
- Attributes **
Data Collection

Plan:
- Attributes **
- Floors**:

Floor n:
- Attributes **
- floorRooms**:

floorRoom n:
- Attributes **
- Points**
- Windows**
- Doors**
- ...

...
Plan:
- Attributes **
- Floors**:

Floor n:
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floorRoom n:
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- Doors**
Plan:
- Attributes **
- Floors**:

Floor n:
- Attributes **
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floorRoom n:
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- Points**
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- …

...
Data Collection

Engineering

Construction Package

Plan:
- Attributes
- Floors

Floor n:
- Attributes
- floorRooms

floorRoom n:
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- Points
- Windows
- Doors

...
Plan:
- Attributes **
- Floors**:
  - floorRooms**:
    - floorRoom n:
      - Attributes **
      - Points**
      - Windows**
      - Doors**
      - ...
    ...
  ...

Floor n:
- Attributes **
- floorRooms**:

Data Collection → Engineering → Construction Package

```python
class wall_line:
    def __init__(self, g_line, w, h, w_type, ds, ws): ...
    def createElements(self, level): ...
    def get_all_points(self): ...
    def divide_by_openings(self, minw_width): ...
    def compare_by_box(self, w_line): ...
    def add_door(self, w_door): ...
    def check_angle(self): ...
    def correct_points(self, x_snaps, y_snaps): ...

class Window_Door:
    def __init__(self, x, y, h, dw_type, opening_unconnected, hrev): ...
    def createElements(self, level, host): ...
    def correct_points(self, x_snaps, y_snaps): ...
    def compare(self, wind_door): ...
    def get_all_points(self): ...

class Floor_Curves:
    def __init__(self, polycurve, floortype, overrides): ...
    def create_elements(self, level): ...
```
Plan:
- Attributes
- Floors:

Floor n:
- Attributes
- floorRooms:

floorRoom n:
- Attributes
- Points
- Windows
- Doors

...
Plan:
- Attributes **
- Floors**:

Floor n:
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- floorRooms**:

floorRoom n:
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- …

…
Plan:
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Floor n:
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floorRoom n:
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- ...

...
Import Scripts Demo

https://youtu.be/khogHRpLVMY
New Engineering Methodology
Data Collection → Engineering → Construction Package

Resistance > Seismic Demand
$WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}}$
Resistance > Seismic Demand

\[ WAP = \frac{\text{Cross section Wall Area}}{\text{Area of the House}} \]
Resistance > Seismic Demand
Actual $WAP \geq$ Required $WAP$

$\text{Retrofit} \ WAP_1$

$\text{Retrofit} \ WAP_2$

$\text{Retrofit} \ WAP_3$

$\vdots$

$\text{Retrofit} \ WAP_n$
Actual $WAP \ ? \ Required \ WAP$

- Retrofit $WAP_1$
- Retrofit $WAP_2$
- Retrofit $WAP_3$
- ...$n$

Common Solutions for one story Houses

- Add ring beams
- Plaster accessible walls
- Add columns at wall intersections
- Confine unconnected walls
- Reinforce openings
Common Solutions for one story Houses

- Add ring beams
- Plaster accessible walls
- Add columns at wall intersections
- Confine unconnected walls
- Reinforce openings

Prescriptive Design

Define Rules

Categorize
Category: One-story Unreinforced Masonry Houses
Buildings with inter story height of no more than 3m, with horizontally perforated clay blocks and no severe damage suggesting lack of foundations or pronounced differential settlement.

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<th>Retrofit Solution</th>
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![Dynamo Player](Dynamo%20Player.png)
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# Data Collection Engineering Construction Package

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Data Collection  Engineering  Construction Package
Door Confinement Demo

https://youtu.be/3kIQjvfJpVY
Data Collection  Engineering  Construction Package
Construction Package
Door Confinement Check:

- Concrete Column
- Connection of the Column
## Data Collection

## Engineering

## Construction Package

<table>
<thead>
<tr>
<th>Category</th>
<th>Prescriptive Design</th>
<th>New Elements</th>
<th>Outputs for Construction Package</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Retrofit Outcome - A</td>
<td>BOQ - A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retrofit Outcome - B</td>
<td>BOQ - B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retrofit Outcome - C</td>
<td>BOQ - C</td>
</tr>
</tbody>
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One Story Unreinforced Masonry

Rule Check 1

Rule Check 2

Rule Check 3

... | ... | ... | ... | ... |
Construction Details
201E09, 203G01, 203G02, 205E05
### Construction Details

**201E09, 203G01, 203G02, 205E05**

<table>
<thead>
<tr>
<th>BC Details</th>
<th>201E09, 203G01, 203G02, 205E05</th>
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<tbody>
<tr>
<td>BC APU</td>
<td>201E09, 203G01, 1.0304.40201</td>
</tr>
<tr>
<td>BC Revit Units</td>
<td>UN, ML, UN, UN</td>
</tr>
<tr>
<td>BC APU Factor</td>
<td>1.1.0.16.0.16</td>
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</table>

#### Materials and Finishes

- **Structural Material**: Concrete, Cast-in-Place

#### Structural

- **Enable Analytical Model**: ✔
- **Rebar Cover - Top Face**: Rebar Cover 1 <25 mm>
- **Rebar Cover - Bottom Face**: Rebar Cover 1 <25 mm>
- **Rebar Cover - Other Faces**: Rebar Cover 1 <25 mm>

#### Dimensions

- **Volume**: 0.037 m³

#### Identity Data

- **Image**: [Image Link]
**1. ARRANQUE DE COLUMNAS**

**2. ENCUADRE DE COLUMNAS TESS**

**3. CONSTRUCCIÓN**

**4. DETALLES DE CONSTRUCCIÓN**

---

**203G01**

**203G02**

**CASO A: COLUMNETA CONFIRMANTE EN ESQUEMA "T"**

**CASO B: COLUMNETA CONFIRMANTE EN INTERSECCIÓN DE TRES MURAS "T"**

**CASO C: COLUMNETA CONFIRMANTE EN PLANTA**

**MURO ESTRUCTURAL**

**MURO NO ESTRUCTURAL**

**ALZADO ENDENTADO EN MUROS NUEVOS**

---

**L** = Longitud del bloque.

**El endentado corresponde a la mitad de la longitud del bloque con el cual se construye el muro, por lo que su dimensión es variable.**
203G02

CASO A: COLUMNETA CONFIRANTE EN ESQUINA "T"

CASO B: COLUMNETA CONFIRANTE EN INTERSECCIÓN DE TRES MURCOS "T"

CASO C: COLUMNETA CONFIRANTE EN PUNTA

MURO ESTRUCTURAL

MURO NO ESTRUCTURAL

L_p Longitud del bloque.

** El entendedo corresponde a la mitad de la longitud del bloque con el cual se construye el muro, por lo que su dimensión es variable.

203G01

TABLA DE ESPECIFICACIONES DE COLUMNAS

<table>
<thead>
<tr>
<th>REF.</th>
<th>Muro</th>
<th>Material</th>
<th>Cociente</th>
<th>Apariencia</th>
<th>Dimensiones</th>
<th>Aclaraciones</th>
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</thead>
<tbody>
<tr>
<td>201E09</td>
<td>3</td>
<td>60</td>
<td>3.0</td>
<td>400</td>
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<td>2.5</td>
</tr>
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</tbody>
</table>

205E05

ALZADO ENDENTADO EN MUROS NUEVOS

COLUMNAS CONFIRANTE VER 203G01.
## Construction Details

201E09, 203G01, 203G02, 205E05
**Construction Details**

201E09, 203G01, 203G02, 205E05

**Bill Of Quantities Information**

<table>
<thead>
<tr>
<th>APU</th>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>20109</td>
<td>Excavation for new column</td>
<td>$ / column</td>
</tr>
<tr>
<td>20301</td>
<td>New column (type CC2)</td>
<td>$ / meter of column</td>
</tr>
<tr>
<td>10303</td>
<td>Demolish subfloor plates</td>
<td>$ / column</td>
</tr>
<tr>
<td>40201</td>
<td>Reconstruct subfloor plates</td>
<td>$ / column</td>
</tr>
</tbody>
</table>
Assigning details and APUs for all new elements created in the script
Producing the BOQ & Calling Details

https://youtu.be/crvAfv2nNg4
All details related to door confinement

BOQ and final cost estimate

Costs associated with door confinement
Data Collection  Engineering  Construction Package

Complete Run of All Retrofitting Scripts
https://youtu.be/Pos28pC4f1Q
Beyond Design: Taking AI to the jobsite
Workflow of Retrofit Projects

Data Collection in Field

Engineering Calculations

Construction Package

Construction
Workflow of Retrofit Projects

1. Data Collection in Field
2. Engineering Calculations
3. Construction Package
4. Construction
Challenges of Structural Retrofitting

- Vulnerable buildings are often located in remote areas
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- High volume of houses in developing countries
Challenges of Structural Retrofitting

• Vulnerable buildings are often located in remote areas
• High volume of houses in developing countries
• Lack of qualified labor for earthquake-resistant construction
Challenges of Structural Retrofitting

- Vulnerable buildings are often located in remote areas
- High volume of houses in developing countries
- Lack of qualified labor for earthquake-resistant construction
- **Construction supervision and quality assurance becomes a bottleneck**
Machine Learning powered by 3D Modeling
Machine Learning powered by 3D Modeling
Go

No Go
Go

No Go

Machine Learning Model
Wrapping up
Do more, with less

• We reduced the processing time of a house from 9 to 1.5 days
Do more, with less

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• Structural engineers are needed to verify the outputs and approve the design at the end
Do more, with less

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• **We are 6 times more productive through BIM and Automation Tools**

For the people