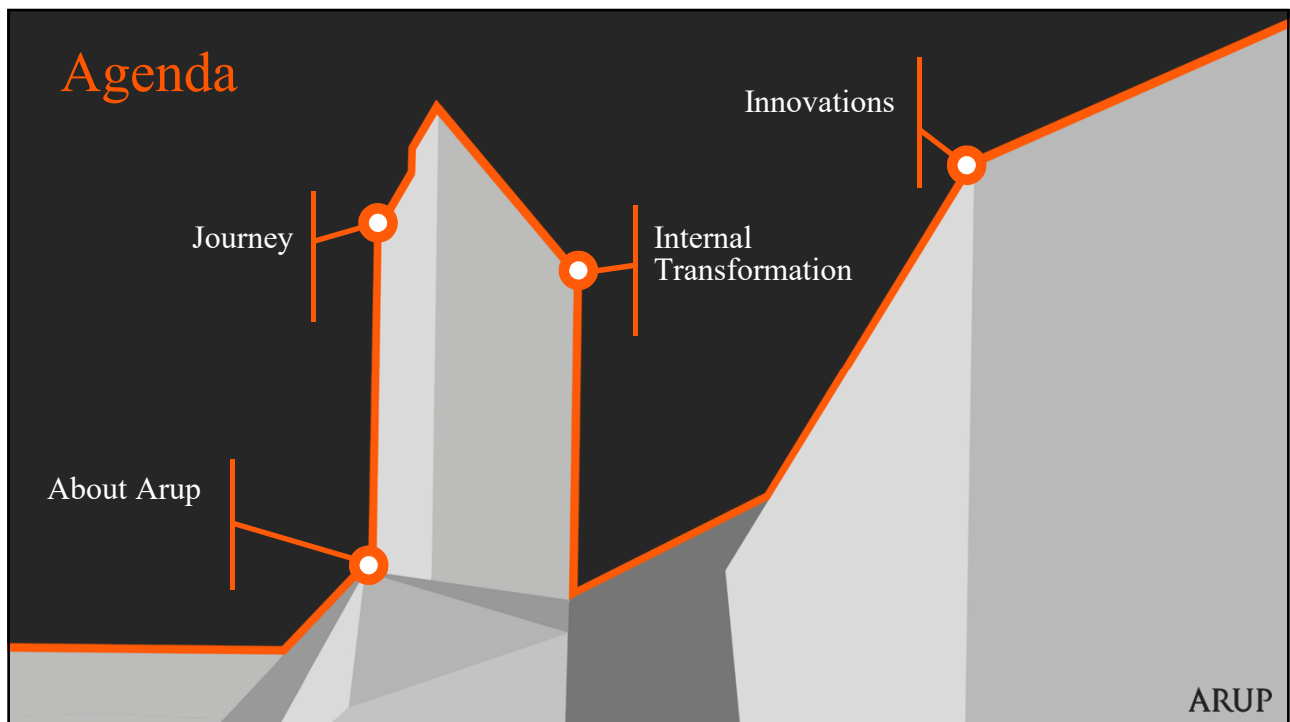
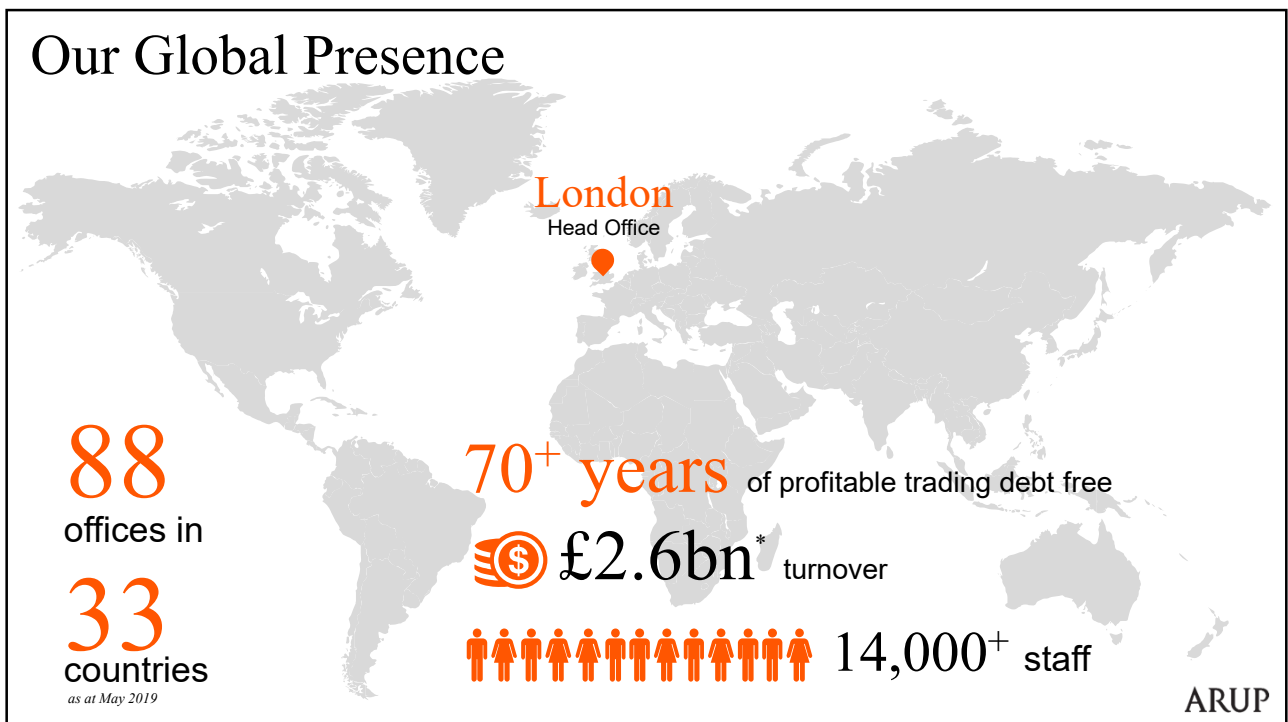
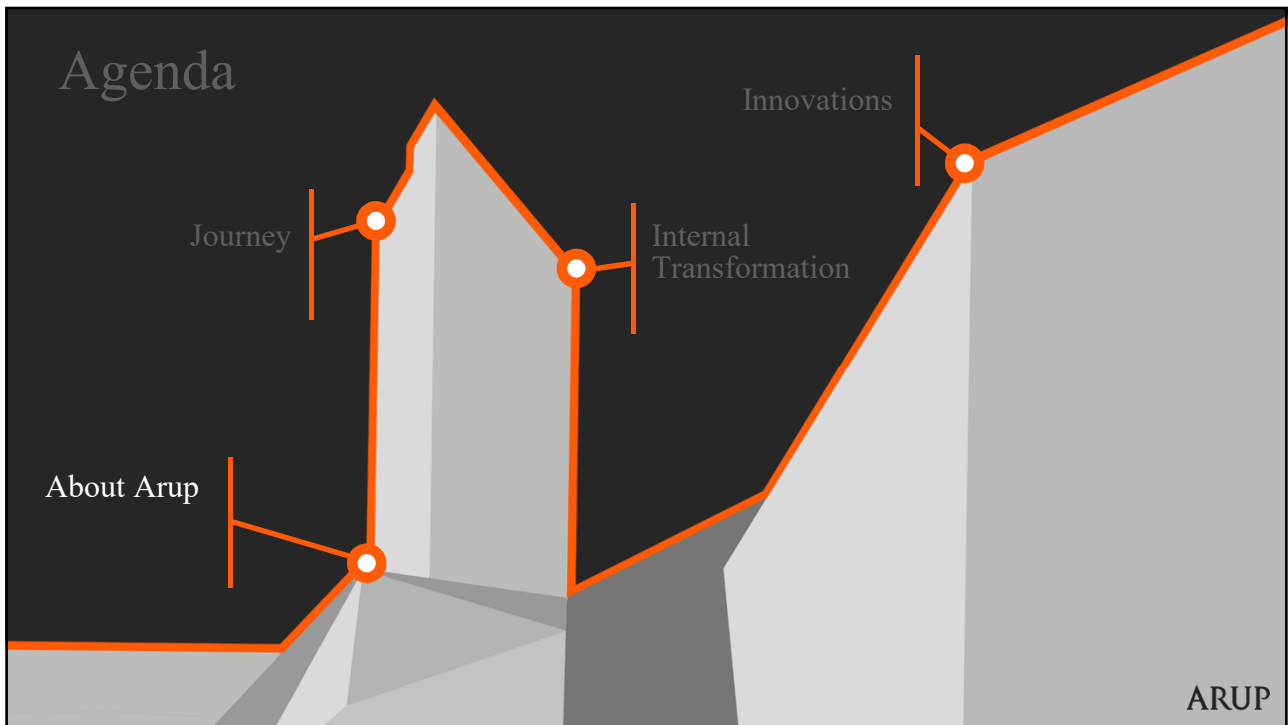






50+ years  
of city-shaping history

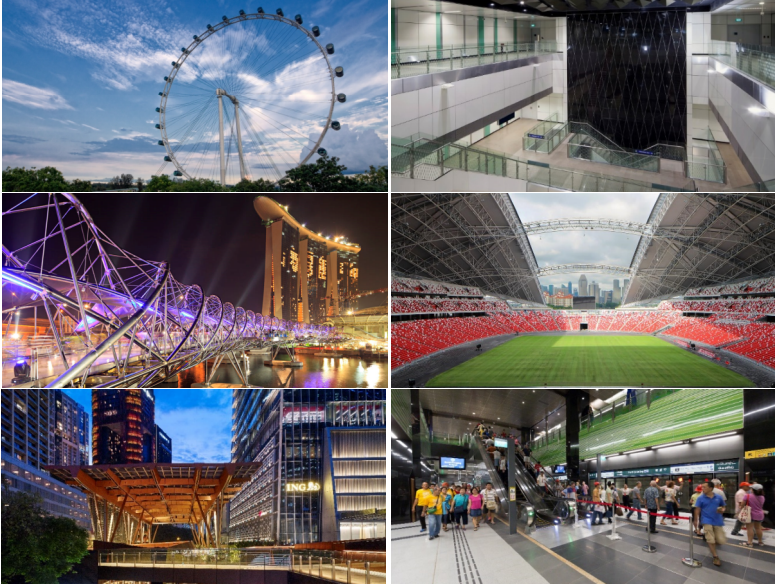
900+ staff

9 office locations

Office locations marked on the map:

- Bangkok
- Phnom Penh
- Manila
- Ho Chi Minh City
- Penang
- Kuala Lumpur
- Brunei
- Kota Kinabalu
- Singapore (~380 staff)**
- Jakarta

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**Arup in  
Singapore**

Breakthrough award  
winning projects in the last  
50 years

**ARUP**

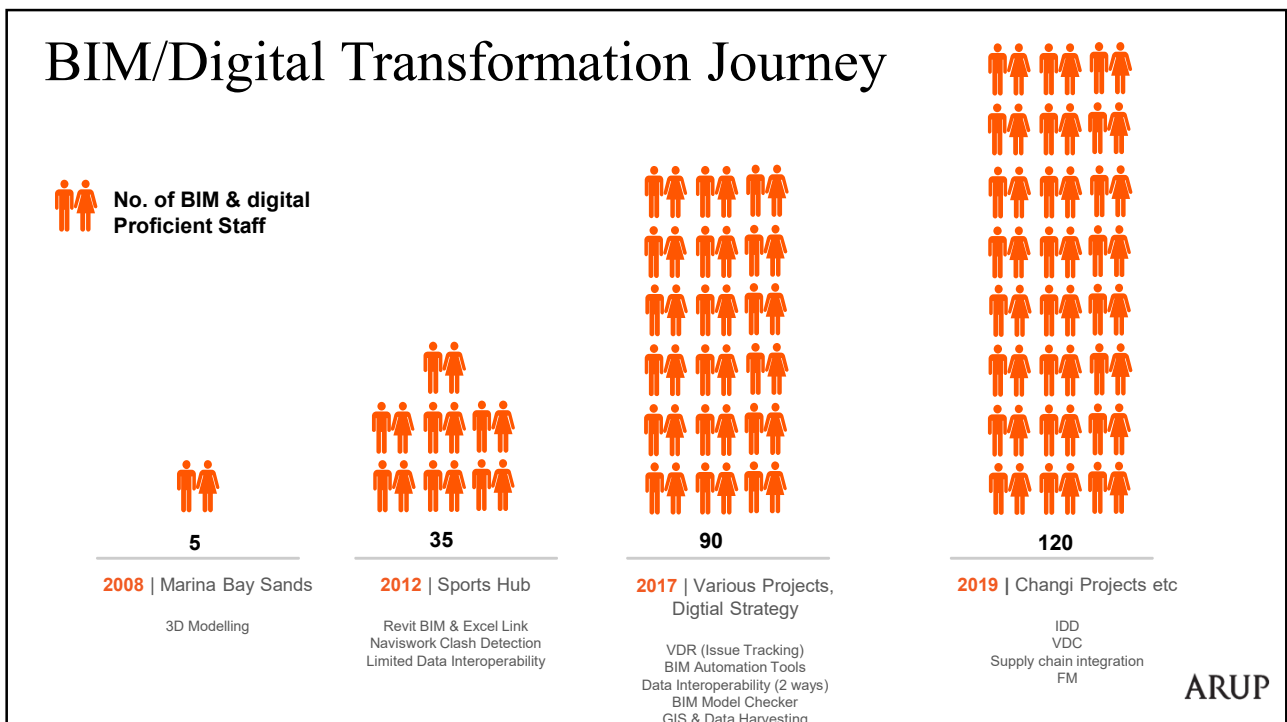
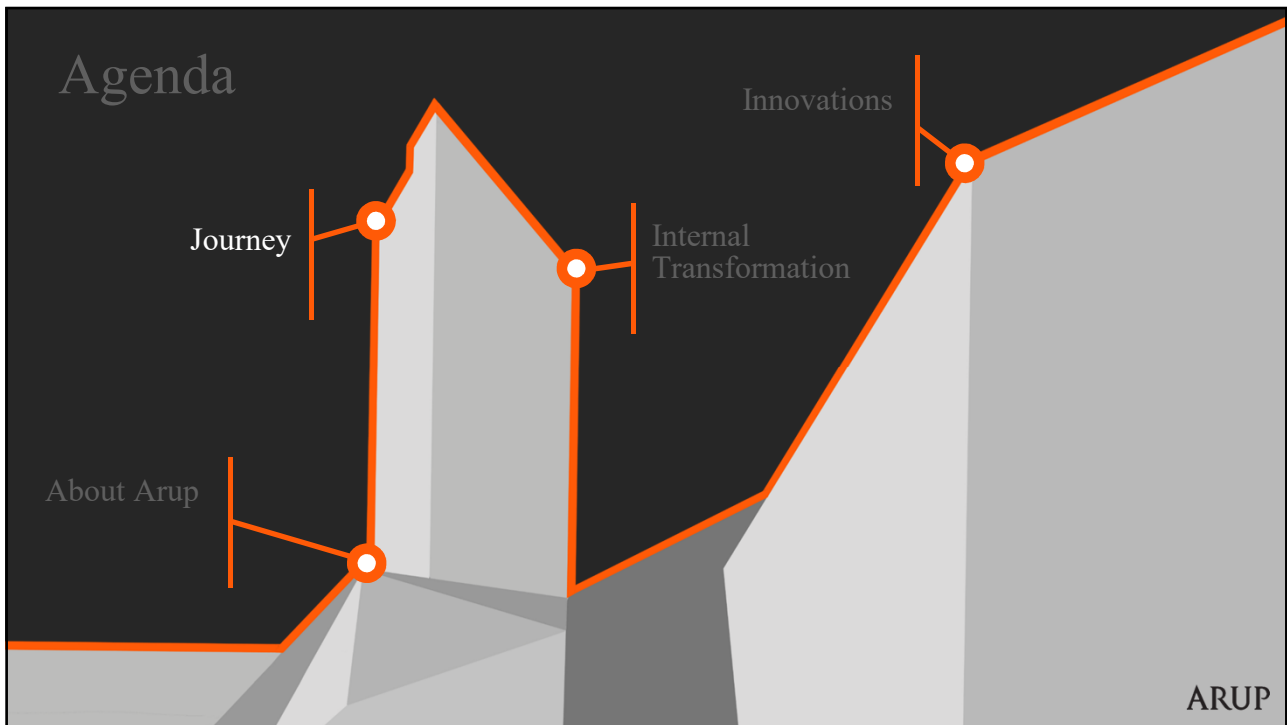
## Arup Singapore | BIM Awards

- ✓ Tekla Global BIM Award 2014 | Singapore Sports Hub
- ✓ BCA BIM Award 2015 | CapitaGreen [Platinum]
- ✓ BCA BIM Award 2015 | Tanjong Pagar Centre [Gold]
- ✓ BCA BIM Award 2015 | Yishun Community Hospital [Platinum]
- ✓ BCA BIM Award 2017 | Australian International School [GoldPlus]
- ✓ BCA BIM Award 2017 | JTC Furniture Hub [GoldPlus]
- ✓ ....



**ARUP**



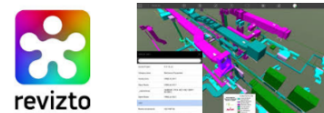
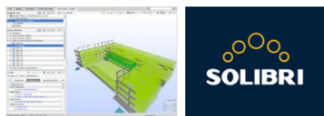
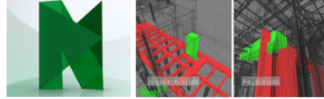


## Digital Delivery Trends

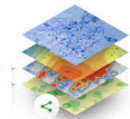
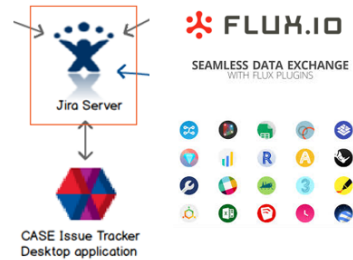
### BIM Modelling Packages



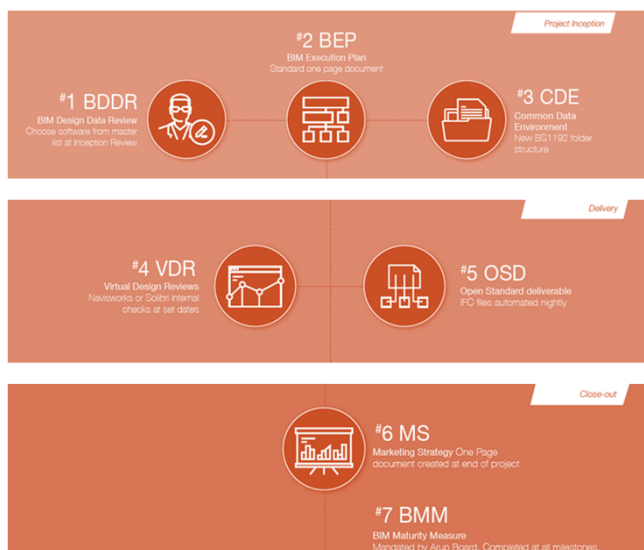
### BIM Review Packages



### BIM Issue Tracking / GIS / Interopt



## Digital Delivery Steps – “BAU” 7 Key Steps



Business As Usual

- 1 BDDR BIM Design Data Review
- 2 BEP BIM Execution Plan
- 3 CDE Common Data Environment
- 4 VDR Virtual Design Review
- 5 OSD Open Standard Deliverable
- 6 MS Marketing Strategy
- 7 BMM BIM Maturity Measure

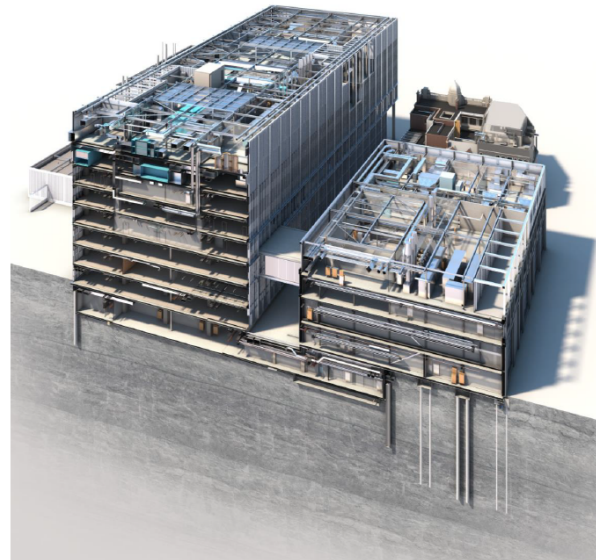
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# Digital Delivery | BIM Maturity Measures

## Why Measure BIM?

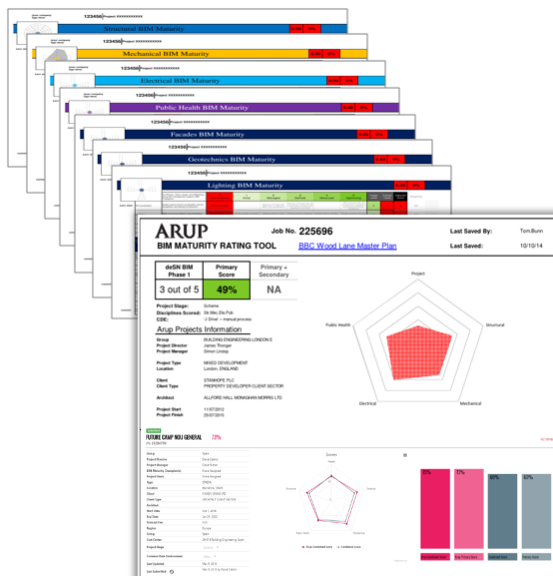
- To promote common understanding
- To identify strengths and weaknesses
- To compare regions, groups and disciplines
- To set targets and assess progress towards meeting them
- To communicate goals and strategies across different levels within the firm

TO DELIVER BETTER PROJECTS  
TO BETTER DELIVER PROJECTS



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# Digital Delivery | BIM Maturity Measures



## Arup BIM Maturity Measure: Overview

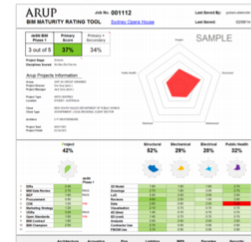
For more details see: [http://networks.interned-arup.com/digital/strategy/section/bim\\_maturity/tema.cfm](http://networks.interned-arup.com/digital/strategy/section/bim_maturity/tema.cfm)

### What is the BIM Maturity Measure?

It is a way of measuring the maturity of BIM use by Arup projects and groups. It has been developed by Arup based on work by Penn State University.

- Measure maturity and progress both within a project and in comparison with other projects
- Completed by PM or discipline lead
- Quick and transparent
- Allows projects to set clear goals and measure progress
- Project data imported from Arup Projects
- Maturity assessed against Arup's *Phase 1* BIM targets and against external benchmarks i.e. UK Government BIM Level 2 maturity
- Results can be amalgamated by group/discipline/region

It consists of a series of multiple choice questions asked about the project's information management process and each discipline's information modelling practices.



### How will it help my group and Arup?

Arup's BIM implementation has suffered from being unable to consistently compare progress across different projects, teams and

Each project is rated by the project team against project wide and discipline specific criteria and then emailed the BIM team. The tool takes about 10 minutes to complete, though a first-timer may take 20 minutes of reading to digest all the choices. The results for each section and the overall rating will be displayed on the cover sheet.

See also BIM Maturity Measure No-Setup & Use

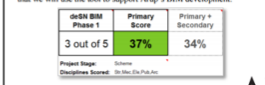


The higher the score, 1 to 5, the greater the BIM engagement. It may not be currently possible to gain high scores in some areas - BIM tools and methodologies are still being developed across the industry and Arup has been and will continue to be at the forefront of this development.



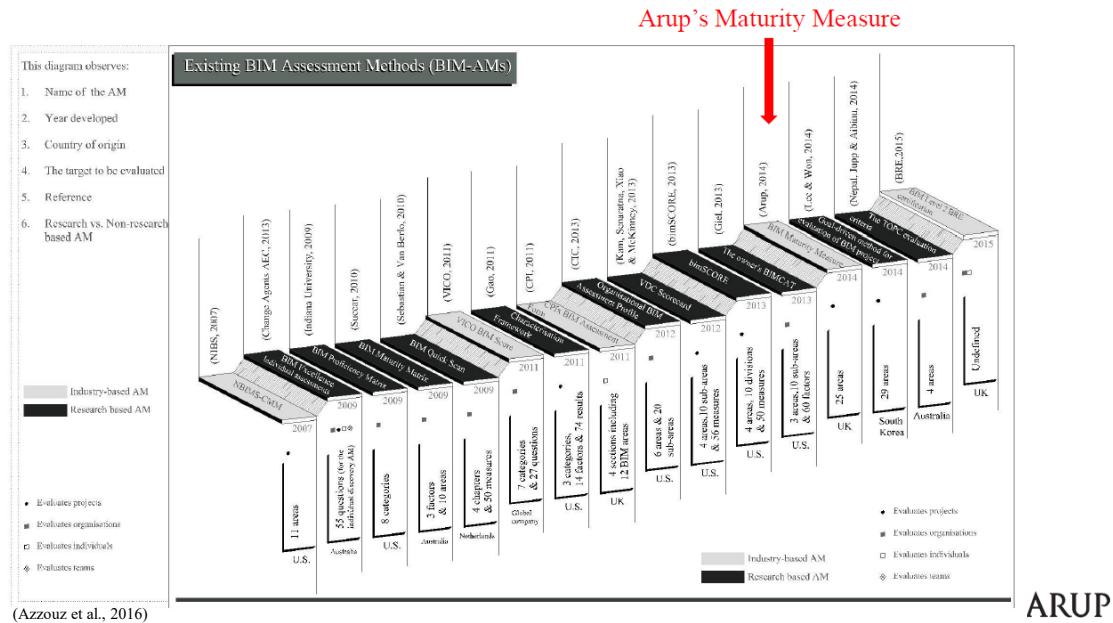
### Rating

It is expected that the maturity ratings will currently be quite low and that we will use the tool to support Arup's BIM development.

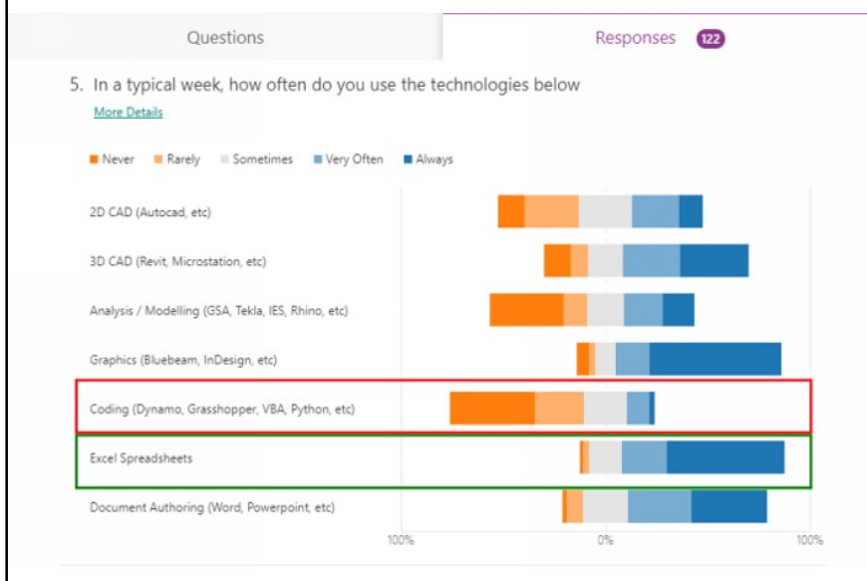


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## Digital Delivery | BIM Maturity Measures



## Digital Transformation | Systematic Steps



20% Ready



50% Ready



## Digital Transformation | Challenges

What are issues preventing wider adoption?

Lack Confidence  
and guidance

Lack of practical  
examples

Big change in  
working practice

From the niche to  
the everyday

Lack of workflow  
planning

Lack of project-  
leader awareness,  
direction and buy-  
in

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## Digital Transformation | Solutions

What have we done?

Lack Confidence and guidance

Training, sharing  
sessions

Lack of practical examples

Pilot project to  
develop Work flow

Big change in working practice

Make it step change or  
Disrupt with change  
management

From the niche to the everyday

Make it a norm or  
“Bau”

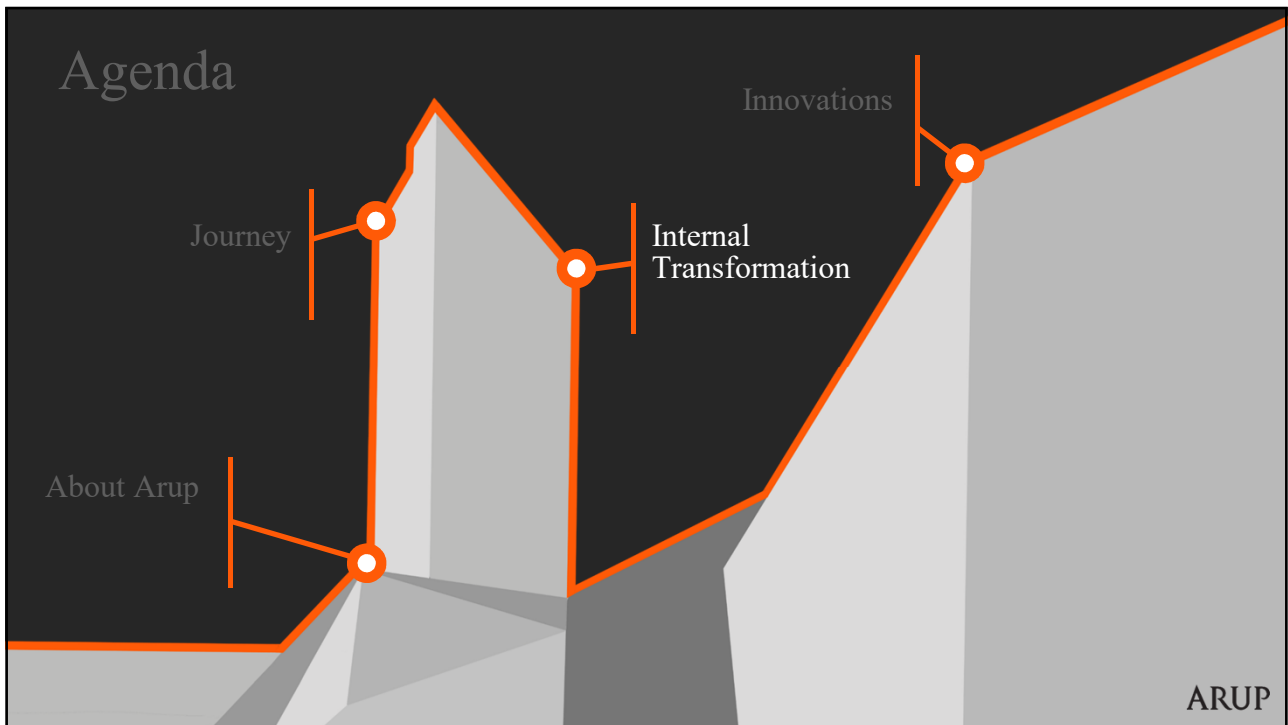
Lack of workflow planning

Establish detail work  
flow

Lack of project-leader awareness, direction  
and buy in

Leadership influence  
and top down change  
management

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## Internal Transformation | 5 Key Approaches

- 👥 Setting Digital Mindset
- ⚙️ Setting Digital Implementation Strategy
- 🔍 Investing in Digital Technology
- 👤 Investing in Digital Skills and Talent
- ▶ Organization Change

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## Internal Transformation | 5 Key Approaches



### Setting Digital Mindset



### Setting Digital Implementation Strategy



### Investing in Digital Technology



### Investing in Digital Skills and Talent



### Organization Change

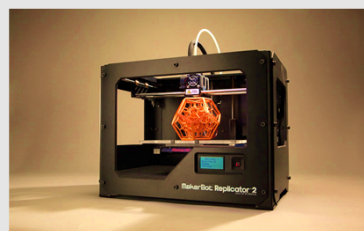
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## Digital Mindset



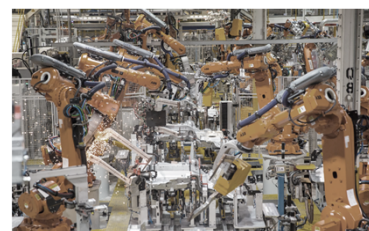
### Hand crafted

*Engineering the products one at a time*



### Mass bespoke

The model for how we need to be consistently working



### Mass production

*Engineering the process that creates the products*

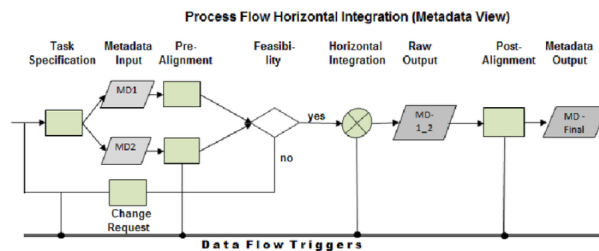
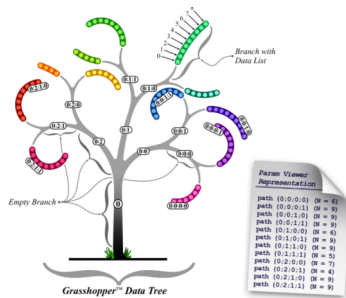
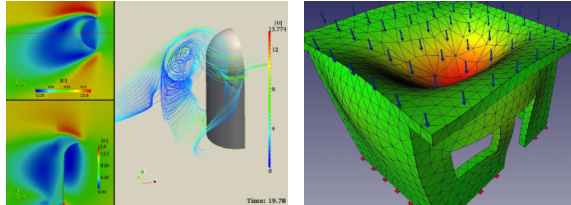
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# Digital Mindset



## IDD = Flow of Data

A supply chain, as opposed to supply chain management, is a set of organizations directly linked by one or more upstream and downstream flows of products, services, finances, or information from a source to a customer. Supply chain management is the management of such a chain



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# Digital Mindset



## BIM is **not** a Software

### BIM = Meta Data

**Metadata** is "data [information] that provides information about other data".<sup>[1]</sup> Many distinct types of metadata exist, among these **descriptive metadata**, **structural metadata**, **administrative metadata**<sup>[2]</sup>, **reference metadata** and **statistical metadata**<sup>[3]</sup>

### Purpose of the data

- Time and date of creation
- Creator or author of the data
- Location on a [computer network](#) where the data was created
- [Standards](#) used
- File size
- Data quality
- Source of the data
- Process used to create the data

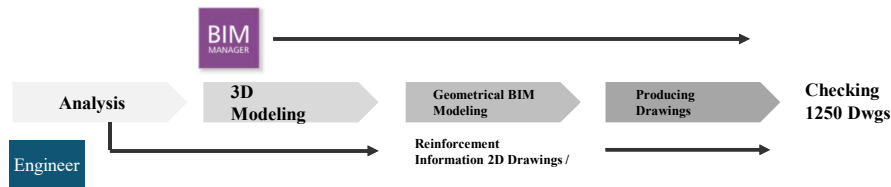


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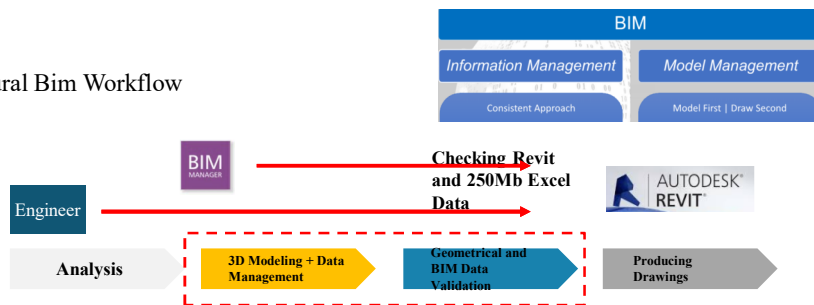
# Digital Mindset



## Traditional Structural Bim Workflow

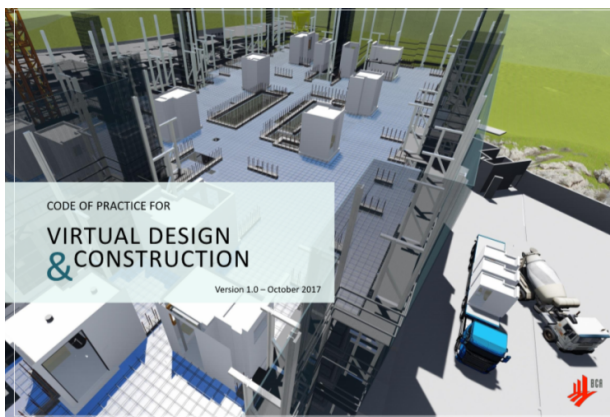


## Arup Structural Bim Workflow



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# Digital Mindset

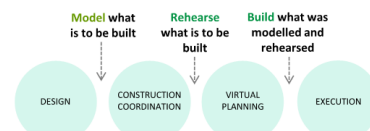


## What is VDC?

Virtual Design and Construction or VDC is the management of **BIM** models as well as **people** and **processes** in order to achieve explicit project or organizational **goals** and to improve **performance**.



In essence, VDC is to  
**“Build Twice”**  
 first **Virtual** and then **Real**



Building twice enables a project team to fully simulate design and construction in a virtual environment first prior to actual execution on site.

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## Digital Mindset | Our Journey of VDC



VDC in Design and Build (D&B) and Design Bid Build (DBB) Projects are difference



**Singapore Sports HUB (D&B)**  
(Construction Completed)  
Arup: Structure + Consultancy



**Furniture Hub (DBB)**  
(Construction On-Going)  
Arup: Structure + MEP + Consultancy



**National Cancer Center (DBB)**  
(Construction On-Going)  
Arup: Structure



**Paya Lebar Quarters (D&B)**  
(Construction On-Going)  
Arup: Structure + Consultancy



**Outram Community Hospital (DBB)**  
(Construction On-Going)  
Arup: Structure



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## Internal Transformation | 5 Key Approaches



Setting Digital Mindset



Setting Digital Implementation Strategy



Investing in Digital Technology



Investing in Digital Skills and Talent



Organization Change

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# IDD - Managing Data Flow



## Computation

What skills should we have?

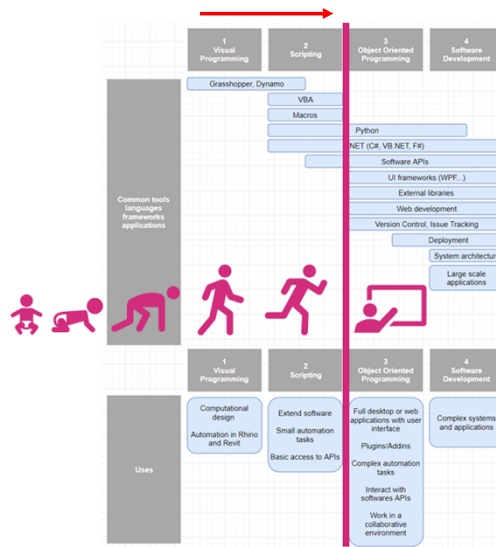
- Read/ write data
- Write functions & sub-routines
- Use of loops & Arrays
- Use API/ Com Interfaces

Why have these skills?

- Manipulate data between software packages
- Understand shared tools
- Adapt and extend existing tools
- Write new tools

Who should have these skills?

- Core skill for Engineers and technicians
- Aim for 40/40/20 split:  
coders/ learners/ non-coders

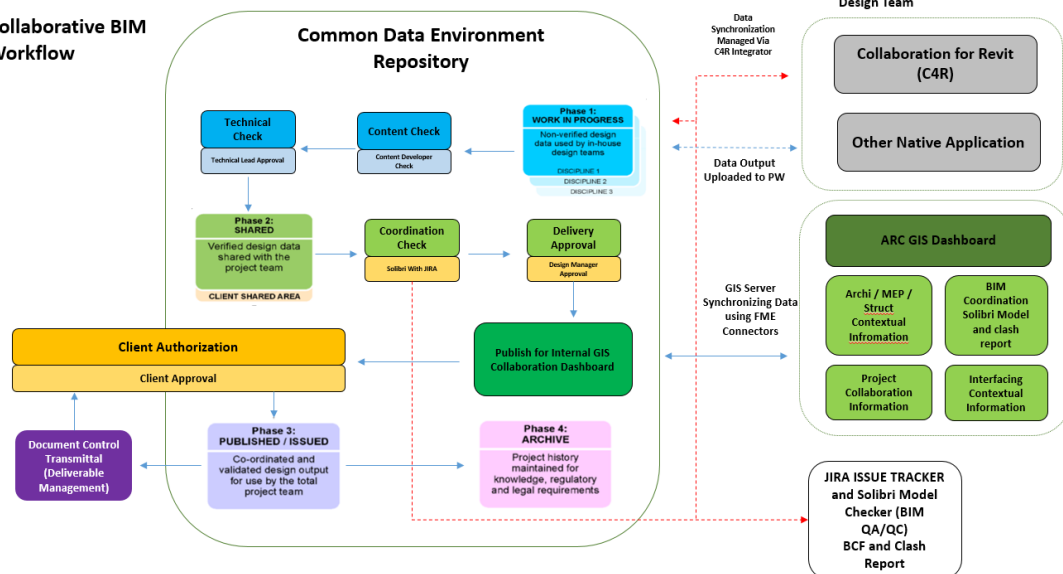


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## How to Work in a Common Environment

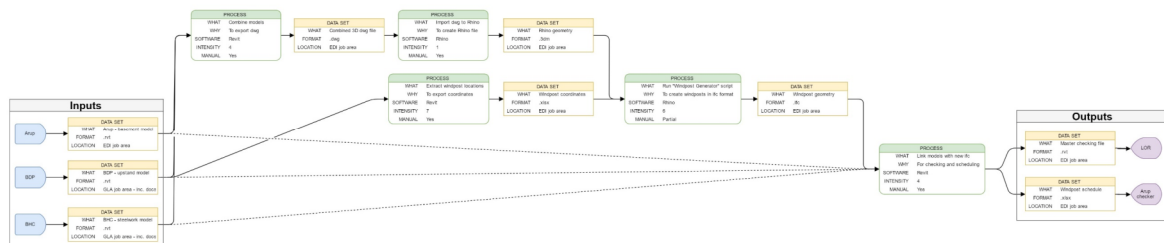


**Collaborative BIM Workflow**

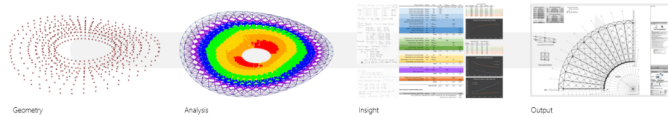


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## Digital Strategy | Workflows



A common set of digitally-enabled engineering workflows is the key to connecting development across a broad range of project types and tool sets.



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## Internal Transformation | 5 Key Approaches



Setting Digital Mindset



Setting Digital Implementation Strategy



Investing in Digital Technology



Investing in Digital Skills and Talent



Organization Change

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# Digital Technology



“ Digital technology is redefining the property sector as we speak, bringing the potential to radically improve our working lives, increase asset value and create more sustainable buildings. However, investors, developers and owners of corporate real estate must be careful – this isn't about gadgets and equipment, it is about strategic thinking that avoids wasting money on the wrong innovations and inefficient capital and operational expenditure. With the right strategy in place, we can align the property sector with the demands of our digitally enabled society and truly deliver buildings for the future. ”



Volker Buscher  
Global Leader, Data

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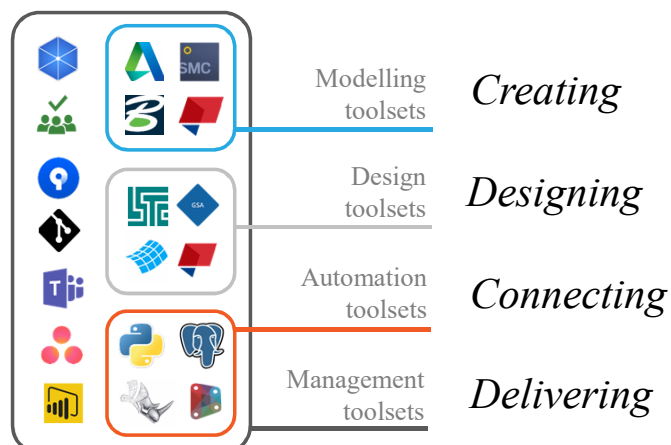
## Digital Technology | Tools



Tool sets must serve the way we want to work and we must become expert users and adaptors of our tools.

The digital process drives everything else so we must own and manage our processes, and do so in a visible way that includes and empowers our teams to do new things.

Mastery of our current tool sets creates a basis for spotting new tools that will help us improve.



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## Digital Technology | Arup University



### Ask

A regional Library team – research to support winning work, project work and keeping current.



### Share

Sharing our knowledge and skills to develop our staff and our business.



### Learn

Enabling high quality technical learning across the region.



### Explore

Exploring new possibilities through research, foresight and innovation.

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## Digital Technology | Have Fun



March 6th, 2018



# Internal Transformation | 5 Key Approaches



Setting Digital Mindset



Setting Digital Implementation Strategy



Investing in Digital Technology



Investing in Digital Skills and Talent



Organization Change

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## Digital Skills and Talents | Digital Skills required



### DIGITAL SKILLS CARDS

#### Generative Design

Using parameters, formulas and visual programming tool to algorithmically create, test and develop design outcomes.

Generative design is a process based on algorithmic thinking that enables the expression of parameters and rules that together define, encode and clarify the relationship between design intent and design response.

**Tool Examples:**

- Grasshopper, Elanform, GeometryGym, Karamba
- Blendspace

#### BIM

The creation, development and presentation of geometric models and object based models created in BIM or GIS data structures.

BIM modelling is the process of developing a mathematical representation of an object in three dimensions via specialized software. Geometry can be created in a number of ways including manual modelling, parametric algorithms, assembling sets of pre-made components, or importing 3D scan point clouds. Once created geometry can either be stored as pure geometrical meshes (surfaces and solids) or as rich data objects (shape files and BIM components) which include additional embedded information.

**Tool Examples:**

- Autodesk, Tekla and Bentley platform tools
- Unity3D
- Rhino and Sketchup
- Enscape, Iri and other VR/AR tools
- ArcGIS/Pro

#### User Interface/Interaction Design (UI)

Designing the functional and visual interactions of users that go together to create memorable experiences.

User Interface (UI) Design is the design of how users interact and experience something. It can be both physical (the experience of wayfinding) or digital (a website) and spans from the top level information architecture (in what order and how information is presented to users) through the steps a user takes and logical layout of components down to the visual design of

**Tool Examples:**

- Sketch
- InVision
- Adobe Creative Suite (Photoshop, InDesign, Illustrator)
- Balsamiq

#### Database Design & Maintenance

The specification, design and maintenance of systems for the storage of and access to data in support of user requirements.

The design, implementation and maintenance of a database, data management system or data warehouse, including scheme, standards and appropriate documentation. This skillset covers database and distributed computing theory, established approaches including design, relational database management system (RDBMS), SQL and modern NOSQL.

**Tool Examples:**

- SQL, MySQL, MS-SQL, PostgreSQL, NoSQL
- MongoDB
- Django
- Document DB's
- Cassandra

#### nD Modelling

The use of BIM and GIS models to serve wider aspects of the design, construction and operational project phases.

An nD model is an extension of a 3D geometry model of an asset to incorporate the design information required at each stage of its lifecycle

- 4D - Time and spatial planning
- 5D - Quantity and cost modelling
- 6D - Lifecycle sustainability modelling
- 7D - Risk and operations planning

Each aspect requires data to be embedded, validated and processed to achieve a particular outcome.

**Tool Examples:**

- Autodesk, Tekla and Bentley platform tools
- Navisworks, Solibri, Bluebeam
- Archi
- Dynamo
- Microsoft PowerBI
- Oracle Primavera

**Approach Examples:**

- Digital Twin

#### Requirements Gathering & Management

The process of capturing the objectives, goals and wishes of the client or end user upfront and early-on.

A requirement is a statement about an intended product that specifies what it should do or how to do it. Requirements gathering seeks to define specific, unambiguous and clear requirements through engagement with the intended stakeholders and users. Requirements can be both functional and non-functional in nature and are often developed iteratively based on

**Tool Examples:**

- Jira
- Jello

**Approach Examples:**

- Interviews
- Questionnaires

#### Workflow Mapping

Mapping a workflow to show the individual tasks and datasets and the connections between them.

Workflow mapping is a method of documenting a process in order to understand the different tasks involved, how they relate to each other, and how the data flows through the system. Mapping out an existing process is the first step towards being able to improve that process. The map captures the logical flow of the process and allows you to identify duplication, bottlenecks and other kinds of waste present. The map can then be recreated to depict an improved

**Tool Examples:**

- DrawIO
- Archimate

**Approach Examples:**

- Workshops
- Observation

#### Machine Learning & AI

Enabling machines to make predictions based on data and experiences rather than by receiving explicit programming instructions.

ML and Artificial Intelligence (AI) use algorithms to detect meaningful patterns and knowledge from existing data to automate decisions. ML can be broadly separated in two classes, i.e. supervised learning (SL), e.g. where the training process is based on data which are labelled by a human, and unsupervised learning (UL), e.g. where a learning function is inferred from unlabelled data. AI functions are as above but with the aim to enable decisions in a similar cognitive way as humans do.

**Tool Examples:**

- Scikit-Learn
- TensorFlow
- Keras

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SFIA Ref: TBC

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SFIA Ref: TBC

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ARUP  
SFIA Ref: D4AN

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## Digital Skills and Talents | Skill Gaps



Structural engineering  
Management skills  
**Communication** skills

Technical & operational skillsets



The structural  
engineer  
(and team)

Process engineering  
**Data** engineering  
**Software** engineering

Digitally enabled skillsets

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## Digital Skills and Talents | Filling the gaps



Information managers  
**Technical services engineers**  
IT and Cloud specialists  
Visualisation specialists  
**Gaming designers**  
Analysts  
**Programmers**  
Data Specialists – Big Data  
**DB administrators**  
Neural networks, machine learning  
IoT  
**Web developers**

Needed during project delivery



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## Digital Skills & Talents | Progressive Mindset



### Portability

Take your design with you wherever you go



### Interaction

More intuitive ways to work, interact and share



### Prototyping

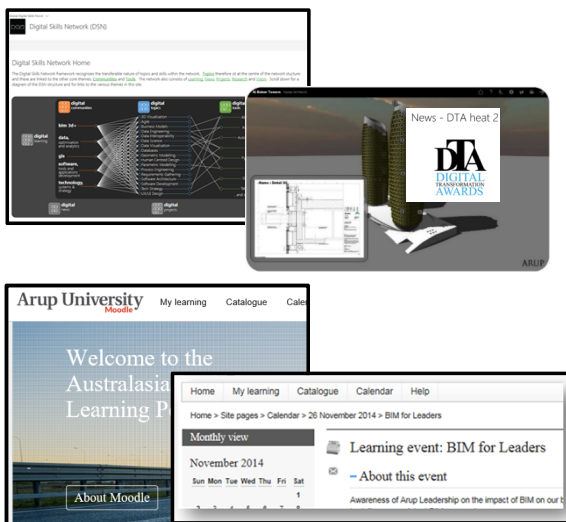
Let's become makers and explore design through objects

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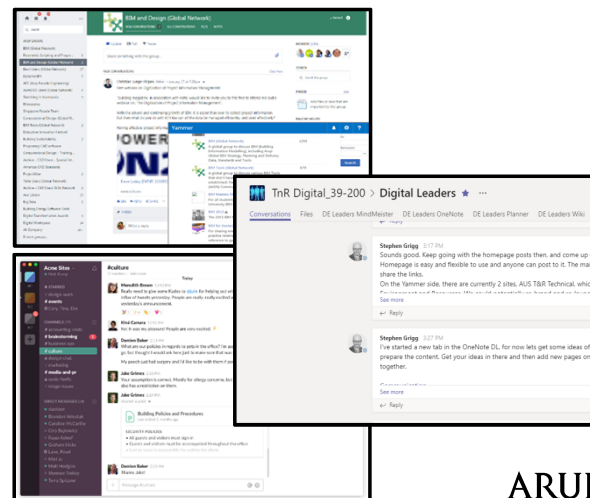
## Digital Skills & Talents | Success Factors



### Learning



### Communication



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## Digital Skills & Talents | Learning

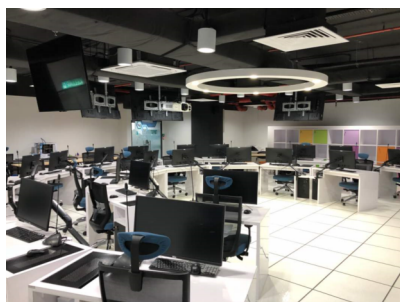


### Basic BIM

*Bespoke, large scale, business driven*



Year 2017  
(Pioneer training)



Year 2018  
(Revit bespoke and  
basic programme)

### Advanced BIM

*Specialist development, partners*



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Arup Professional Services v1.04

Training Courses – Breakdown

Below are brief breakdowns of what content will be covered for the proposed bespoke training courses.

#### Revit MEP Advanced – 3 day course

Ideas for advanced (master) Revit training:

1. Coordinates
  - a. Shared
  - b. Project base point
  - c. Survey point
  - d. Revit internal origin
2. MEP family creation
  - a. Connector settings
  - b. Family categories
  - c. Family sub categories
  - d. Part types (breaks into, etc)
  - e. Controlling reference planes/lines to allow families that not just stretch in size but are articulated, eg rotate connector from front face to top face
  - f. Nested families
  - g. Type catalogues
  - h. Lookup tables
  - i. Formulas
  - j. Parameters
  - k. Detail levels

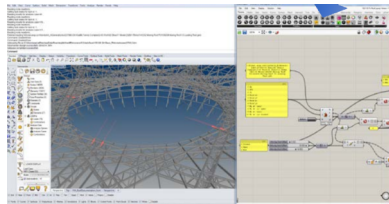
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# Digital Skills & Talents | Learning

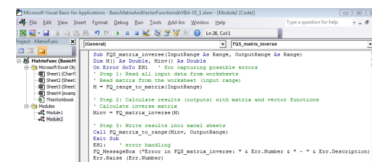


## Parametric Skill Upgrade

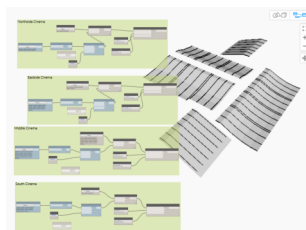
Visual Programming



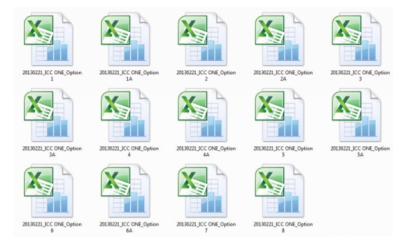
Coding



Creating Complex Geometry Using Rhino-Grasshopper



Database



Creating Sloping Beam along Surfaces Using Revit-Dynamo

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# Digital Skills & Talents | Learning



## Interoperable Skill Upgrade

We have new **courses** for you!



Basic Interoperability Rhino & Revit

|                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                      |                                                                                                                                                                                                                        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>PARAMETRIC MODELING</b><br>Learn Parametric Modeling from its very basic principles to advance form generation and data management.<br><a href="#">START PATH</a>                                                                             | <b>EXPLICIT MODELING</b><br>Learn how to create 3D designs quickly and easily using leading software in the building industry.<br><a href="#">START PATH</a>                                                                         | <b>BIM</b><br>Learn Building Information Modelling and get the most out of your projects by harnessing the power of data extraction and collaboration.<br><a href="#">START PATH</a>                                   |
| <b>INTEROPERABILITY</b><br>With the advent of various software, exchanging data and streamlining complex design workflow is more important than ever. This path will guide you in learning these essential skills.<br><a href="#">START PATH</a> | <b>SIMULATION AND ANALYSIS</b><br>Learn how to do an environmental analysis in a structural simulation to understand your design and be able to create a better sustainable and performative building.<br><a href="#">START PATH</a> | <b>VISUALIZATION</b><br>May it be photorealistic renders or diagrammatic images, architects communicate many things through visualizations. Follow this path and become a master in com.<br><a href="#">START PATH</a> |
| <b>AUTOMATIZATION</b><br>Tired of repeating the same task over and over again? This path will allow you to create your own tools to automate tasks, so you can focus on the things that matter, like designing.<br><a href="#">START PATH</a>    | <b>DIGITAL FABRICATION</b><br>From 3D-printing to CNC milling, this path covers everything you need to know about how to use advanced machinery to assist your project.<br><a href="#">START PATH</a>                                |                                                                                                                                                                                                                        |

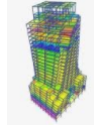
# Digital Skills & Talents | Learning



## Visualisation Skill Upgrade

CSI COMPUTERS & STRUCTURES, INC.

APPLICATION PROGRAMMING INTERFACE



AUTODESK  
FORGE

APIs ▾

Microsoft Excel API  
Office 365

Microsoft



amazon  
web services

Coding



Figure 2: A Central Database Server Optimized for Data Storage and Retrieval



Figure 7: NoSQL Store for Version Control

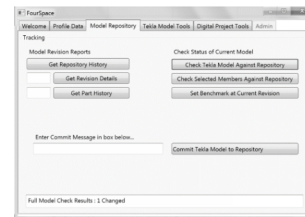


Figure 8: Structural Analysis + TEKLA Model Version Control

Database

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## Internal Transformation | 5 Key Approaches



Setting Digital Mindset



Setting Digital Strategy



Investing in Digital Technology



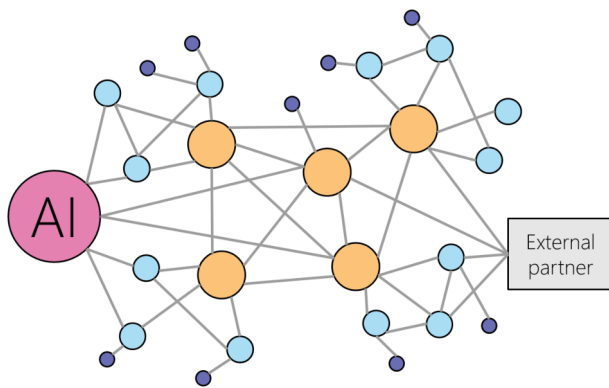
Investing in Digital Skills and Talent



Organization Change

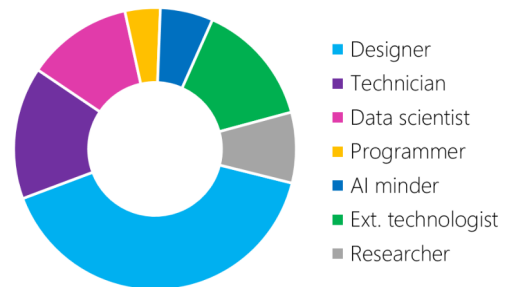
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## Teams

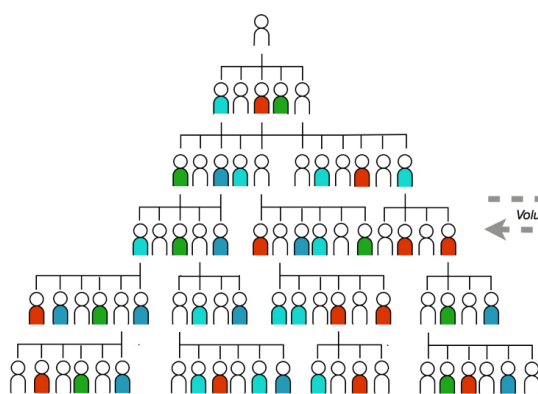


The composition of the team should be driven by the outcomes we are seeking.

Roles, skills and tasks are products of the processes we build.

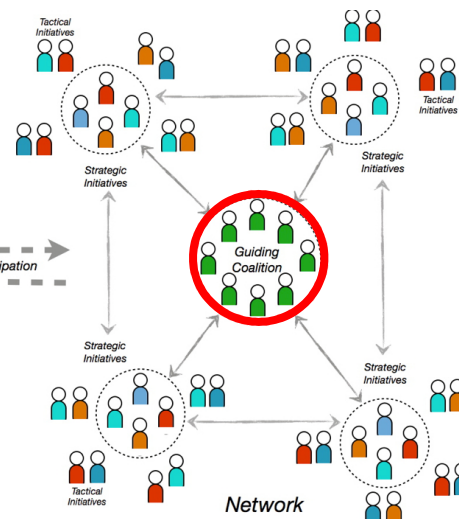


## Teams



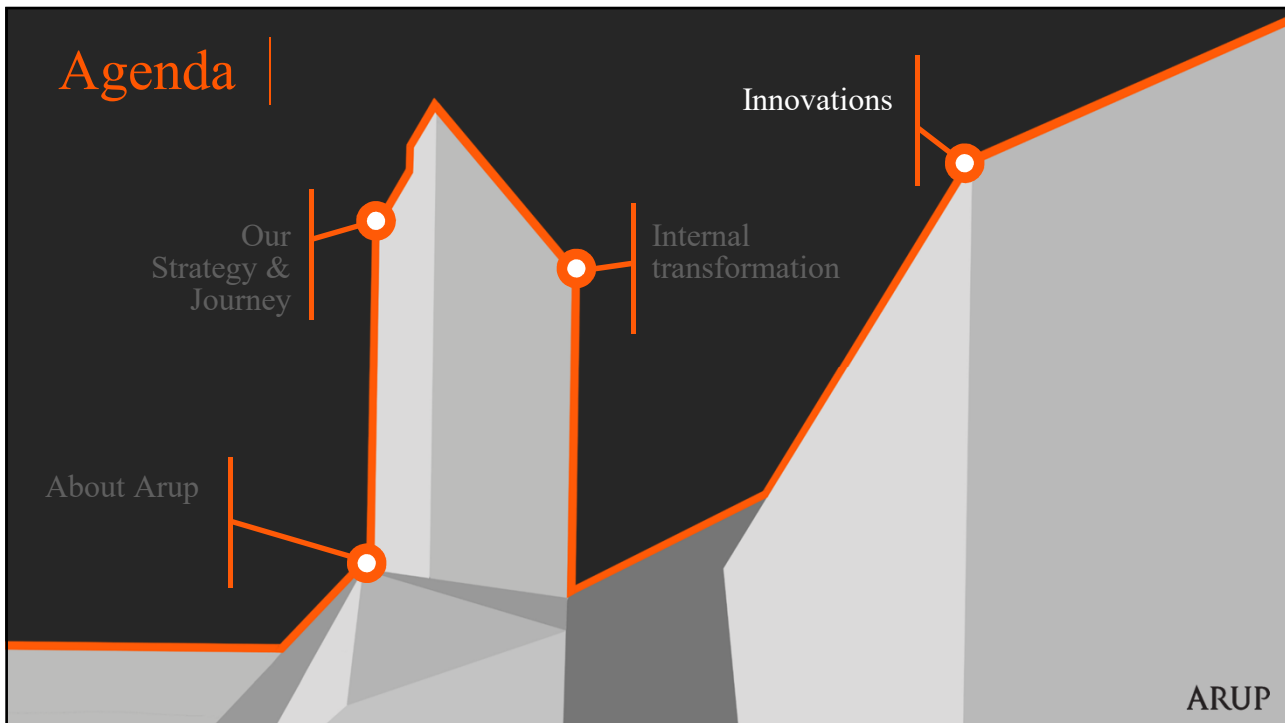
*Hierarchy*

Voluntary Participation



*Network*





## Innovations | Industry Sharing and Collaboration

### Agencies and Industry



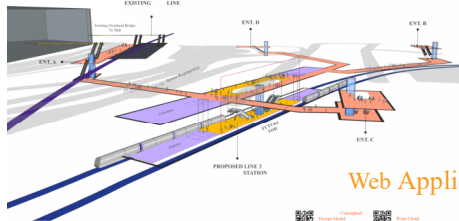
### Varsities & Organization



### Technology

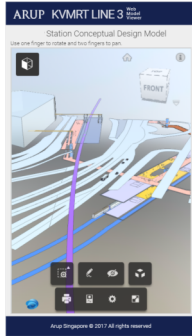


# AR | Metro Project

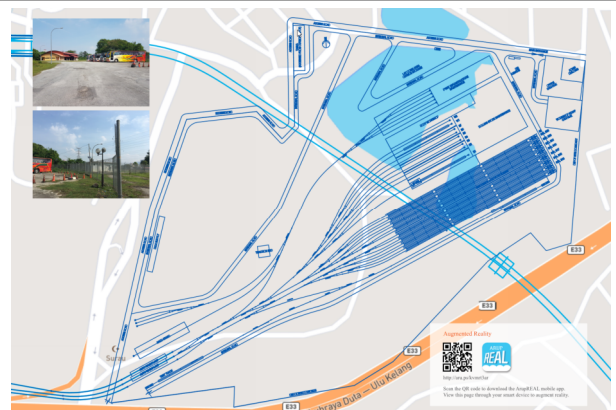


Web Applications

## 1 3D Model Viewer



## 2 Point Cloud Viewer



## 3 ArupREAL AR



ARUP

# AR | Metro Project



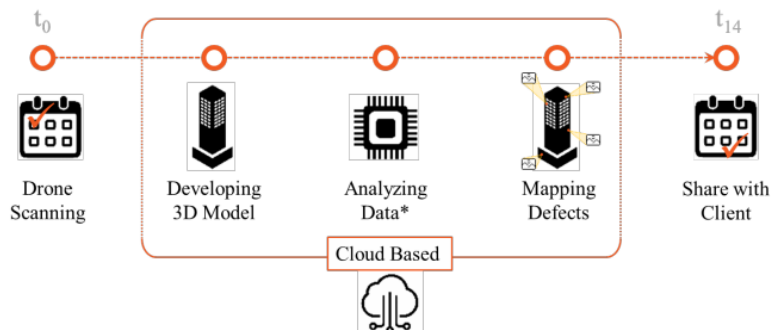
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## AR | OveAR

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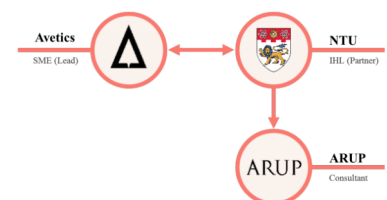
## Drone Façade Inspection (Research)

## 14-day Methodology

 $t_n$  – represents time at  $n^{\text{th}}$  day

\* Phase 01 – includes image processing algorithms and codes to identify defects like cracks and spalling concrete in concrete, plaster, tile surfaces  
 Phase 02 – involves defect identification using artificial intelligence including corrosion, efflorescence and discoloration to metal supports and along with the materials in phase 01

## Team



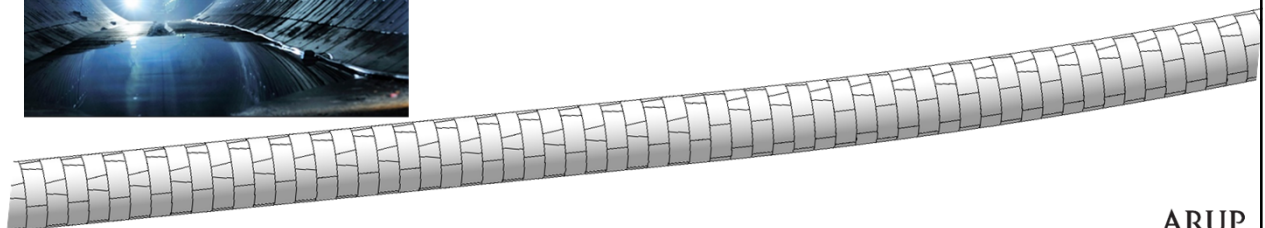
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## Arup DriveSim | Simulator



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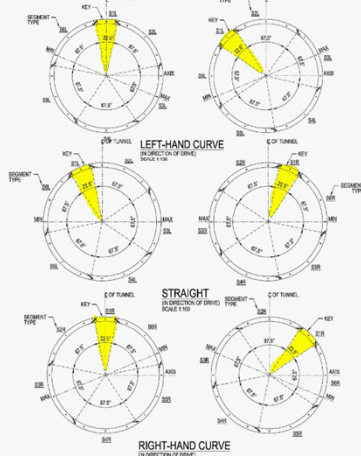
## Arup Parametrics for Segmental Tunnel Lining Configuration



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## 1. Tunnel Alignment

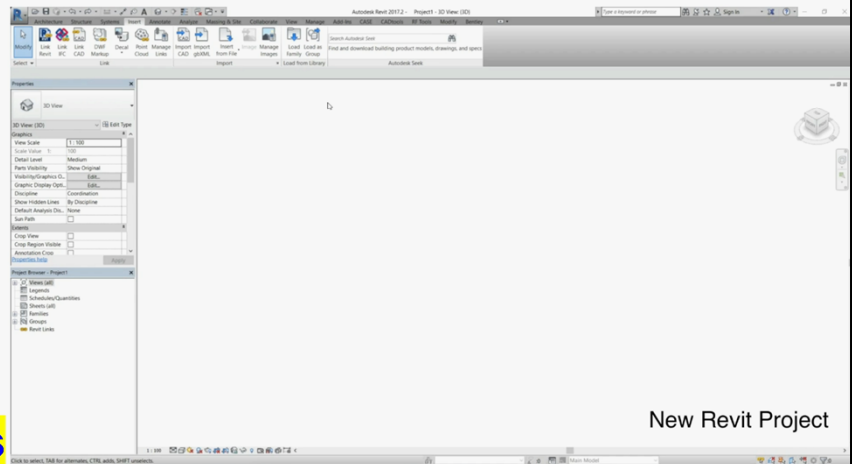
## 3. Key Angle Rules



## Key Considerations

## 2. Segment Min/Max Width Rules

| 4m Internal Diameter        |                   |                   | 6m Internal Diameter         |                   |                   |
|-----------------------------|-------------------|-------------------|------------------------------|-------------------|-------------------|
| Case:                       | Segment Max width | Segment Min width | Case:                        | Segment Max width | Segment Min width |
| Straight                    | 1400              | 1400              | Straight                     | 1600              | 1600              |
| Radius 40 (Right)           | 1487              | 1313              | Radius 150 (Left and Right)  | 1638              | 1562              |
| Radius 150 (Left and Right) | 1422              | 1378              | Radius 200 (Left)            | 1628              | 1572              |
| Radius 250 (Right)          | 1414              | 1386              | Radius 300 (Right)           | 1620              | 1580              |
| Radius 300 (Left)           | 1412              | 1388              | Radius 500 (Left)            | 1609              | 1591              |
|                             |                   |                   | Radius 1200 (Left and Right) | 1604              | 1596              |



## CoT with NTU / BCAA (Research) | Code Complying Machine

### Cities of Tomorrow (CoT) R&D

The CoT R&D Programme is a multi-agency effort, led by Ministry of National Development, to identify challenges that cities face and develop R&D solutions to address the challenges.

A total of \$150 million has been set aside for CoT, which is part of the \$900 million allocated to the Urban Solutions and Sustainability (USS) domain under the Research, Innovation and Enterprise 2020

### Proposed Teaming

Principal Investigator



Co-Principal Investigator

BCA ACADEMY

Engineering Consultant

ARUP

Consultant (E-Corenet)



Collaborators



ARUP



# CoT with NTU / BCAA (Research)

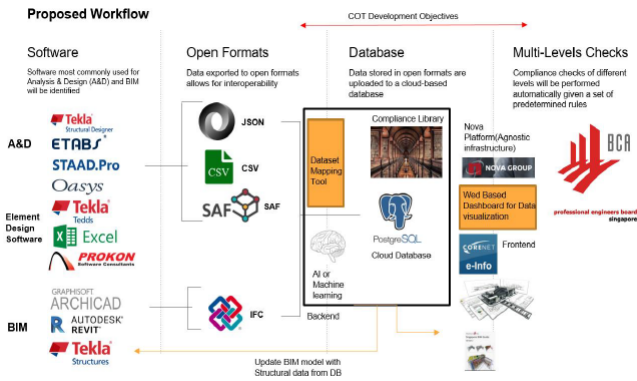


Figure 2 The proposed workflow for Structural A&D submission and processing

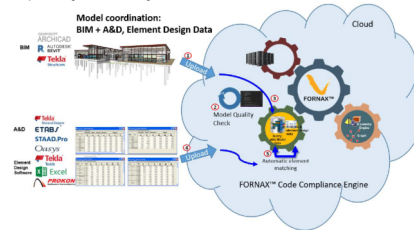


Figure 5 The workflow for developing Code Compliance Engine

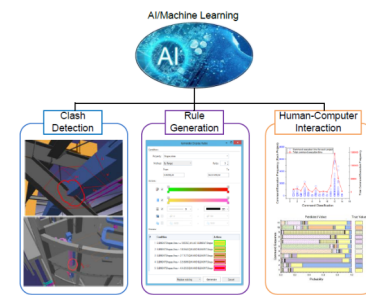


Figure 8 Role of AI/Machine Learning in the developed Code Compliance Engine

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# ARUP

We shape a better world