

# Gathering23

Accelerating BIM adoption

## Digital Twins and Beyond: Integrating BIM and GIS for Urban Transformation

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## What is Digital Twins?

“A Digital Twin is an integrated Multiphysics, multiscale, probabilistic simulation of an as-built vehicle or system that uses the best available physical models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying Twin”

(Glaessgen and Stargel, 2012)

Autonomous systems will need access to very realistic models of the current state of the process and their own behaviours in interactions with their environment in the real world, which is typically called DT

(Rosen et al., 2015)

DT as a set of virtual information constructs that fully describes a potential or actual physical manufactured product from the micro atomic level to the macro geometrical level

(Grieves and Vickers, 2016)

“A digital twin is a computerized model of a physical device or system that represents all functional features and links with the working elements.”

(Y. Chen, 2017)

“The digital twin is a living model of the physical asset or system, which continually adapts to operational changes based on the collected online data and information and can forecast the future of the corresponding physical counterpart.”

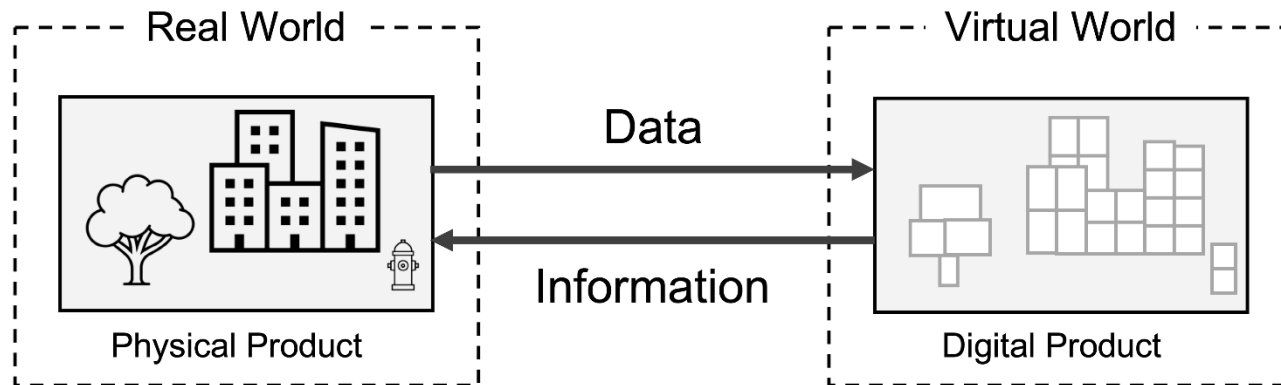
(Liu et al., 2018)

“A Digital Twin is a virtual instance of a physical system (twin) that is continually updated with the latter’s performance, maintenance, and health status data throughout the physical system’s life cycle.”

(Madni et al., 2019)

“DTs are considered a virtual development or representation of a real system or world”  
(Grieves M., 2014)

## The three elements of Digital Twins?



# Digital Twins applicability



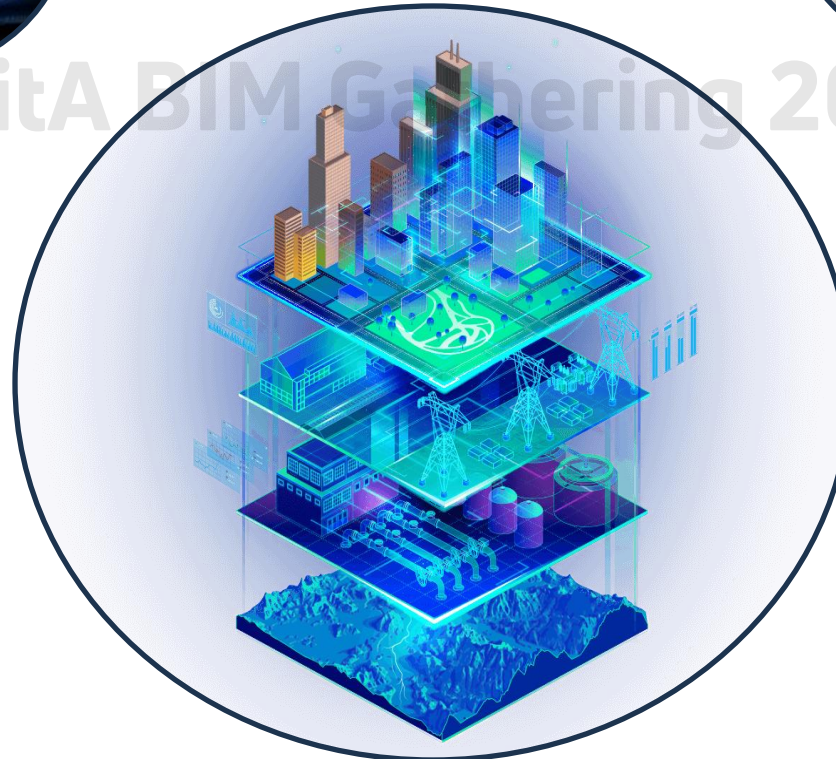
ptc



Softeq Development Corp.



Noria Corporation



The Healthcare Technology Report

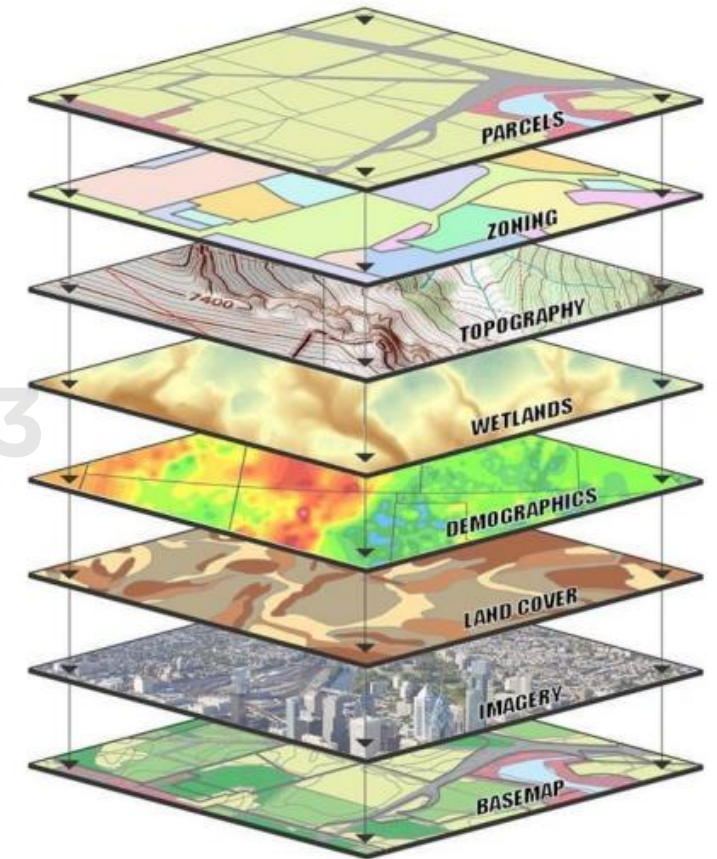
## BIM and Digital Twin

- BIM is usually applied at the initial stages of the project (Planning, Design and construction) phases.
- Digital Twins are implemented after construction for ongoing monitoring, maintenance, and optimization.



## What is GIS?

- GIS is an acronym - Geographic Information Systems
- GIS as computer-based tools for creating, storing, analysing, and presenting geographic data about real-world features (Zhang & Drake, 2014).
- Any discipline that uses maps uses GIS
- A geospatial digital twin represents the building within the context of its surroundings.

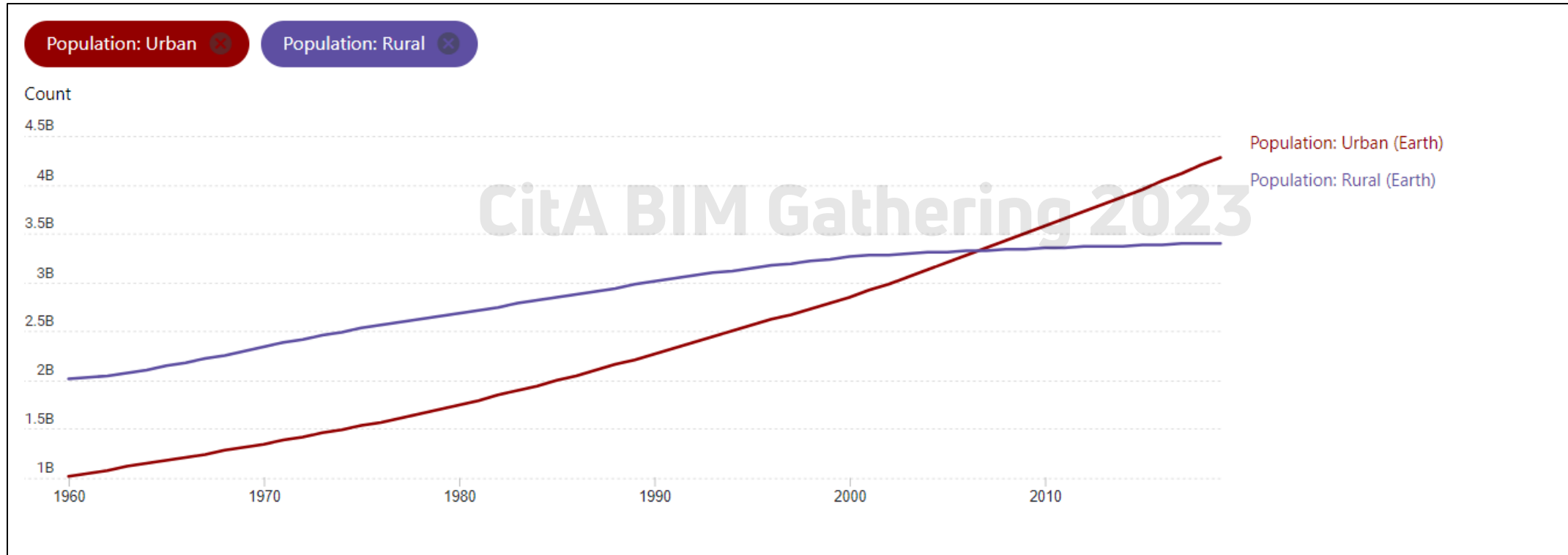


GIS layers

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**So what?**



### Challenges in urban areas



Source: datacommons.org



## More and more complex buildings

Rapid urbanization and lack of available land has forced decision makers to take advantage of space above and below ground (Shojaei et al., 2017).



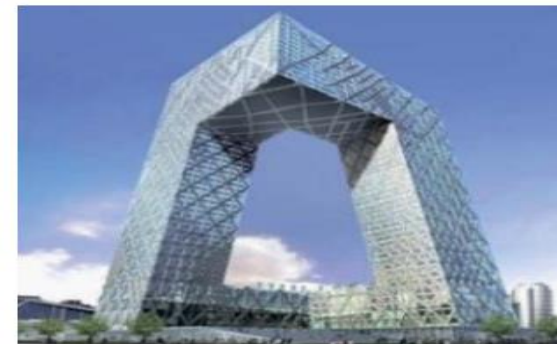
Morocco (Hajji et al., 2023)



Australia (Jazayeri et al., 2014)



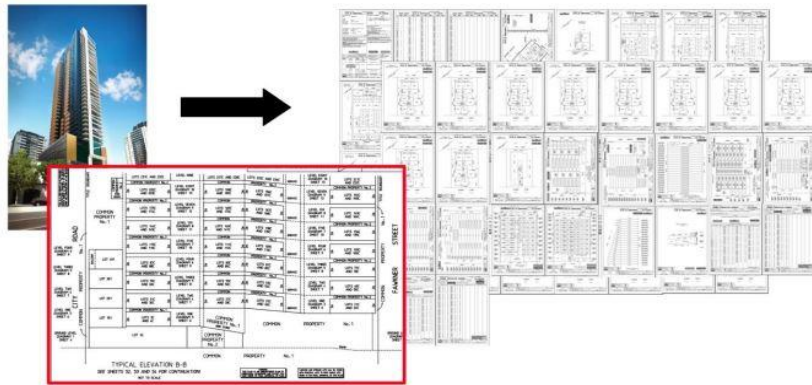
The Netherlands (Broekhuizen, 2021)



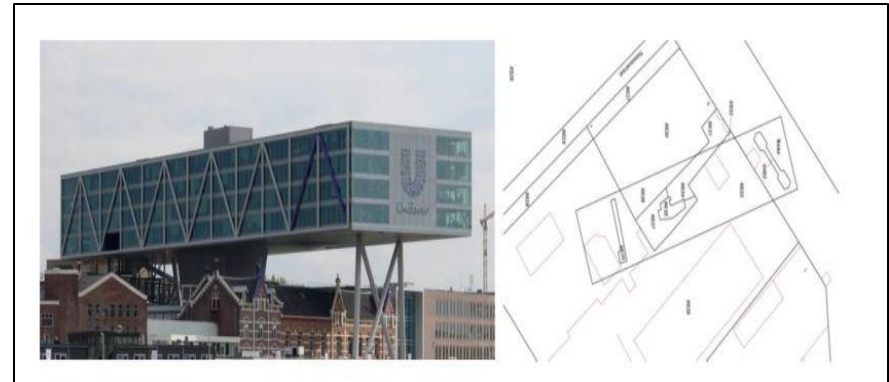
China (Ying et al., 2015)

# Conventional 2D Land Administration Systems (LAS) are not Efficient

2D LAS has limitations in representing complex buildings and infrastructures (Guler & Yomralioglu, 2022; Petronijević et al., 2021; Sun et al., 2019; Atazadeh et al., 2017).



Rajabifard et al. (2014)



Stoter et al. (2013)

## Land Administration Systems (LAS) in Ireland

- Land Registry (up to ~2010)
- Property Registration Authority (post ~2010)
- Now merged with Ordnance Survey Ireland and the Valuation Office to form Tailte Eireann.

How will we better plan, design,  
construct and operate urban areas  
and infrastructure in a more  
sustainable way for the future?

We must Change our Ways...

# Solution is 3D LAS

Old Way

New Way

Analog

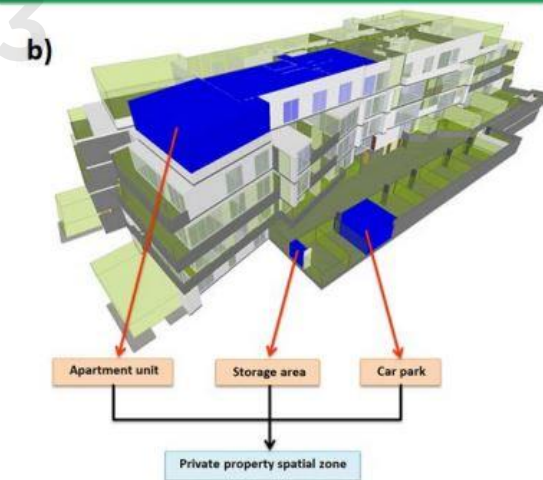
Digital

Simpler

Comprehensive

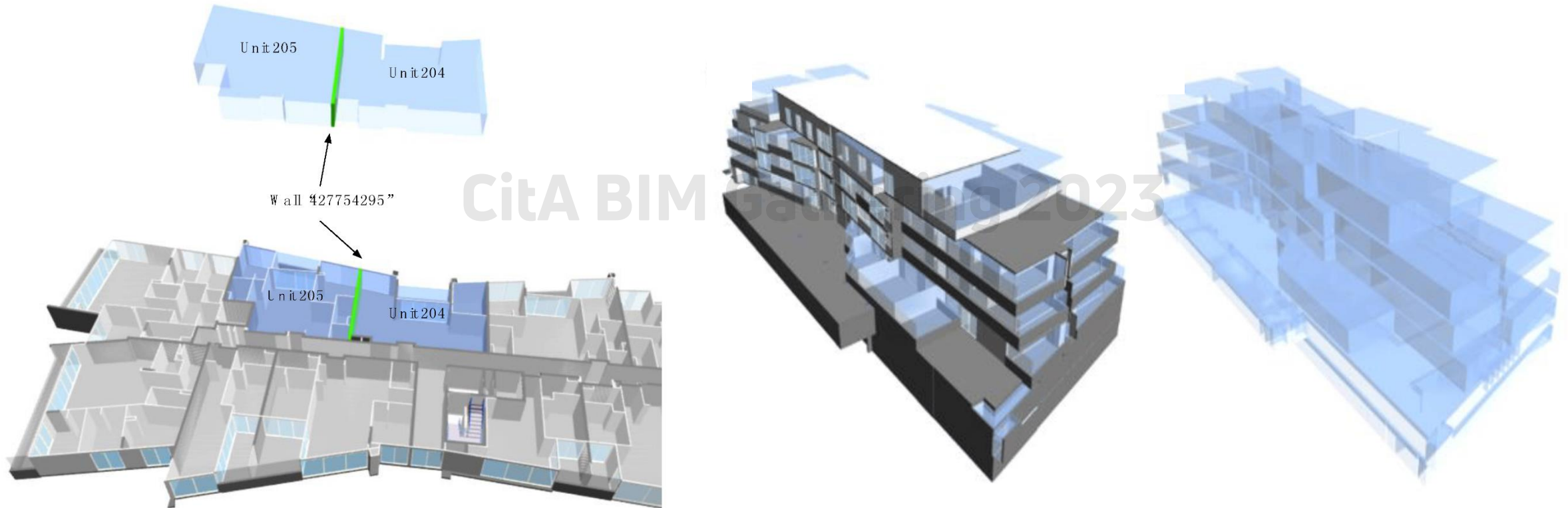
rural areas

complex urban planning



a) Old way b) New way  
(Atazadeh et al., 2016)

## Solution is 3D LAS



(Atazadeh et al., 2019)

## 3D LAS at a city level

- **Urban Planning and Development**
  - **Land Use and Zoning**
    - Transportation Planning
  - Smart Infrastructure Development
    - Energy Management
      - Air Quality
    - Water Resource Management
  - Urban Renewal and Redevelopment
    - Public Safety
    - Social Equity
  - **Smart City Applications**



(Uppsala municipality)

[Home](#)[Project](#)[Digital Permits](#)[Consortium](#)[Community Of Practice](#)[Outcomes](#)[News](#)

## Project

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## Project Overview



Change toolkit for digital building permit project (CHEK) is an innovation and research EU-funded project that will provide an innovative toolkit supporting the digitalization of building permit issuing and automated compliance checks.



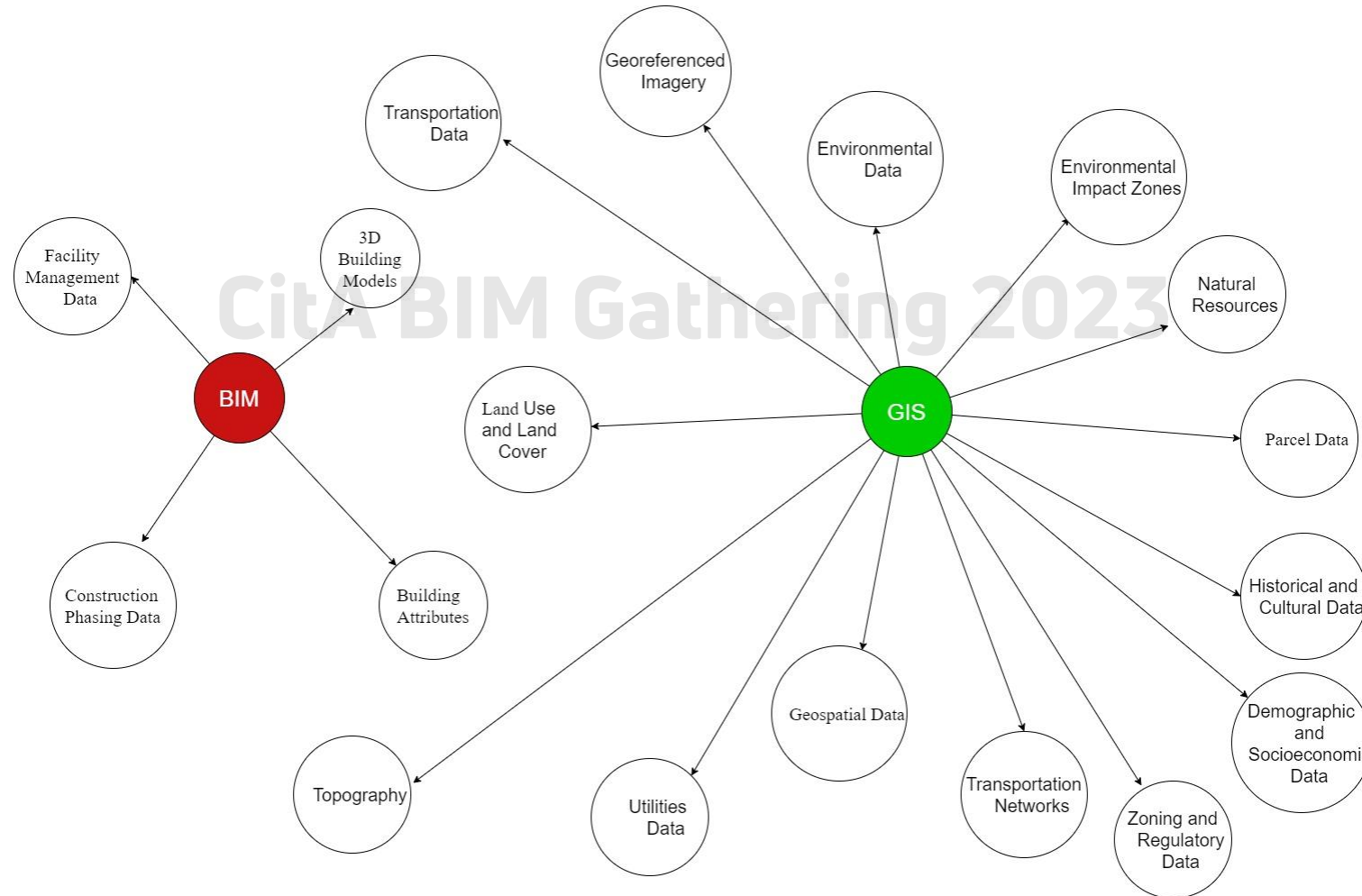
## Many countries started transitioning from 2D to 3D LAS

**Countries already using 3D LAS :** Sweden, Norway, Australian states of Victoria and Queensland, in Canada Brunswick and British Columbia, as well as Chinese cities such as Shenzhen(Kitsakis et al., 2018),The Netherlands and Singapore (Stoter et al., 2019)



**Countries testing 3D LAS:** New Zealand (Gulliver et al., 2017), Indonesia (Putraningtyas et al. 2021), Morocco (Hajji et al. 2021), South Korea (Kim et al. (2015), Turkey (Guntel and Aydinoglu 2021)

## What Types of Data?



# Open-data for integration

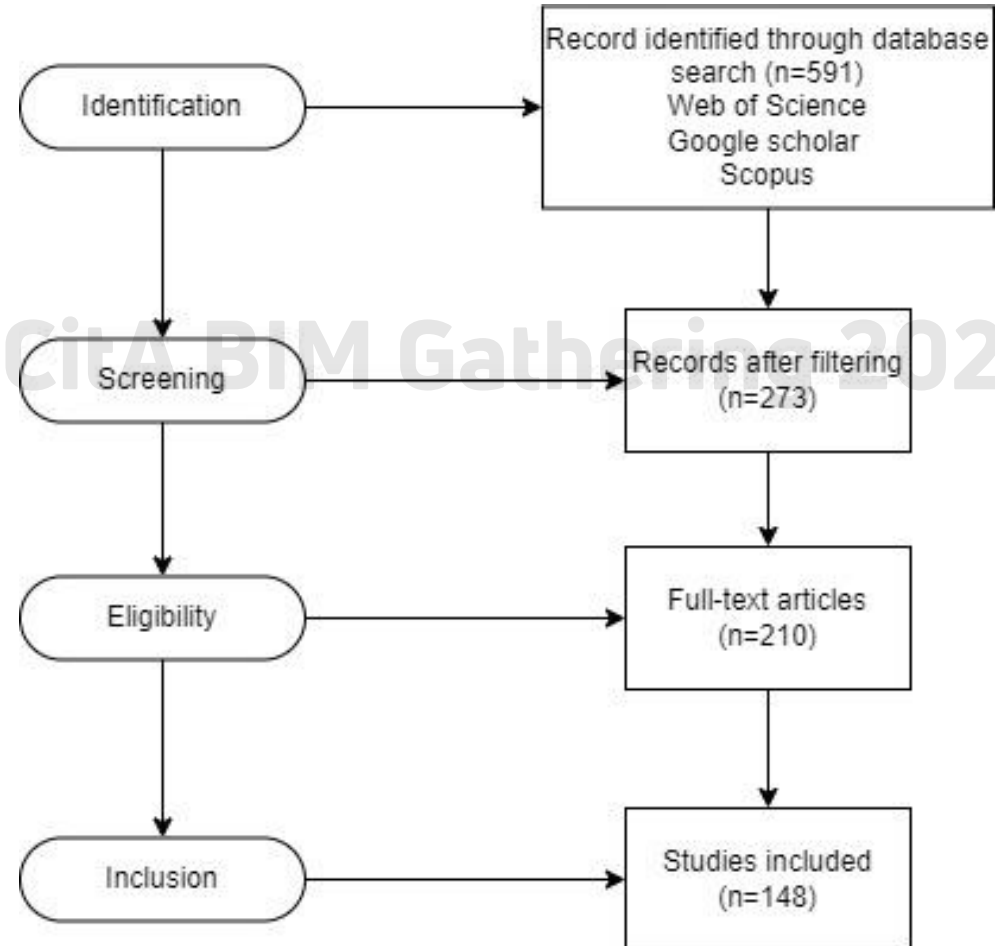
Open-data for  
increasing  
interoperability and  
meeting the EU  
Open Data Directive

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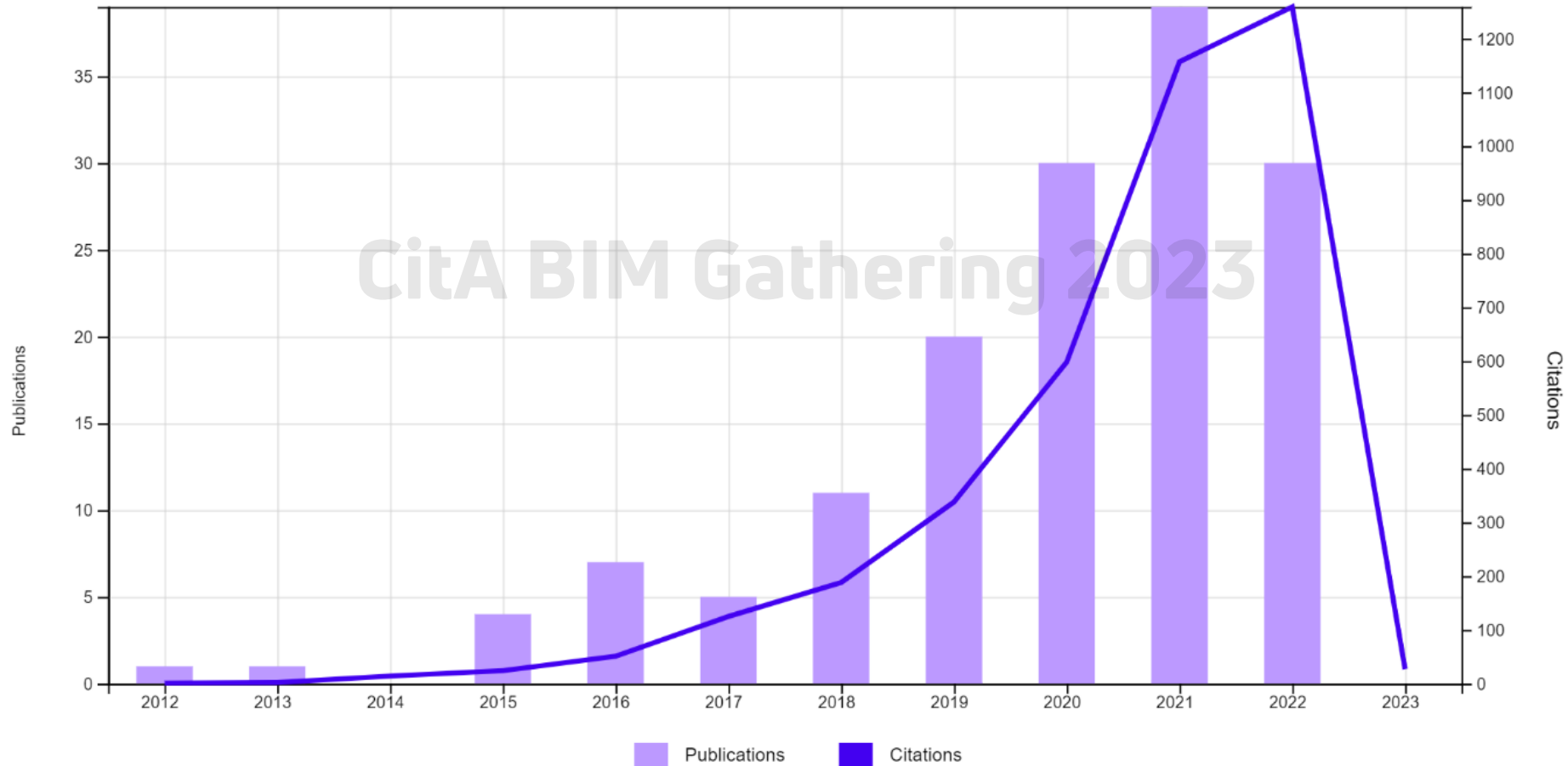


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# Literature Review



# Literature Review

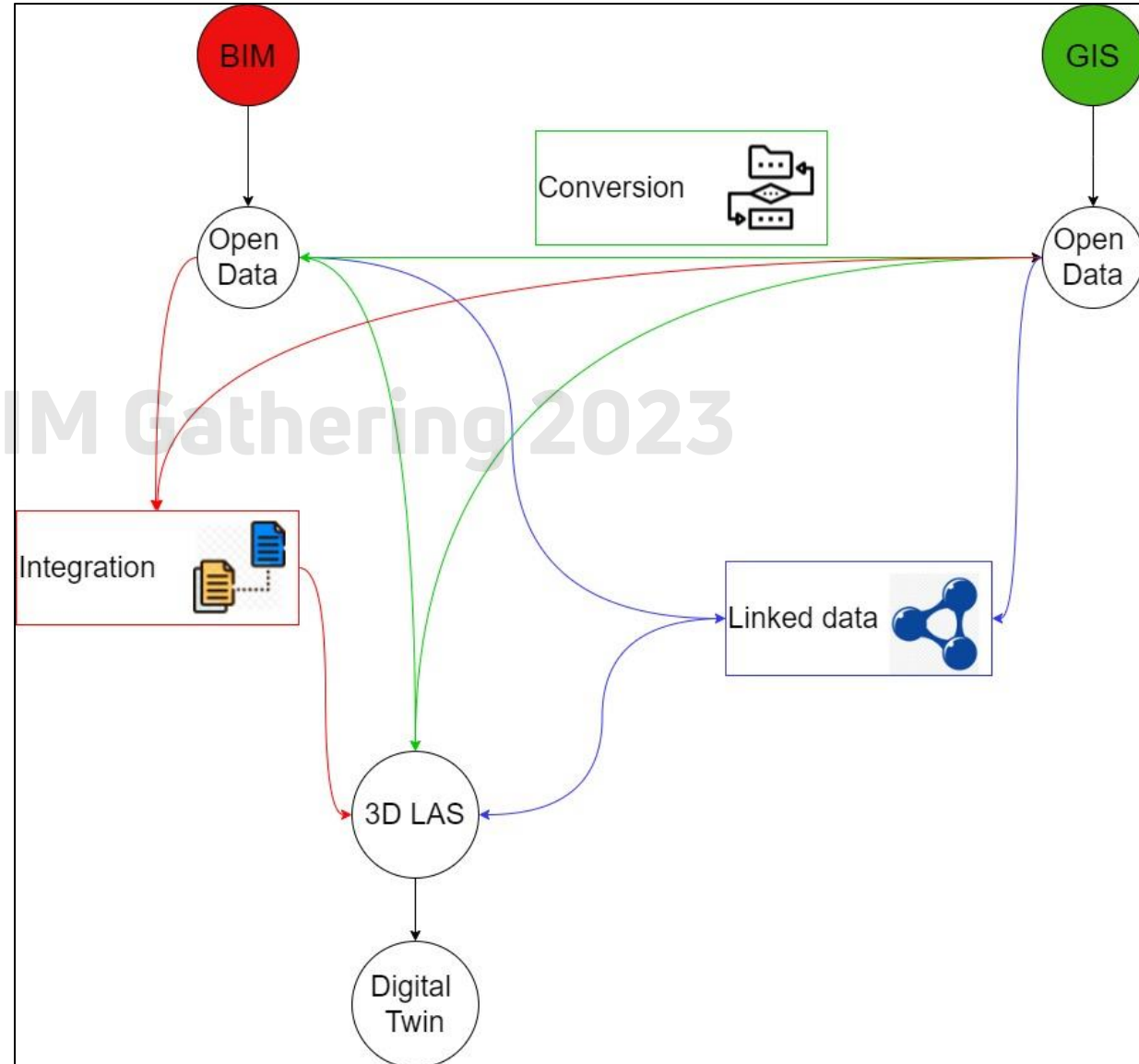


# Literature Review

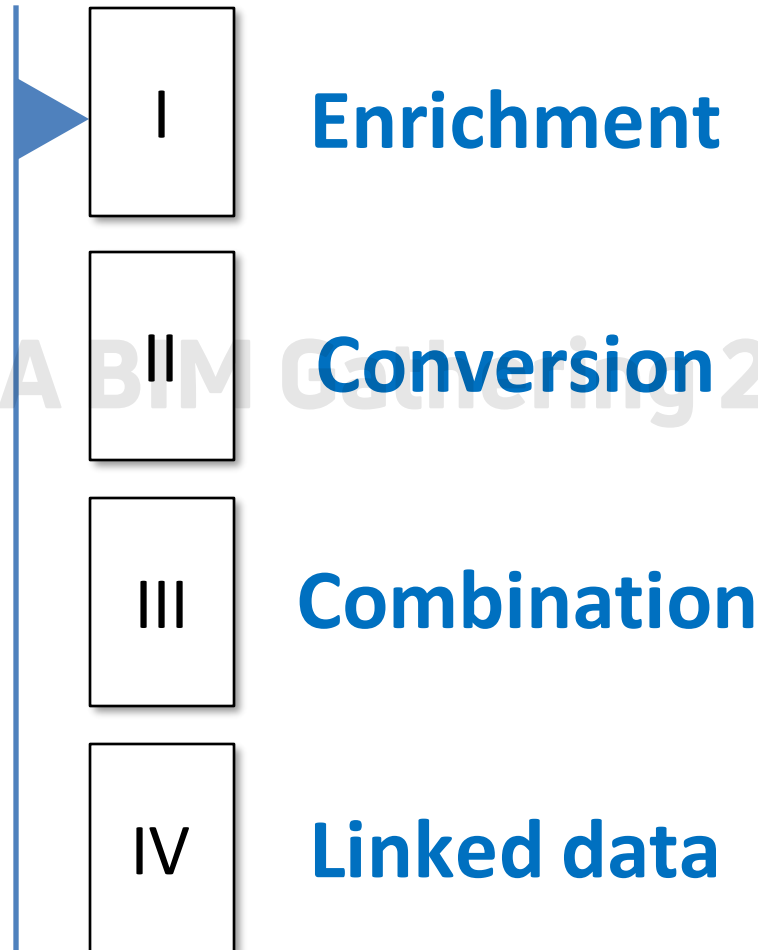
Journal	Record Count	% of 148
ISPRS International Journal of Geo-Information	26	17.568
Automation in Construction	21	14.189
Applied Sciences	8	5.405
Sustainability	6	4.054
Buildings	4	2.703
Journal of Information Technology in Construction	4	2.703
KSCE Journal of Civil Engineering	4	2.703
Computers in Industry	3	2.027
Energies	3	2.027
Engineering, Construction and Architectural Management	3	2.027
Journal of Construction Engineering and Management	3	2.027
Journal of Spatial Science	3	2.027
Sustainable Cities and Society	3	2.027
Advanced Engineering Informatics	2	1.351
Building and Environment	2	1.351
Frontiers in Built Environment	2	1.351
Frontiers of Engineering Management	2	1.351
IEEE Access	2	1.351
International Journal of Geographical Information Science	2	1.351
Land Use Policy	2	1.351
Remote sensing	2	1.351
Transactions in GIS	2	1.351
Tunnelling and Underground Space Technology	2	1.351
Advances in Civil Engineering	1	0.676
Advances in Geodesy and Geoinformation	1	0.676

# Integration Techniques

- I **Enrichment**
- II **Conversion**
- III **Combination**
- IV **Linked data**



## Integration Techniques



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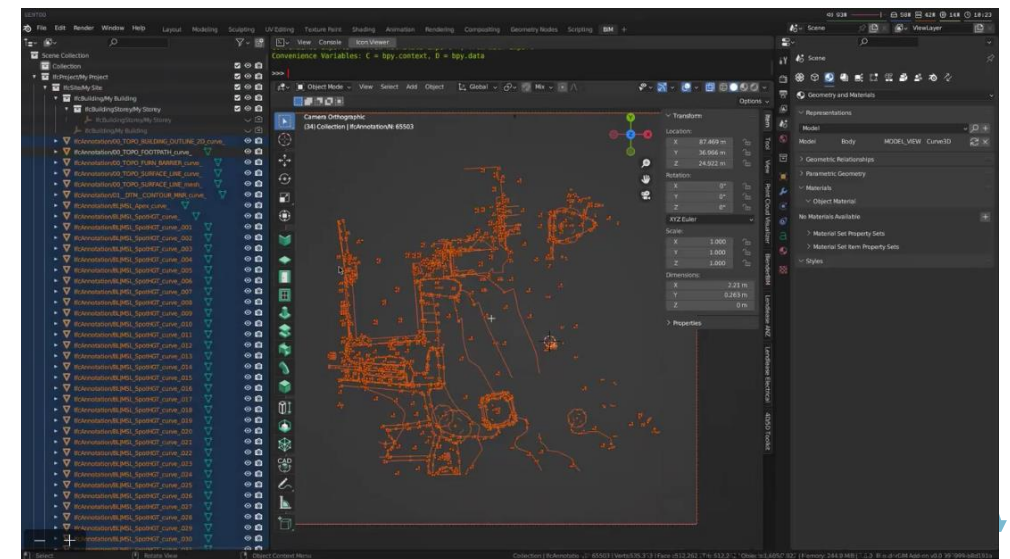


### I Enrichment

- CityGML Application Domain Extension (ADE)
- Enriching IFC4x3 entities (IfcAnnotation) with geospatial surveying information - cooperation with buildingSMART
- Adding point visualization capabilities to BIM viewer (blenderBIM)

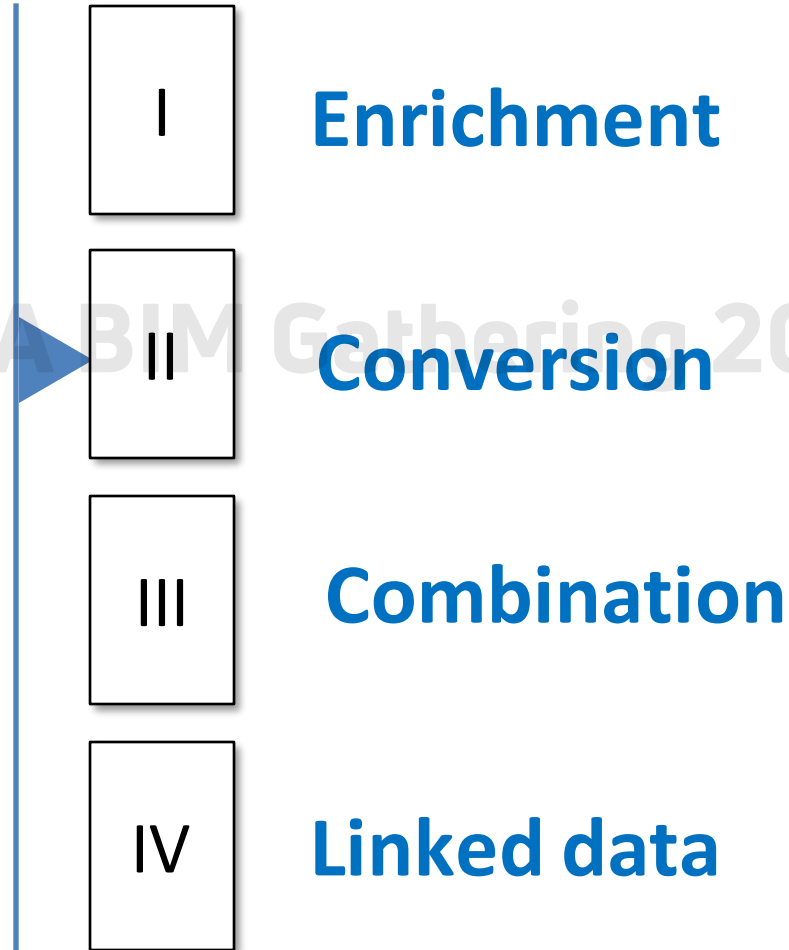
IfcAnnotation predefined types (original)	IfcAnnotation predefined types (new)
ASSUMEDPOINT	SURVEY
ASBUILTAREA	SURVEY
ASBUILTLINE	SURVEY
NON_PHYSICAL_SIGNAL	CONTOURLINE
ASSUMEDLINE	CONTOURLINE

IFC Schema Enrichment



blenderBIM

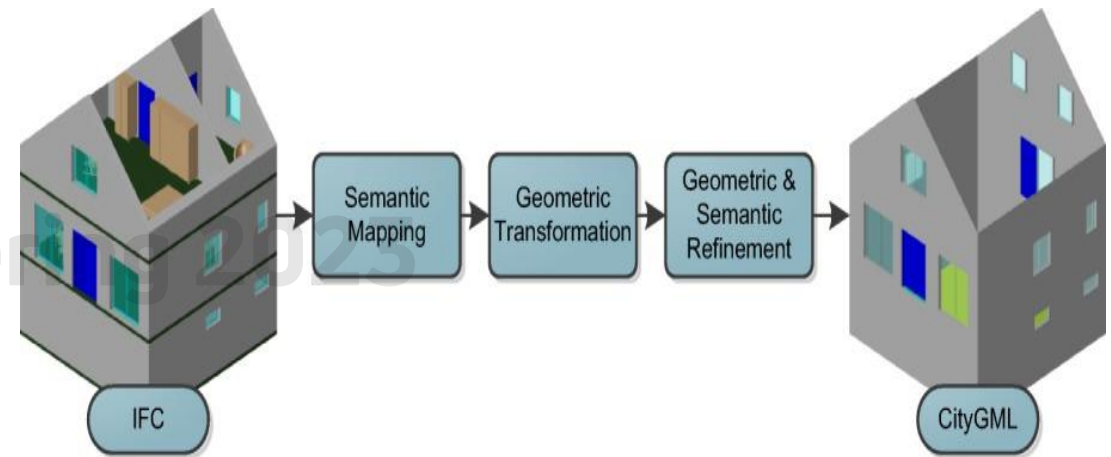
## Integration Techniques



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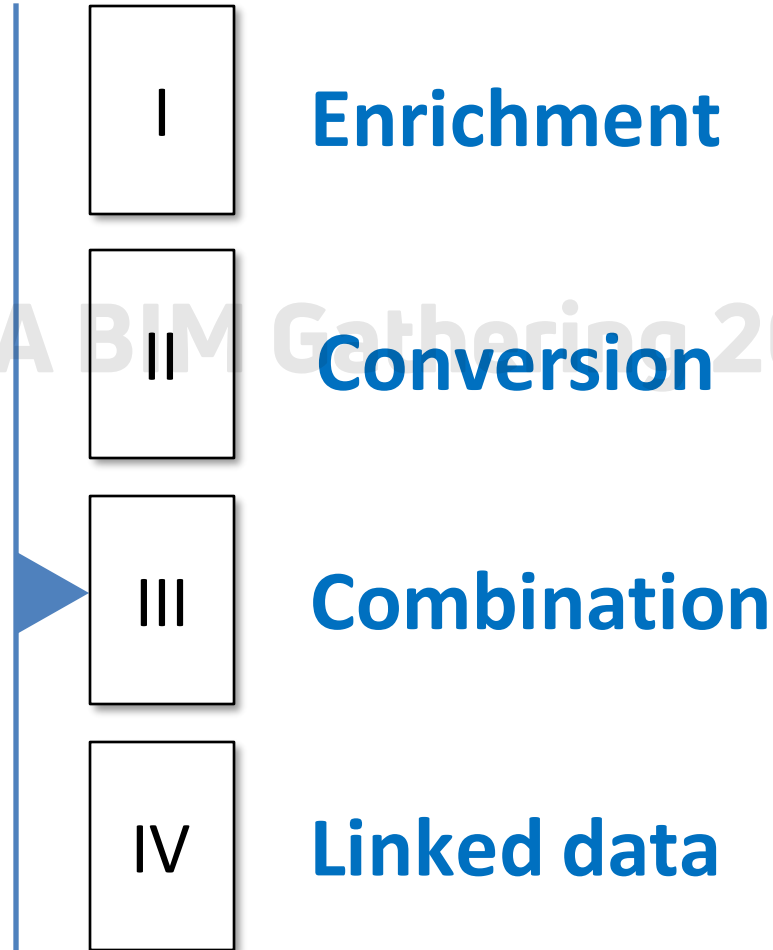
## II Conversion

- Commercial software convert IFC into CityGML (Yu & Teo, 2010)
- Most attempts have been unidirectional (IFC to CityGML), this can lead to information loss (Herle et al., 2020).
- Information loss can be semantic or geometrical



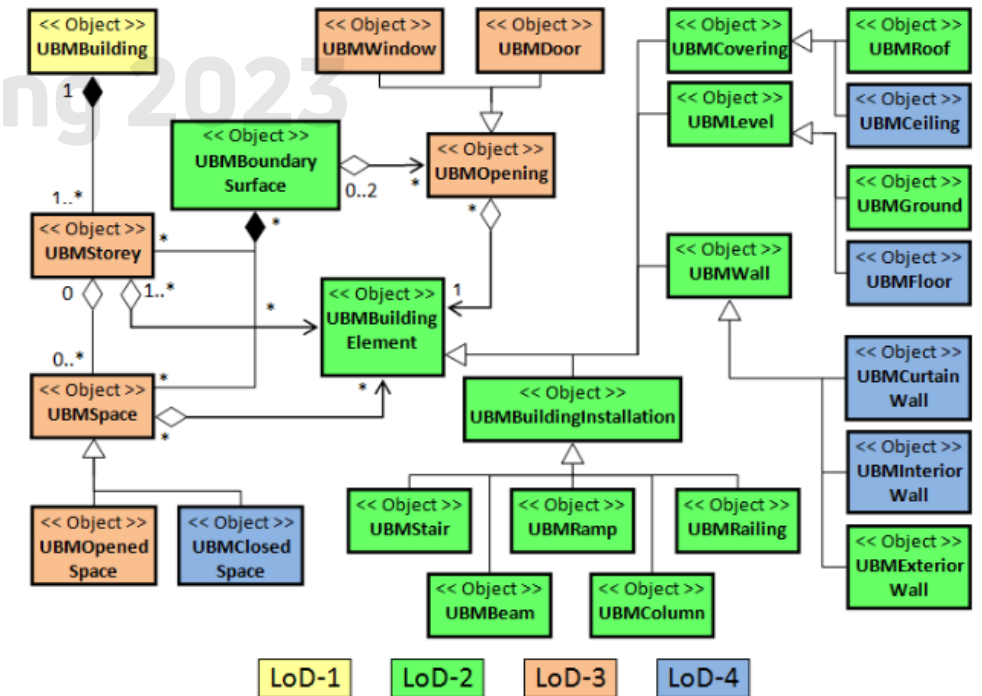
Donkers et al. (2016)

## Integration Techniques

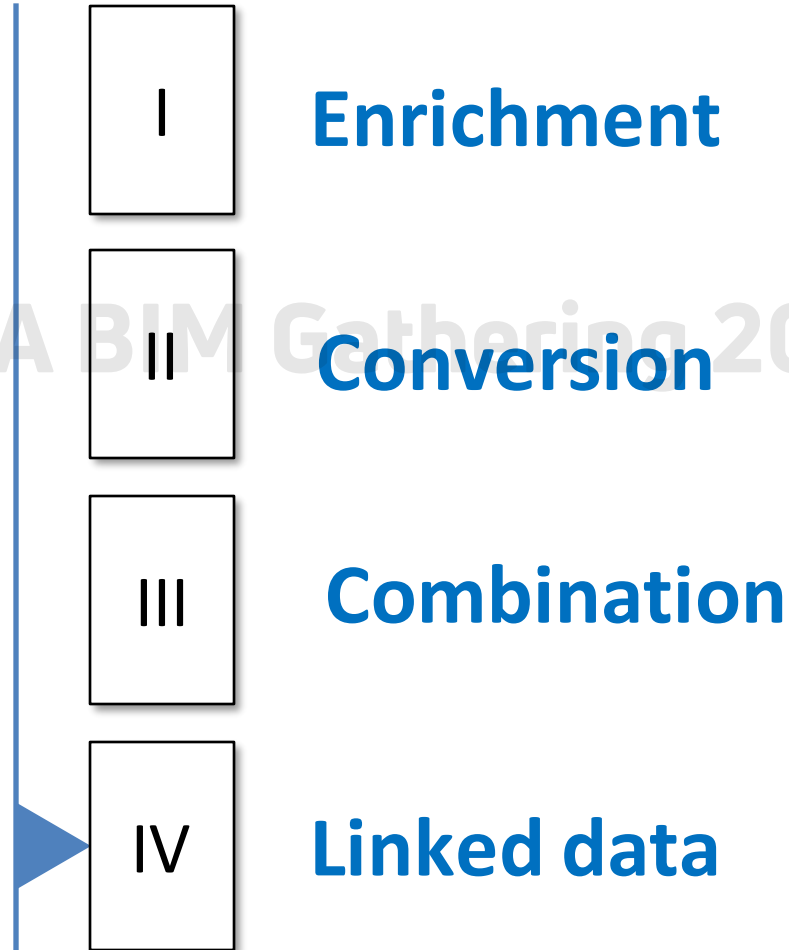


## III Combination

- A unified model that encompasses both the CityGML and IFC models (El-Mekawy et al., 2012).
- Data integration and standard extension at this level for GIS and BIM integration are fast to achieve but are not reversible (Xia et al., 2022).



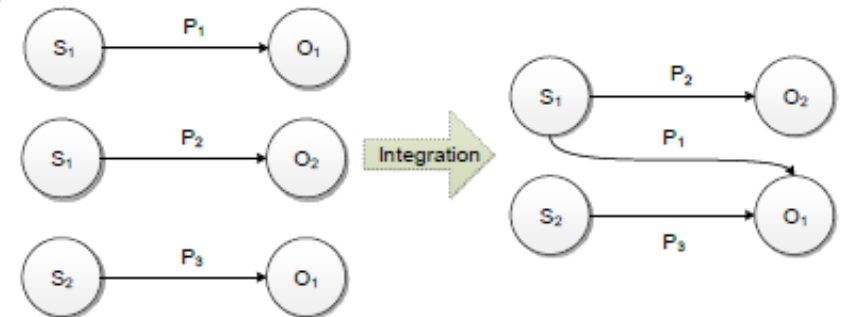
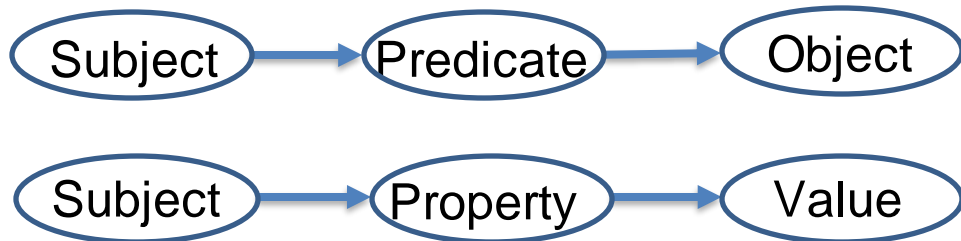
## Integration Techniques



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## IV Linked data

- Web 1.0 (Documents)
- Web 2.0 (Pages)
- Web 3.0 (Semantic web –data)



Initial implementation of this technique can be a slow process  
(Karan & Irizarry, 2015)

# Towards Digitalization in Ireland

## BIM mandate in Ireland

- BIM stage 2 – BIM mandate on public projects from 2024.
- BIM requirements will initially apply to higher value projects – over €100 million – and cascade down to projects below €1 million over a 4 year period (gov.ie)

## Digitalisation in Ireland

Build Digital Project – Project Ireland 2040



**Build Digital Project**  
A national centre of excellence



Rialtas na  
hÉireann  
Government  
of Ireland

Tionscadal Éireann  
Project Ireland  
**2040**

Transform the Irish construction and built environment sectors to be digitally enabled, standards-based, agile, collaborative, and sustainable participants in the delivery of Project Ireland 2040.

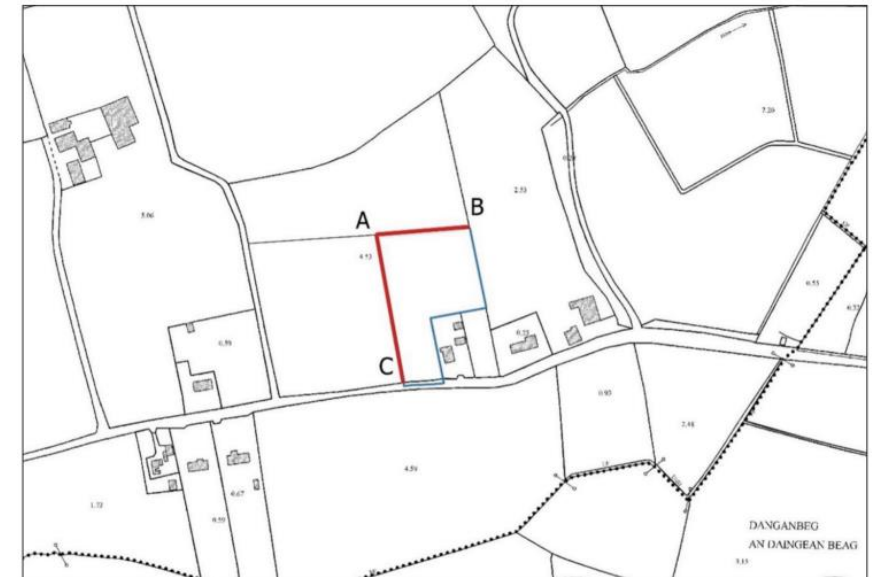


# Ireland use-case

## Surveying

In 3D LAS utilizing BIM models could help geospatial surveyors plan and perform the surveying tasks on Multi-Unit developments more efficiently and in a shorter time period.

- Mapping for registration of title to a parcel (Title Plan)
- Mapping for the definition of the legal boundaries



Source: (SCSI)

## Ireland use-case

### Registration

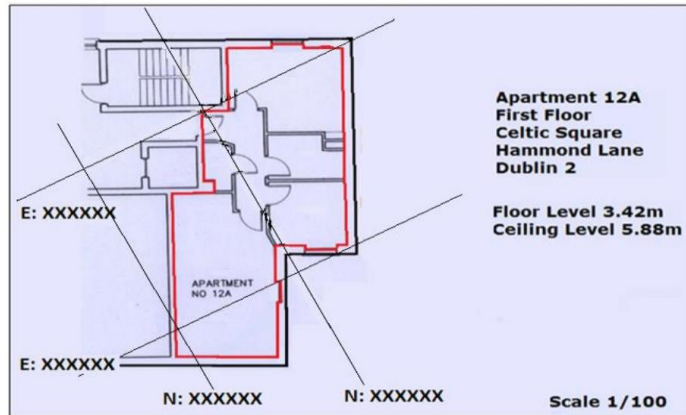
According to latest BOUNDARIES report by Society of Chartered Surveying Ireland (SCSI) (April 2023):

- The legal boundary in multi-storey buildings cannot be easily inspected, and may be complex.
- The development of BIM technology may influence this issue in the future

# Ireland use-case

## Registration

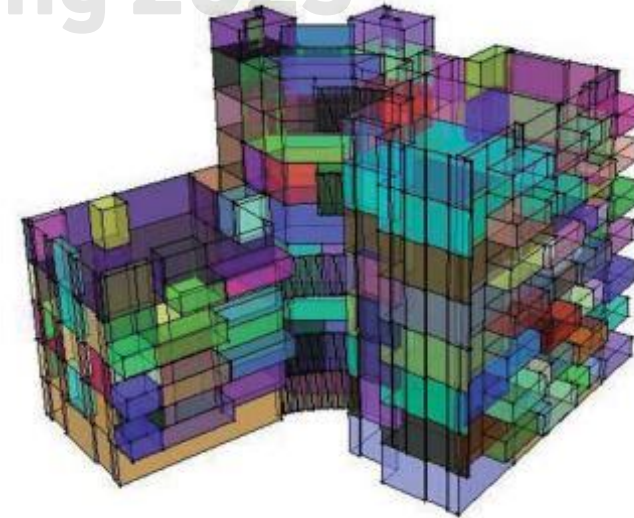
**Now**



Property Registration Authority (PRA)

**Future**

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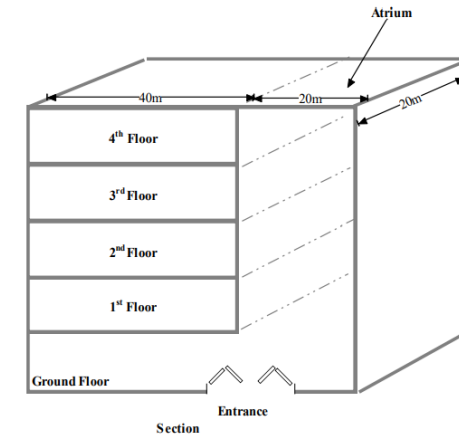
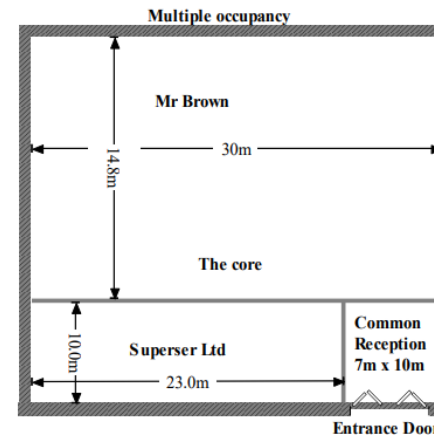
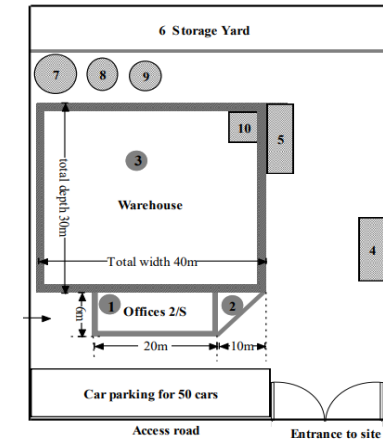
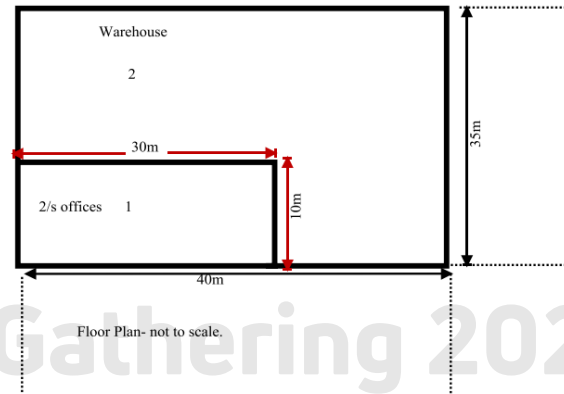
(Ying et al., 2015)

# Ireland use-case

## Valuation

BIM models for calculating:

- Gross External Areas (GEA)
- Net Internal Area (NIA)
- and zoning.



# Conclusion

- Digital Twins of cities has the potential for solving numerous problems in cities.
- 3D Land Administration Systems (LAS) is the foundation for an effective city DT.
- Integration of BIM and GIS play crucial role in creating 3D LAS and producing city DT.
- Integration of BIM and GIS data is complex and mostly application dependent.
- A combination of different BIM and GIS integration techniques produces best results.

# References

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# Gathering23

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CitA

THANK YOU

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Training

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For what's next

**d** **real**

SFI centre for  
research training in  
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