BIM
and Waste Management

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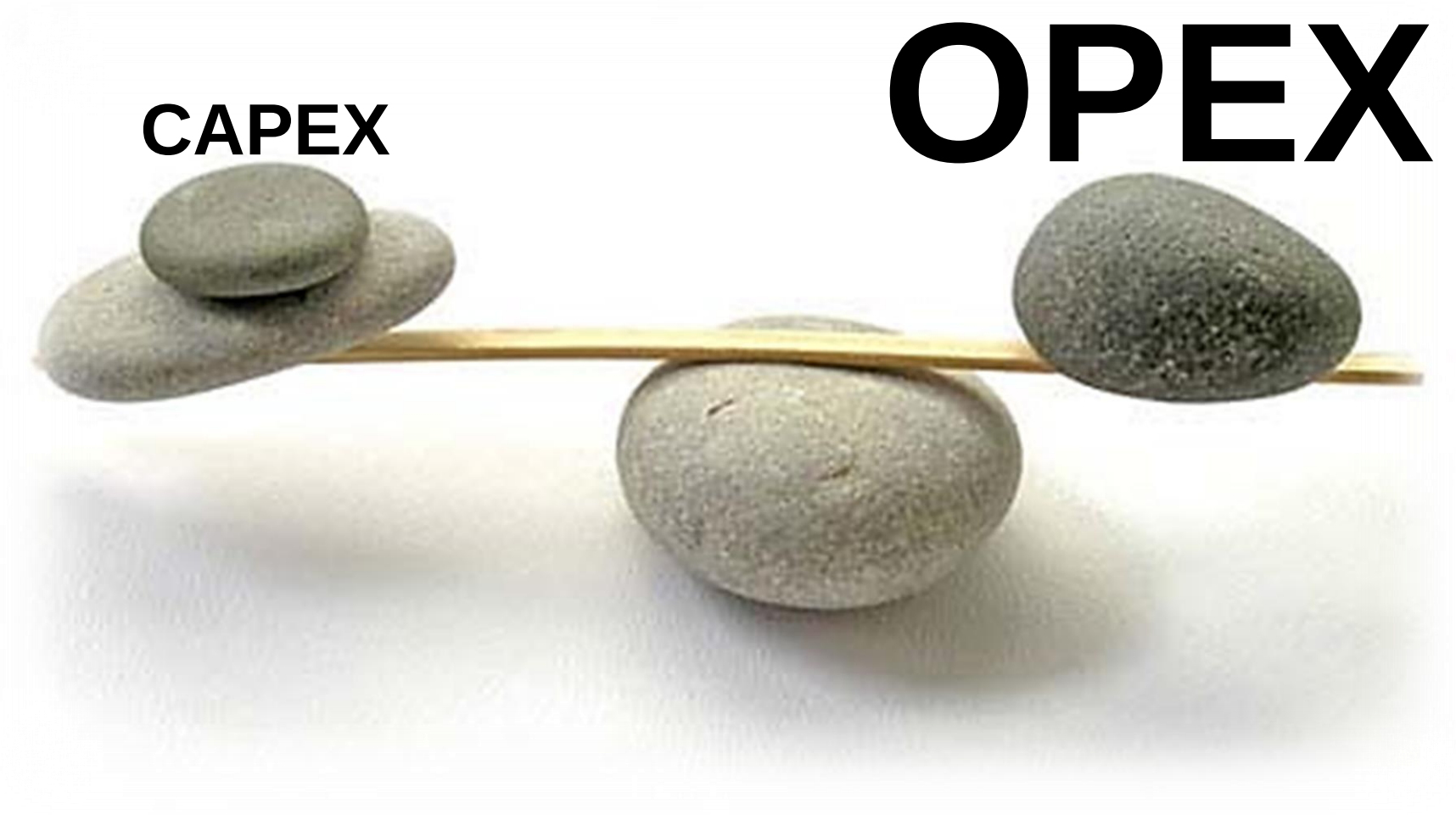
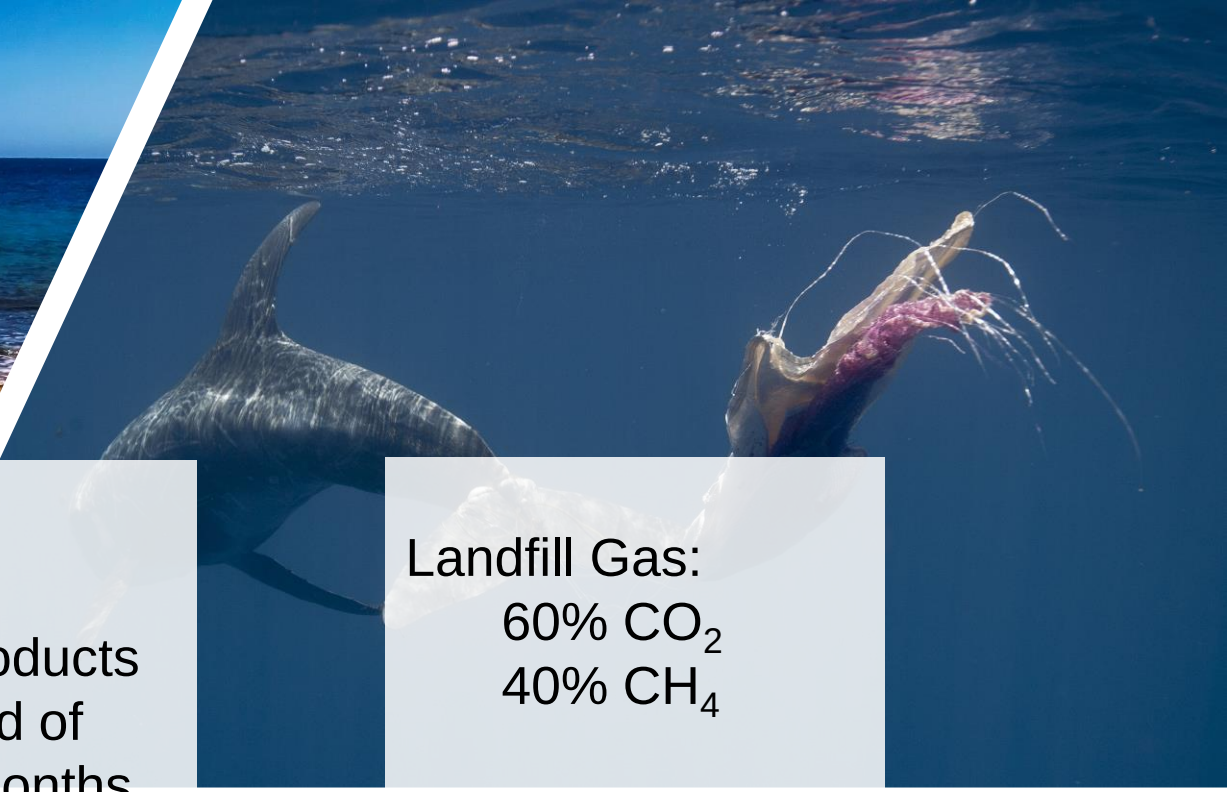
The University of Bath

BIM FM

UNFULFILLED POTENTIAL


CAPEX
OPEX



2.2 billion tonnes waste generated per year

99% of products disposed of within 6 months

Landfill Gas:
60% CO_2
40% CH_4

O_3 Impact:
CH_4 = 25x CO_2

118 Buildings with different purposes (accommodation, catering, education)

Over 20,000 people (students and staff)

Aprox. 280 tons of waste per year (general + recyclable)

Improve the efficiency of waste management

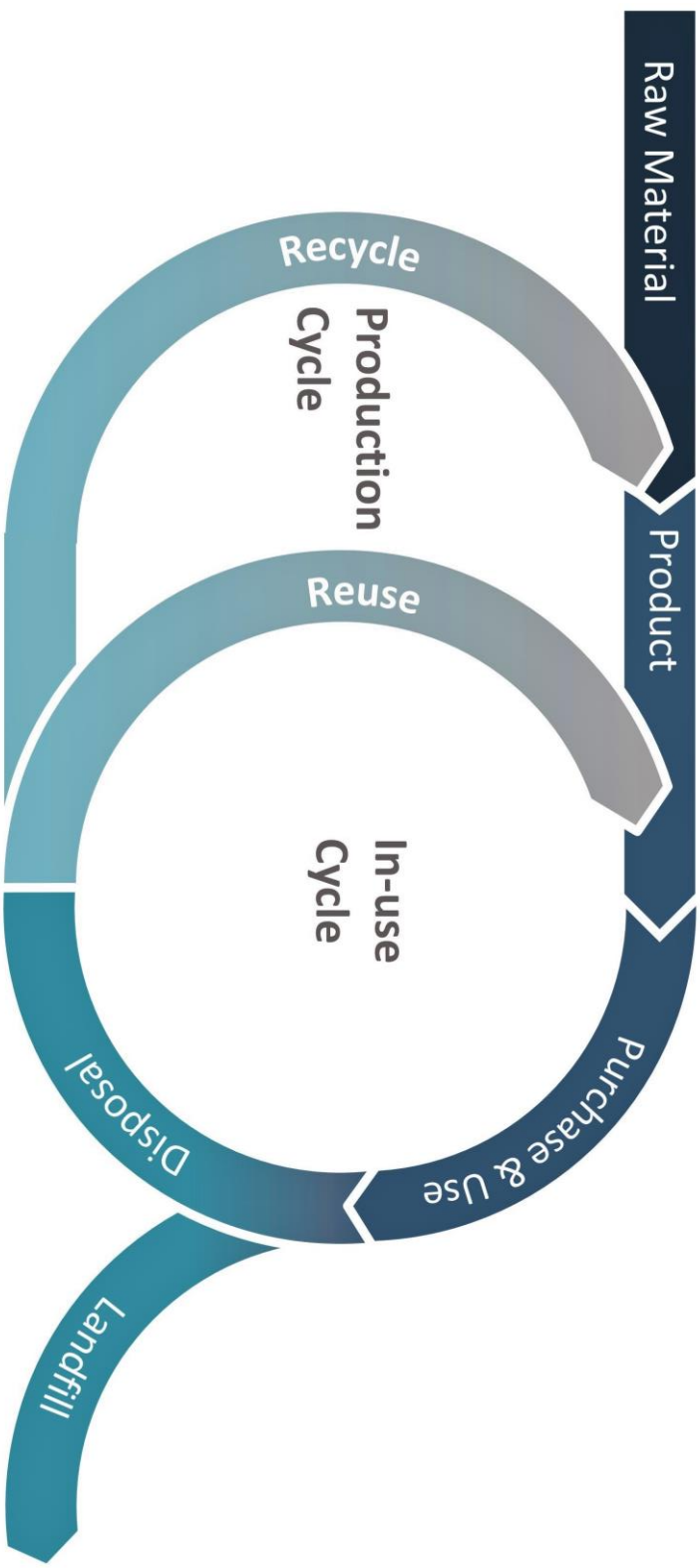
Improve collection

Reduce generation of waste

WASTE MANAGEMENT GOVERNANCE PRACTICES

PHYSICAL RESOURCE RECOVERY

SOCIAL ENVIRONMENTAL BEHAVIOUR



INFORMATION MODELLING

- Flows of People
- Flows of Waste
- Flows of Service
- Building Geometry

INFORMATION PROTOCOLS

Organisation	*Description*	*Year*
00	EIR, BIMSmart Template	2013
01	EIR, Large Higher Education Facility - UK	2016
02	EIR, Medium Local Government - UK	2016
03	EIR, Medium Local Government - UK	2016
04	EIR, Large Higher Education Facility - UK	2016
05	EIR, Large Government Department - UK	2016
06	BEP, Large Higher Education Facility - UK	2016
07	BEP, Large Government Department - UK	2016
08	BEP, Large Higher Education Facility – UK	2016

Table 1: EIR & BEP Research Sample Profile

Construction Bias

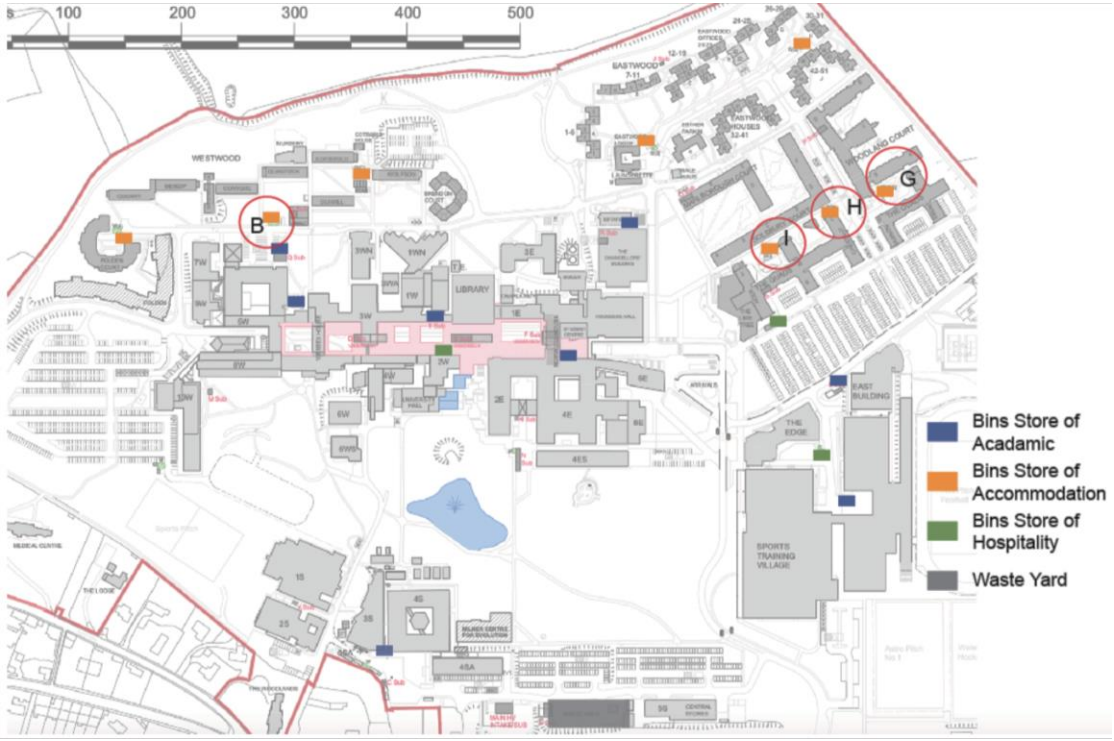
BIM & FM ‘Illiteracy’

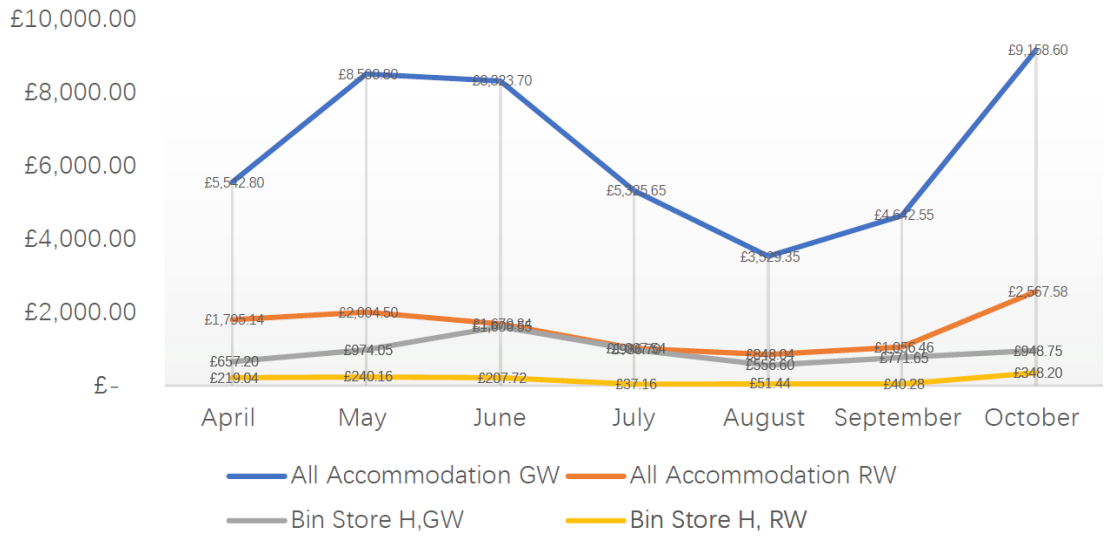
Fragmentation

Minute OM Information

Source: Comlay, J. & Codinhoto, R. (2017) Facilities Management: Granularity of Information for a Digital Information Platform. In Proceedings of the International Conference on Sustainable Futures (ICSF) Bahrain 2017

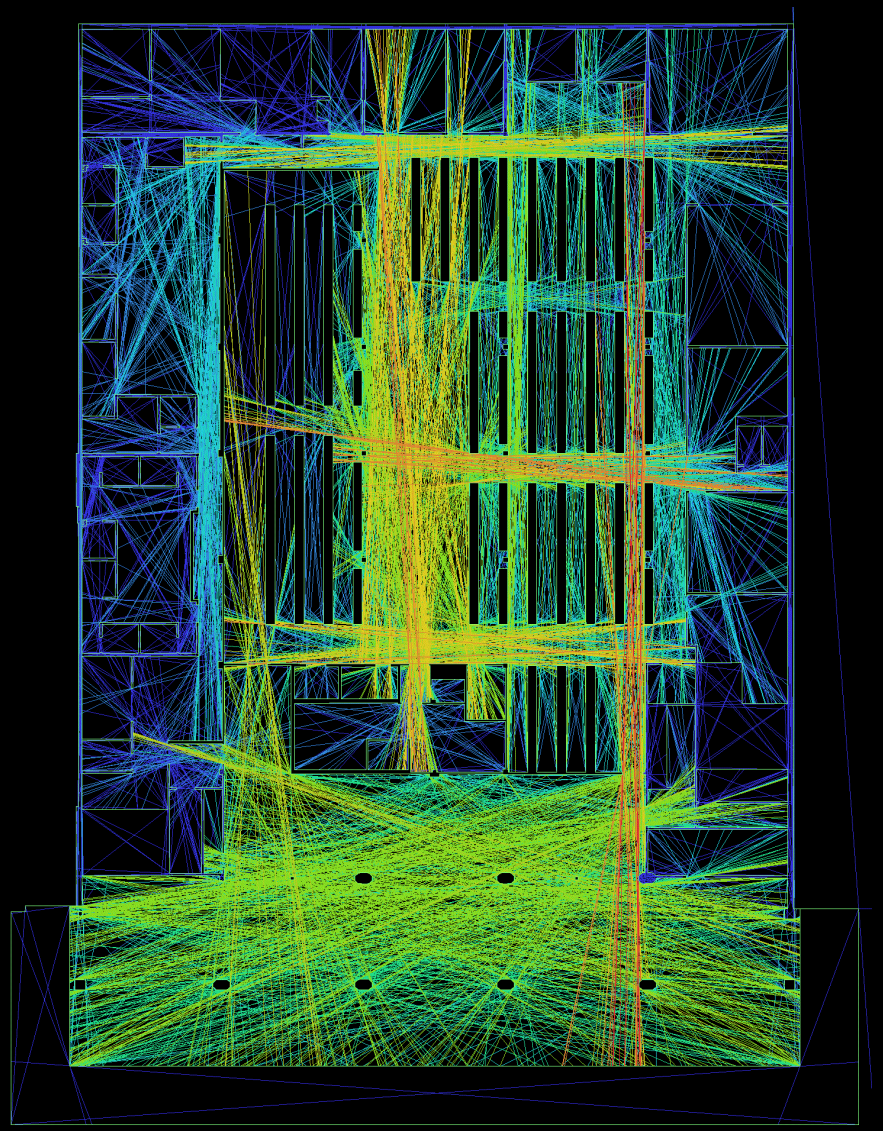
WASTE Data



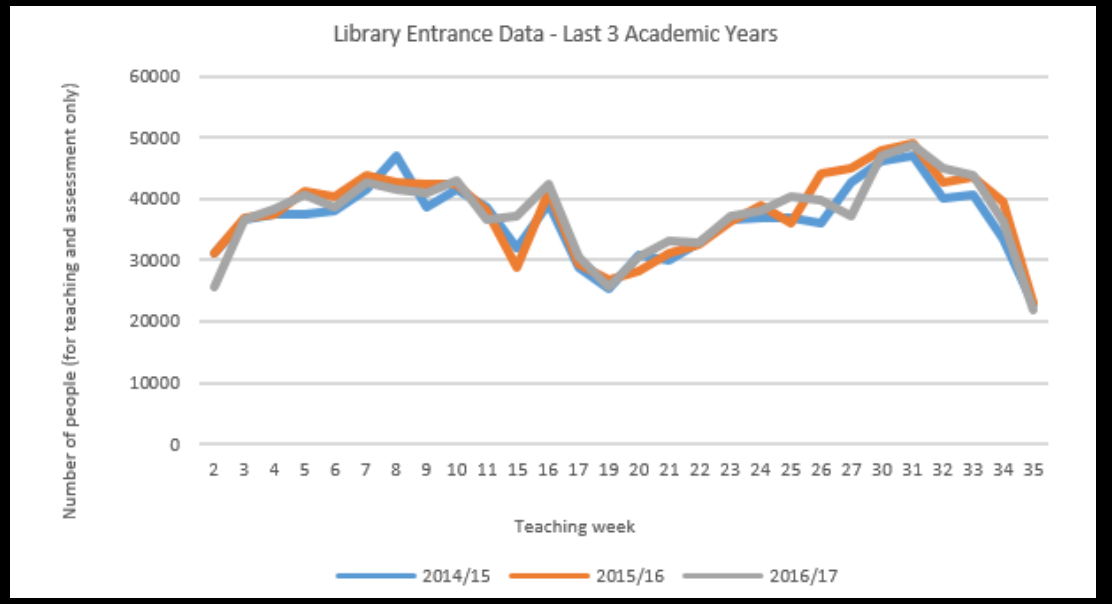


Waste Costs

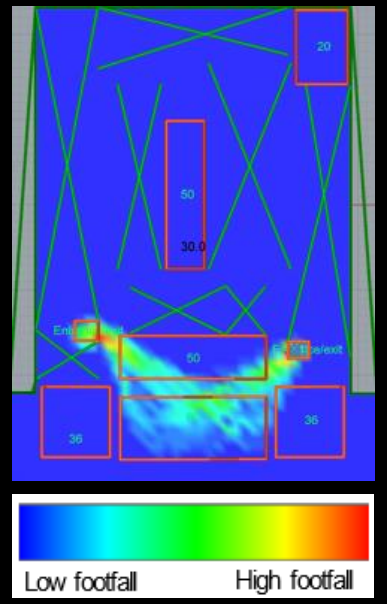
EXPERIMENT ONE: LIBRARY



Space Syntax

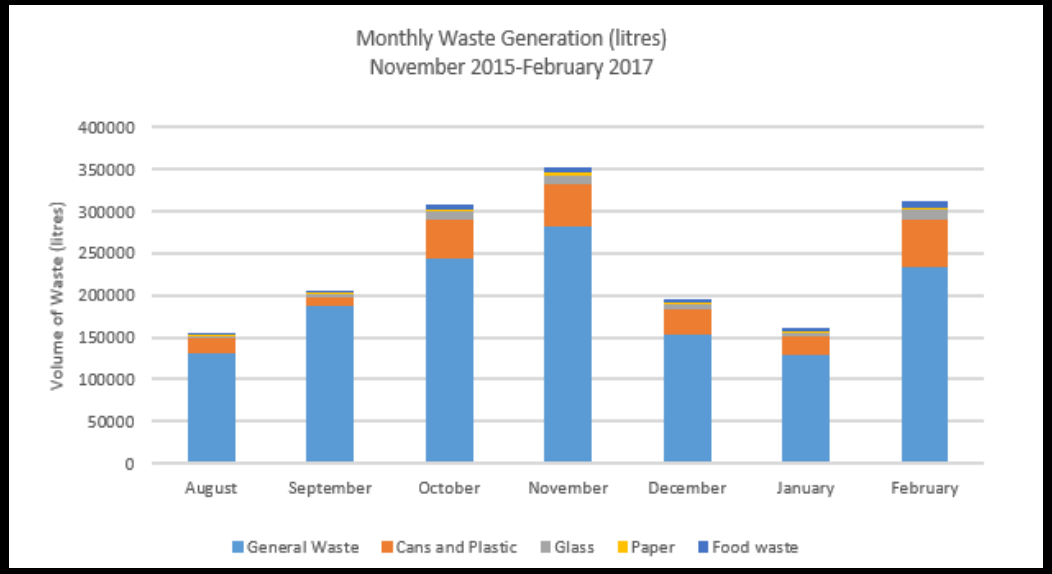


Library occupation variation (population only includes those in the Library for teaching and assessment purposes) (Estates 2017)

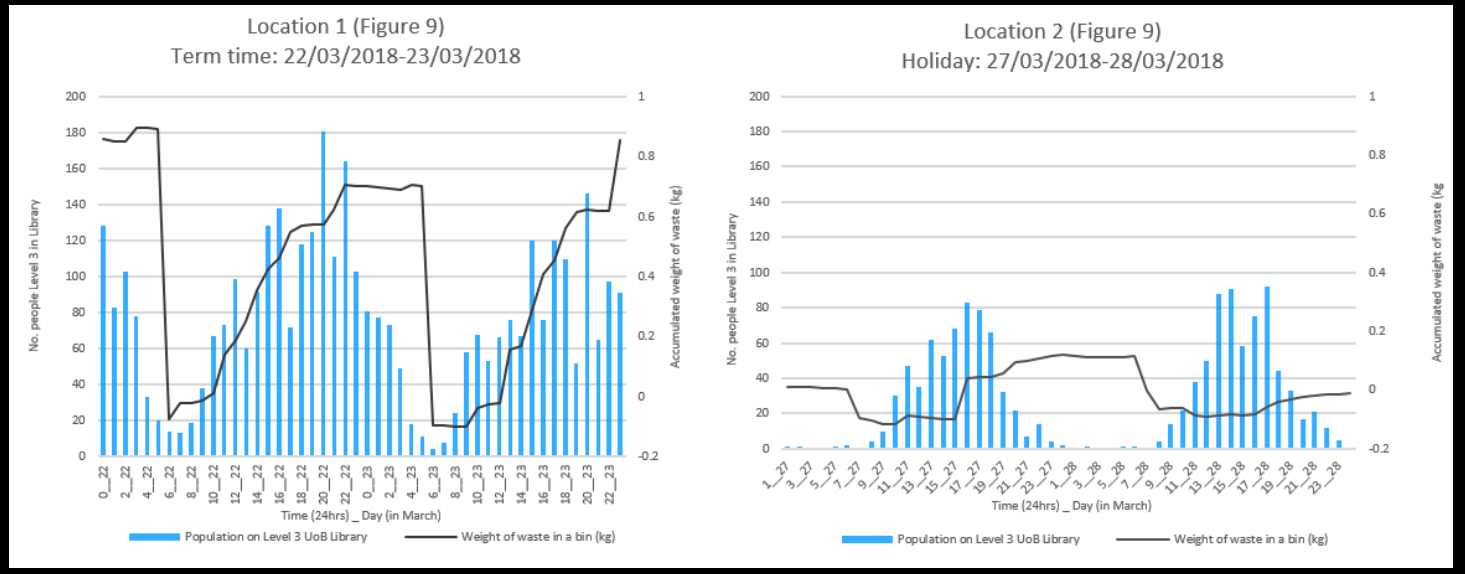


Crowed Footfall Analysis

PEOPLE Data Flow



Monthly waste variation on the UoB campus (not all sources of waste are included in data) (Estates 2017)



Library level 3 population versus weight of waste in bins; term and holiday time

WASTE Data Flow

Definitions

T - Bin period

T1 - Bin that reaches full capacity at every collection

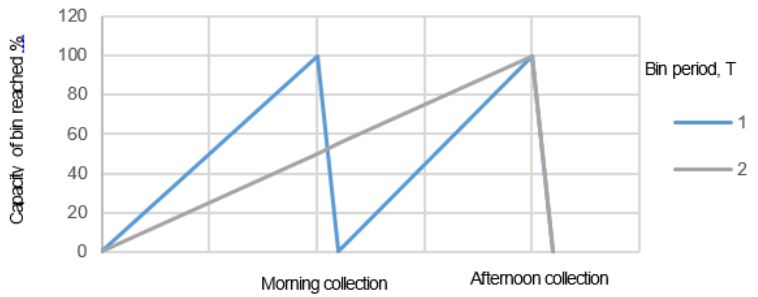
T2 - Bin that reaches full capacity at every other collection

C - Collection regime

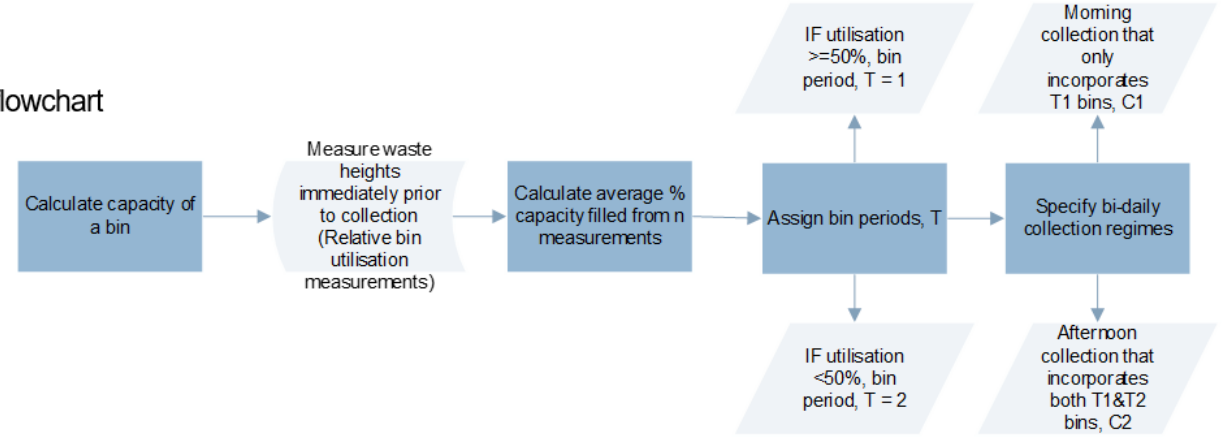
C1 - Collection regime that only includes T1 bins

C2 - Collection regime that includes all bins

Bin collection periods



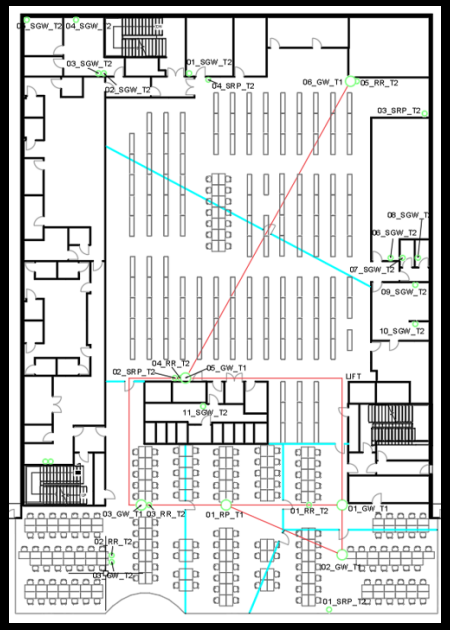
Excel flowchart



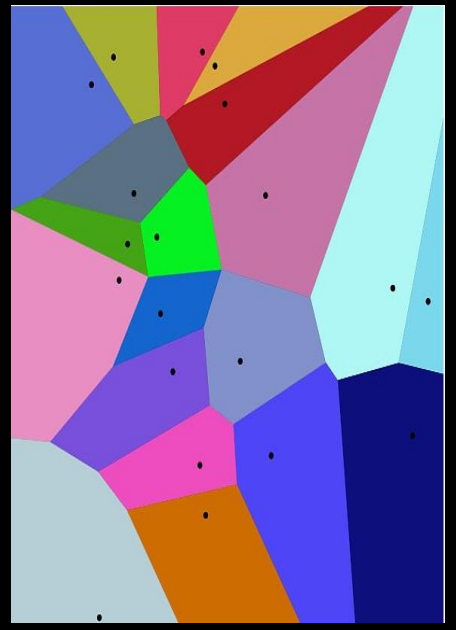
Collection regimes assigned using bin periods

SERVICE Data Flow

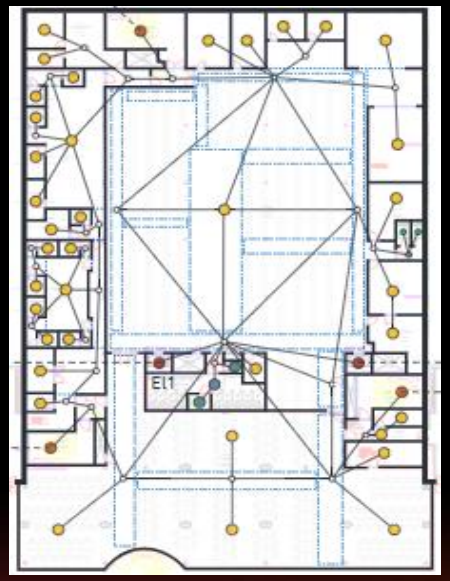
GEOMETRY



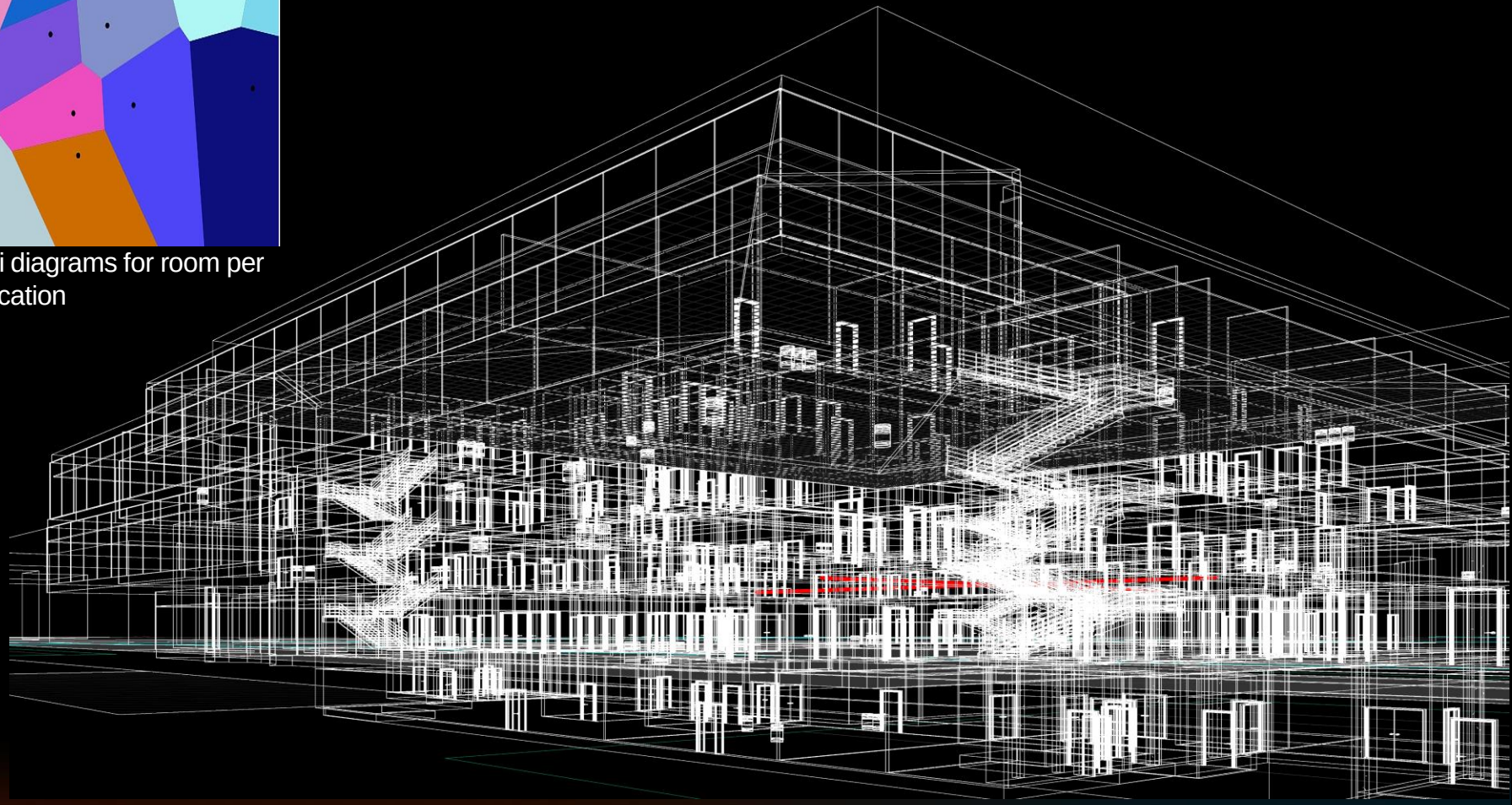
Level 3 C1 collection network visualisation in Gephi setup



Voronoi diagrams for room per bin allocation



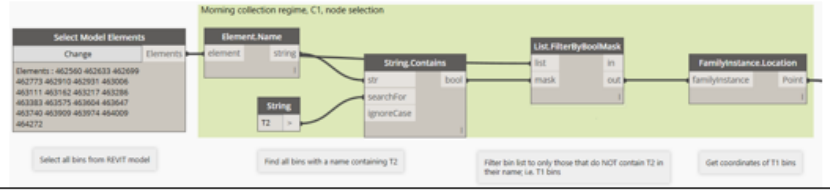
Dijkstra Algorithm for volume and distance



Revit Model LOD 200

SHORTEST PATH

1.



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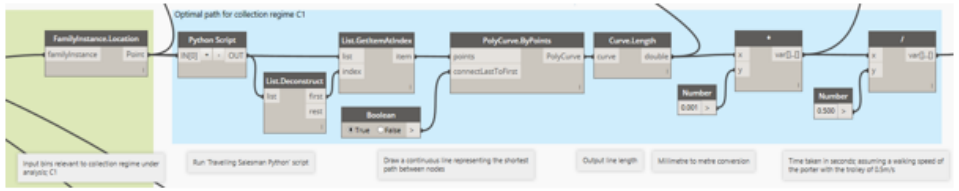

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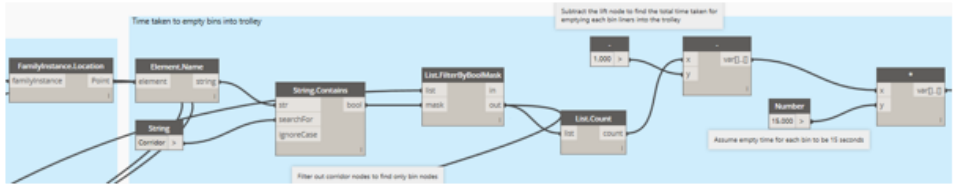

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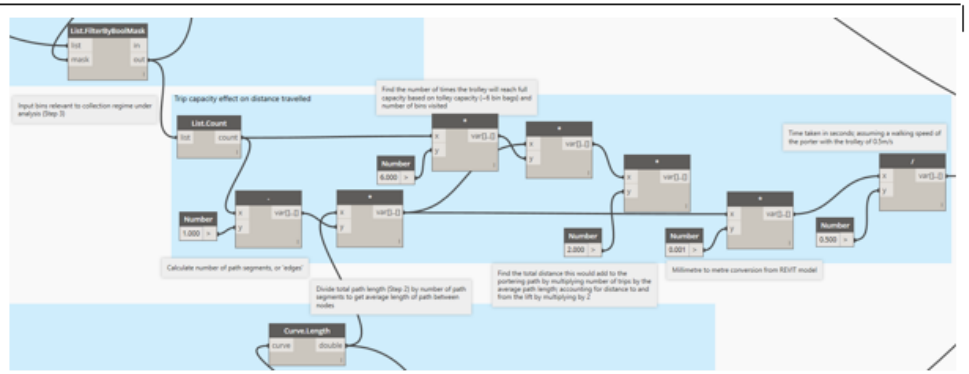

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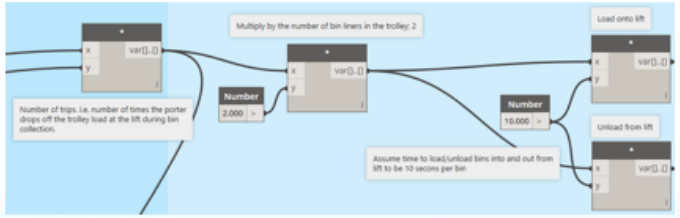
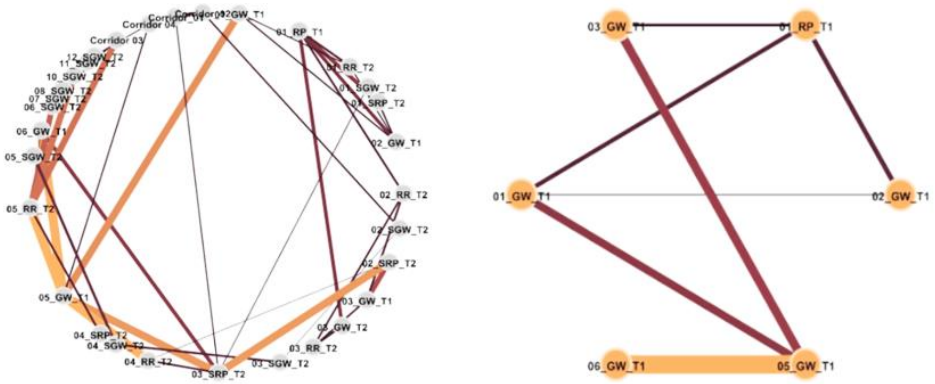


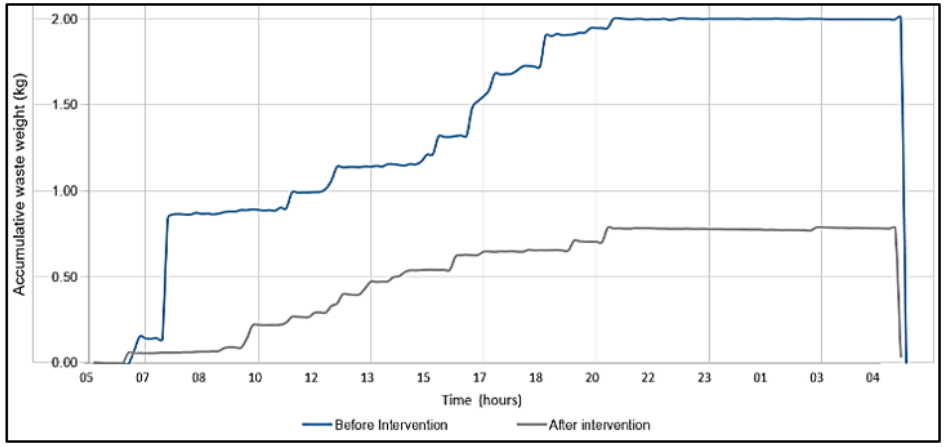
Shortest porter path using the ‘Travelling Salesman Problem’ algorithm

Network statistic in Gephi	Level 3		Level 2	Level 4	Level 5	*Bin collection time in Dynamo*	
	C1	C2	C1	C1	C1	*Seconds*	*Seconds per bin*
Nodes	5	31	8	8	6		
Edges	7	40	9	10	7		
Av. Degree	2.3	2.6	2.3	2.5	2.3	62%	-77%
Av. Weighted Degree	33	4	36	28	41	-89%	83%
Network Diameter	3	10	4	4	3	97%	-88%
Graph Density	0.47	0.09	0.32	0.36	0.47	-91%	94%
Av. Clustering Coefficient	0.33	0.25	0.14	0.14	0.36	91%	-80%
Modularity	0.24	0.46	0.32	0.24	0.17	4%	47%
Av. Path Length	1.67	4.25	1.96	2.00	1.67	97%	-87%

C1 and C2 bin network visualisation and statistic comparison



Ghephi: Level 3 C2 and C1 bin network



Bin weight before and after the Digital message screen intervention

RESULTS

≈ 16 days per year (1 floor)

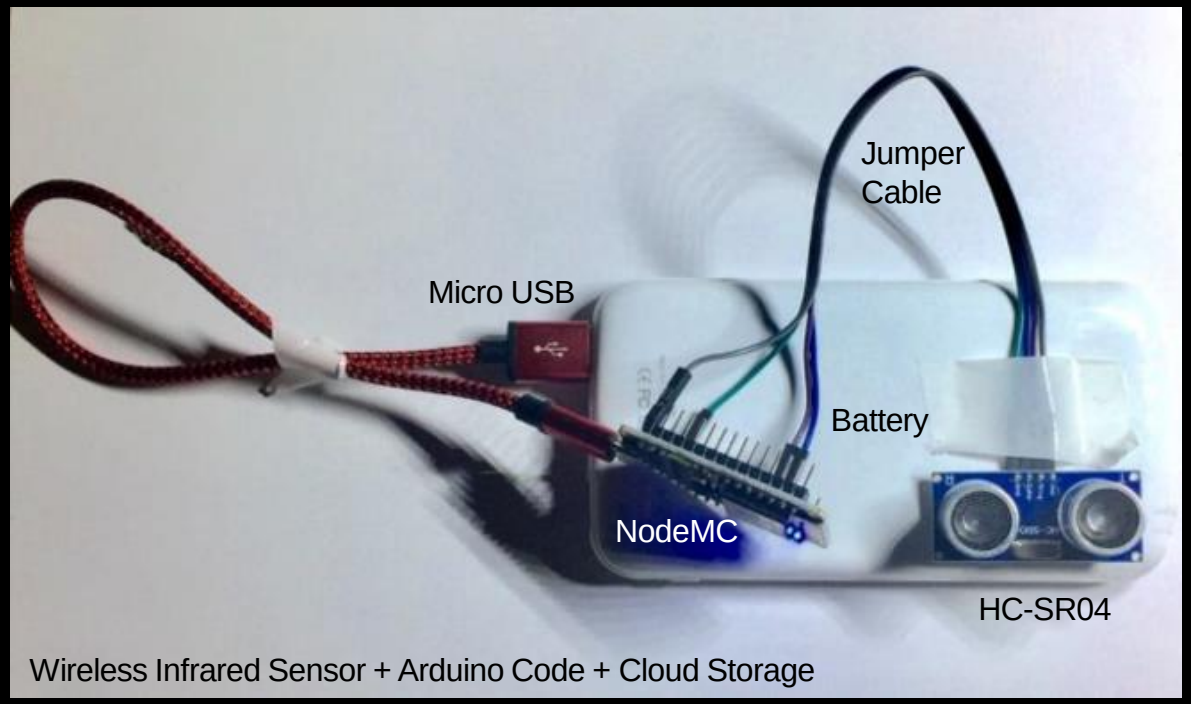
≈ 80 days per year (library)

≈ 9.5k days (UoB)

Positive nudge impact

Source: Beecher, O. (2018) Towards a method for reducing the operational costs and environmental impact of Municipal Solid Waste Management Systems through Building Information Modelling and 'Nudge Theory'-inspired interventions; a case-study approach in the University of Bath Library. Dissertation.

EXPERIMENT TWO: LIBRARY



Wireless Infrared Sensor + Arduino Code + Cloud Storage

WASTE Data Flow

FIGURE 26: FLOOR 3 GENERAL WASTE HEIGHTS BIN 3

FIGURE 27: FLOOR 3 GENERAL WASTE HEIGHTS BIN 4

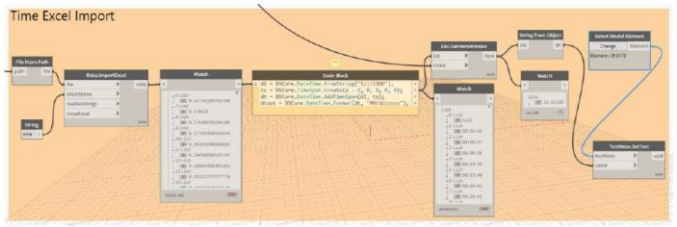


FIGURE 11: EXCEL TO DYNAMO IMPORT - TIME

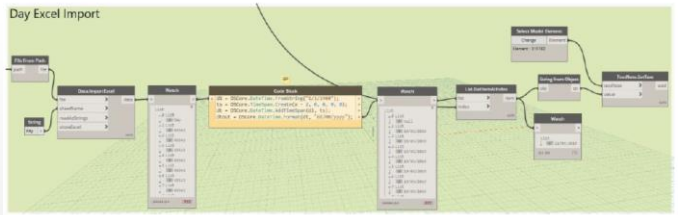


FIGURE 12: EXCEL TO DYNAMO IMPORT - DAY

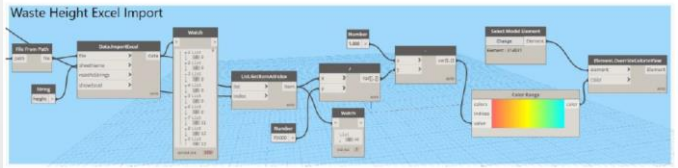


FIGURE 13: EXCEL TO DYNAMO IMPORT - WASTE HEIGHT

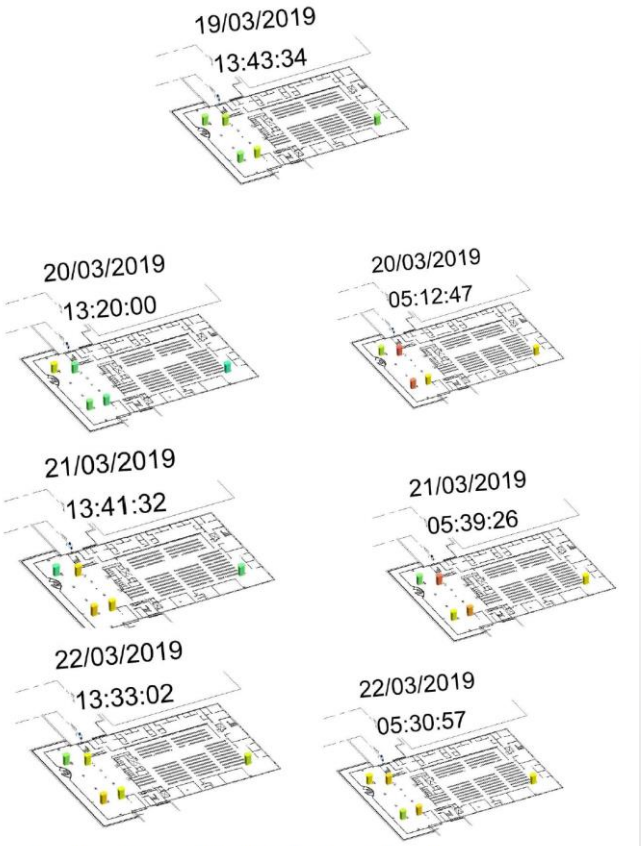
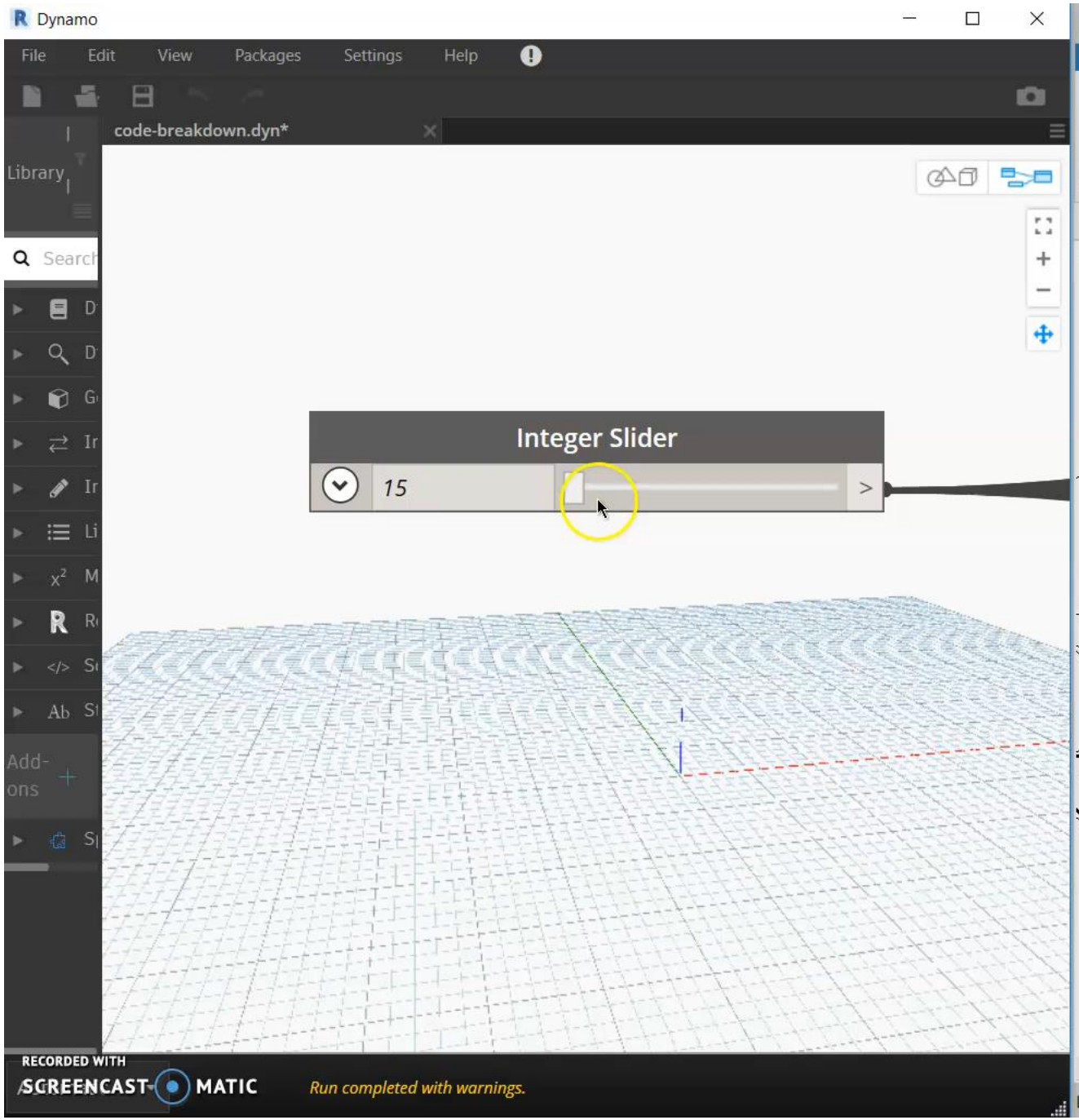


FIGURE 35: FLOOR 3 COLOUR OF BINS JUST BEFORE COLLECTION 19/03 - 22/03

Cloud data from Sensors

‘Kambin’ Dynamo Code

Live waste management on Revit Model


Dynamo
File
Edit
View
Packages
Settings
Help
code-breakdown.dyn*
Library
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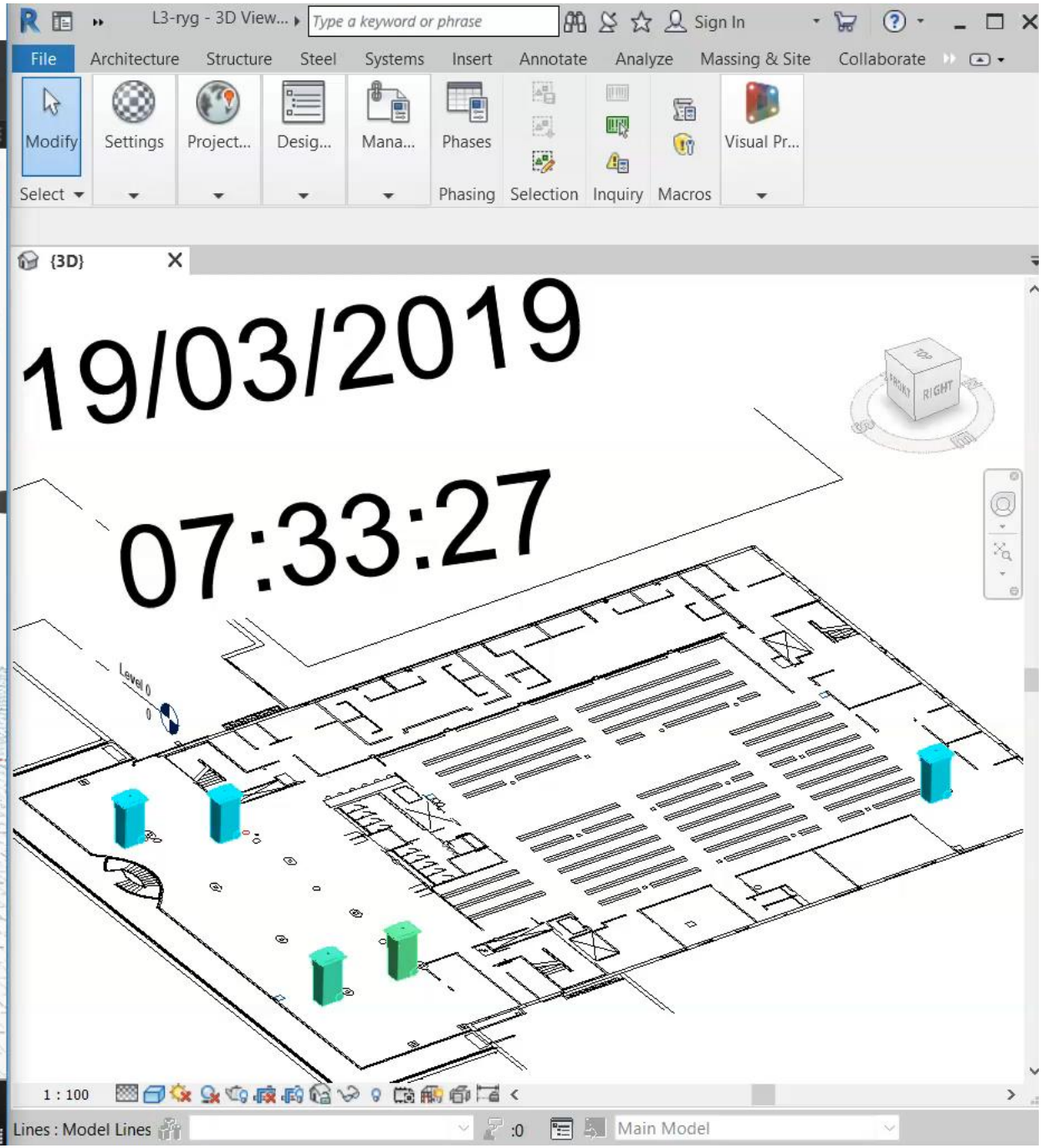
Run completed with warnings.


L3-ryg - 3D View...
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Sign In
File
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Structure
Steel
Systems
Insert
Annotate
Analyze
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Collaborate
Modify
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Select
Phasing
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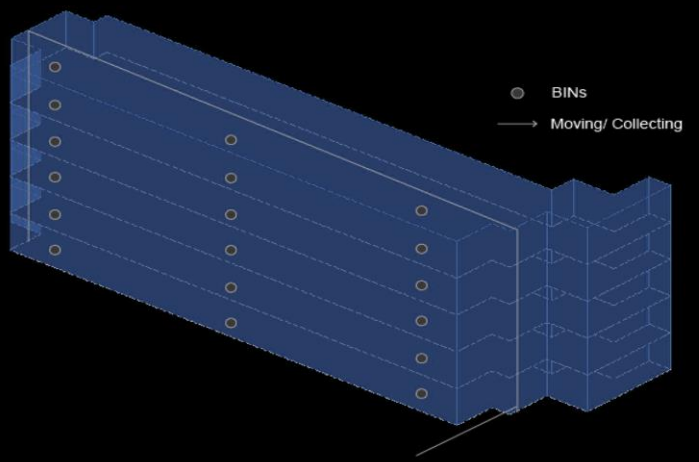
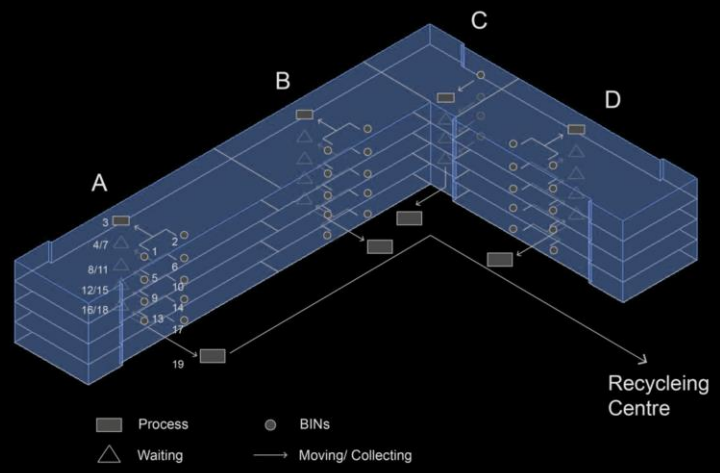
Macros
{3D}
19/03/2019
07:33:27
Level 0
1 : 100
Lines : Model Lines
Main Model

EXPERIMENT THREE: ACCOMODATION



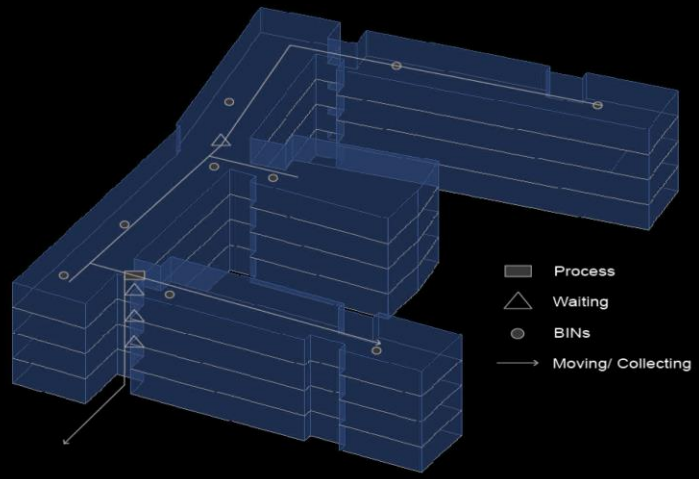
Quarry

≈ 70 hours per year



Marlborough Court

≈ 75 hours per year



Woodland Court

≈ 104 hours per year

Conclusions

Current available information suffice for a waste information model

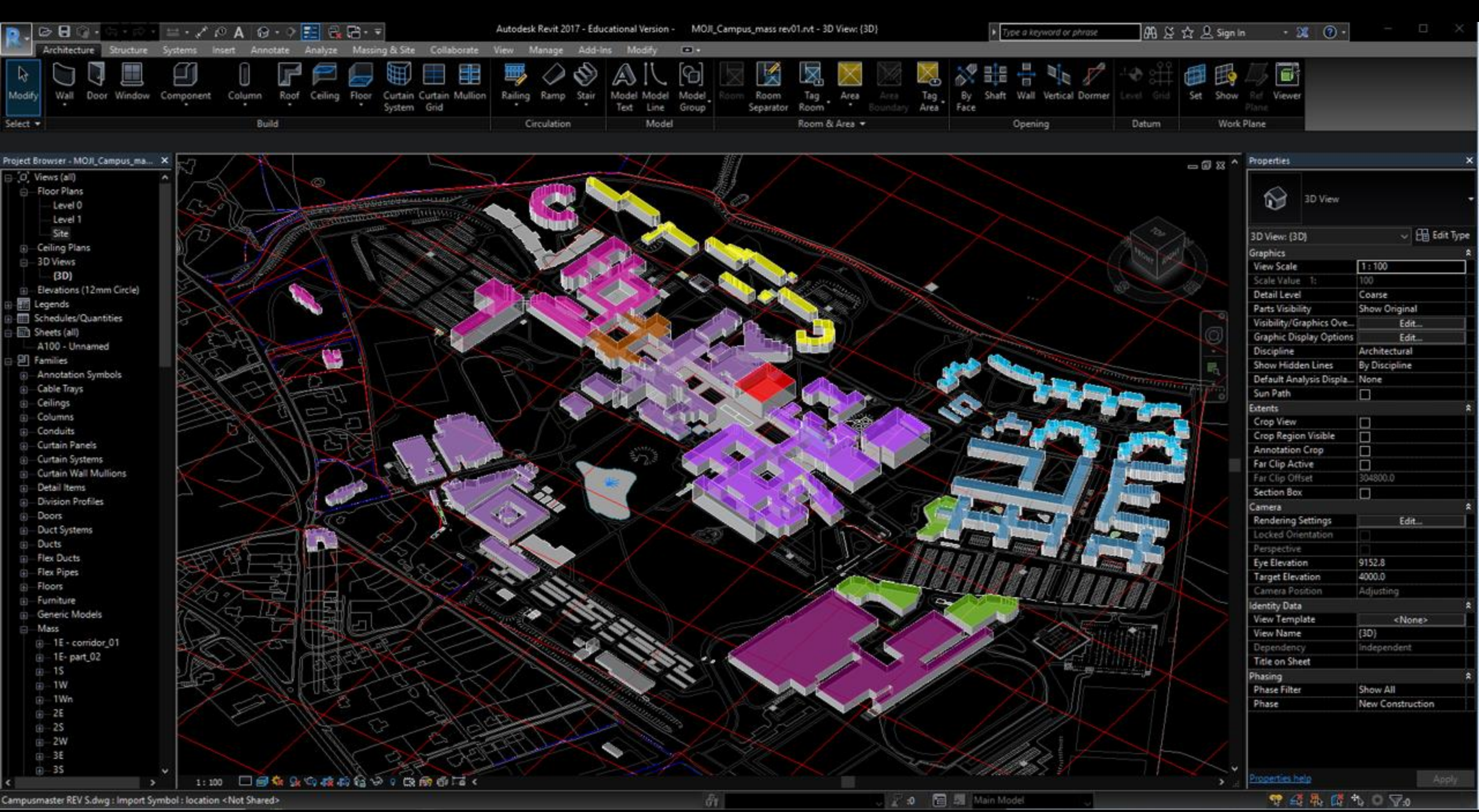
IoT can increase accuracy of Waste Management System

Significant amount of time can be saved with Waste Collection

A digital system supports reduction of waste generation.

Modelling legacy is major barrier


NEXT STEPS


Autodesk Revit 2017 - Educational Version - MOJI_Campus_mass rev01.rvt - 3D View: {3D}
Architecture Structure Systems Insert Annotate Analyze Massing & Site Collaborate View Manage Add-Ins Modify
Modify Wall Door Window Component Column Roof Ceiling Floor Curtain System Curtain Grid Mullion Railing Ramp Stair Model Text Model Line Model Group Room Room Separator Tag Room Area Area Boundary Tag Area By Face Shaft Wall Vertical Dormer Level Grid Set Show Ref Plane Viewer
Select Build Circulation Model Room & Area Opening Datum Work Plane
Project Browser - MOJI_Campus_ma...
Views (all)
Floor Plans
Level 0
Level 1
Site
Ceiling Plans
3D Views
{3D}
Elevations (12mm Circle)
Legends
Schedules/Quantities
Sheets (all)
A100 - Unnamed
Families
Annotation Symbols
Cable Trays
Ceilings
Columns
Conduits
Curtain Panels
Curtain Systems
Curtain Wall Mullions
Detail Items
Division Profiles
Doors
Duct Systems
Ducts
Flex Ducts
Flex Pipes
Floors
Furniture
Generic Models
Mass
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1E- part_02
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Properties
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Detail Level Coarse
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Visibility/Graphics Ove... Edit...
Graphic Display Options Edit...
Discipline Architectural
Show Hidden Lines By Discipline
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Crop Region Visible
Annotation Crop
Far Clip Active
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Perspective
Eye Elevation 9152.8
Target Elevation 4000.0
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Apply
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Campusmaster REV S.dwg : Import Symbol : location <Not Shared>
Main Model

Reinventing the Wheel

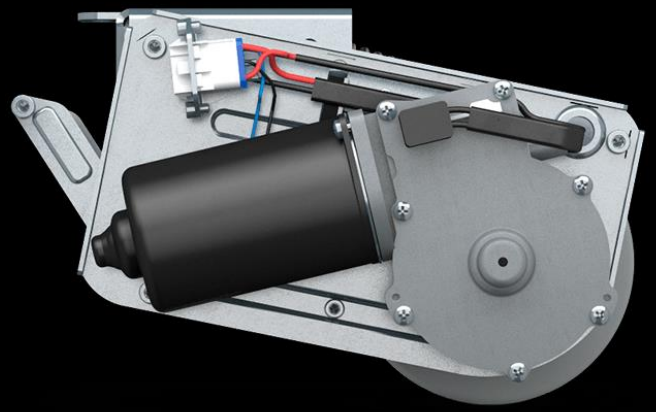

Image Source: https://www.tente.com/en-gb/product-families/castors/e-drive

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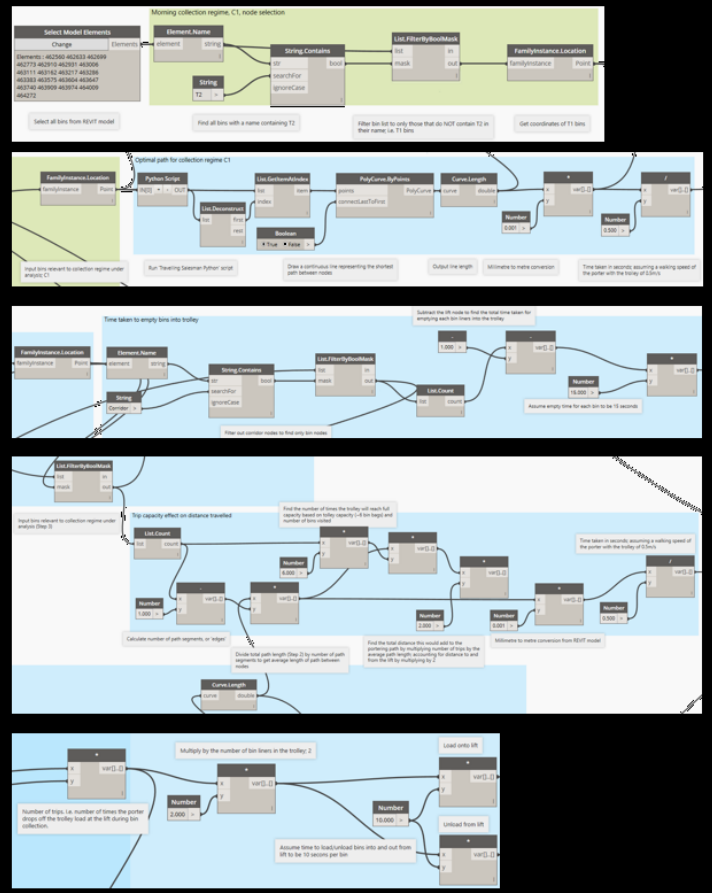

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Source: https://hackaday.com/2017/07/02/a-beverage-cooler-that-comes-to-you/

Acknowledgements

Research

- Dr Ricardo Codinhoto (UoB)
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- Ms Wei Wen zhang (MBD)
- Ms Ojaswini Singh (MBD)
- Mr Rongqi Chen (MBD)
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- Mrs Liz Russell - Waste & Recycling Manager
- Mr Peter Phelps – Energy and Environment Managers
- Mr David Stacey – Faculty Librarian
- Mrs Jane Lankenou – Project Coordinator, Waste Services, Environmental Services, Bath & North East Somerset Council

Thank you!!!

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