SEMANTIC DIGITAL TWINS IN INDUSTRIALISED CONSTRUCTION

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OVERVIEW

- Innovate UK(iUK) project (~£1M): DfMA houses

- Main contributions by BCU
  - Life cycle cost estimation of DfMA
  - Life cycle CO_2 emissions estimation of DfMA
  - Semantic Modeling of DfMA
  - Knowledge-Based Engineering(KBE) tool

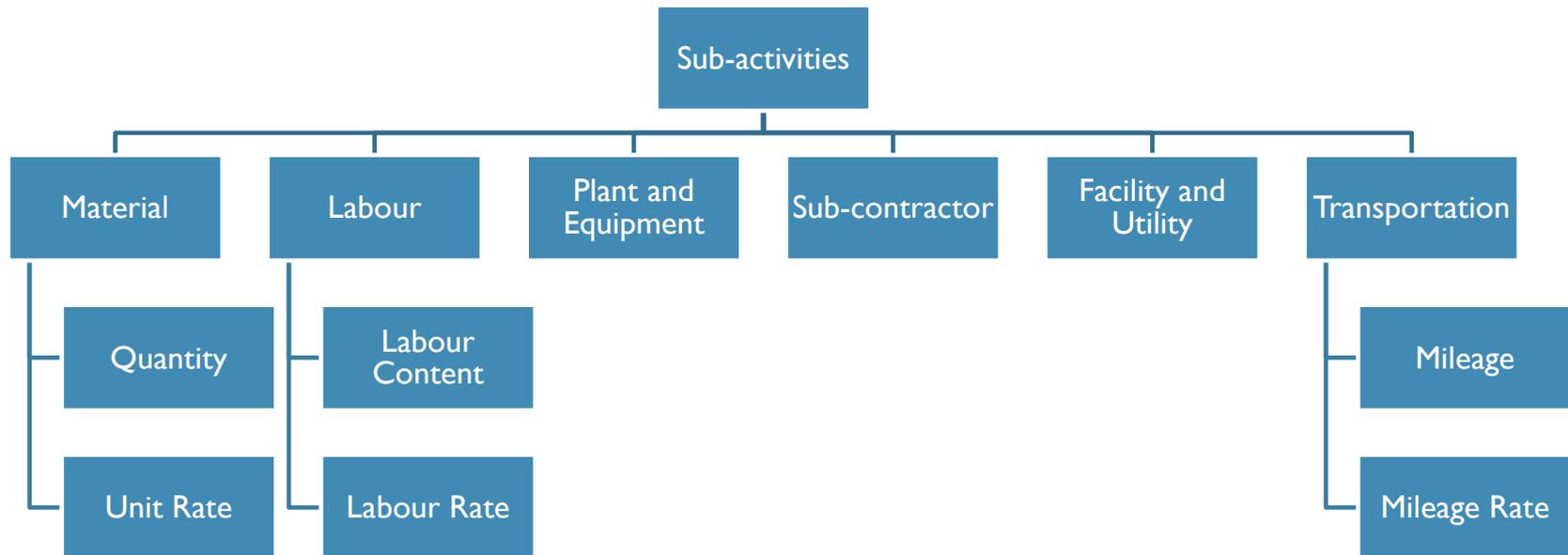- **5 levels of breakdown:**
  - Activity centre (Level 1)
  - Activity group (Level 2)
  - Activity (Level 3)
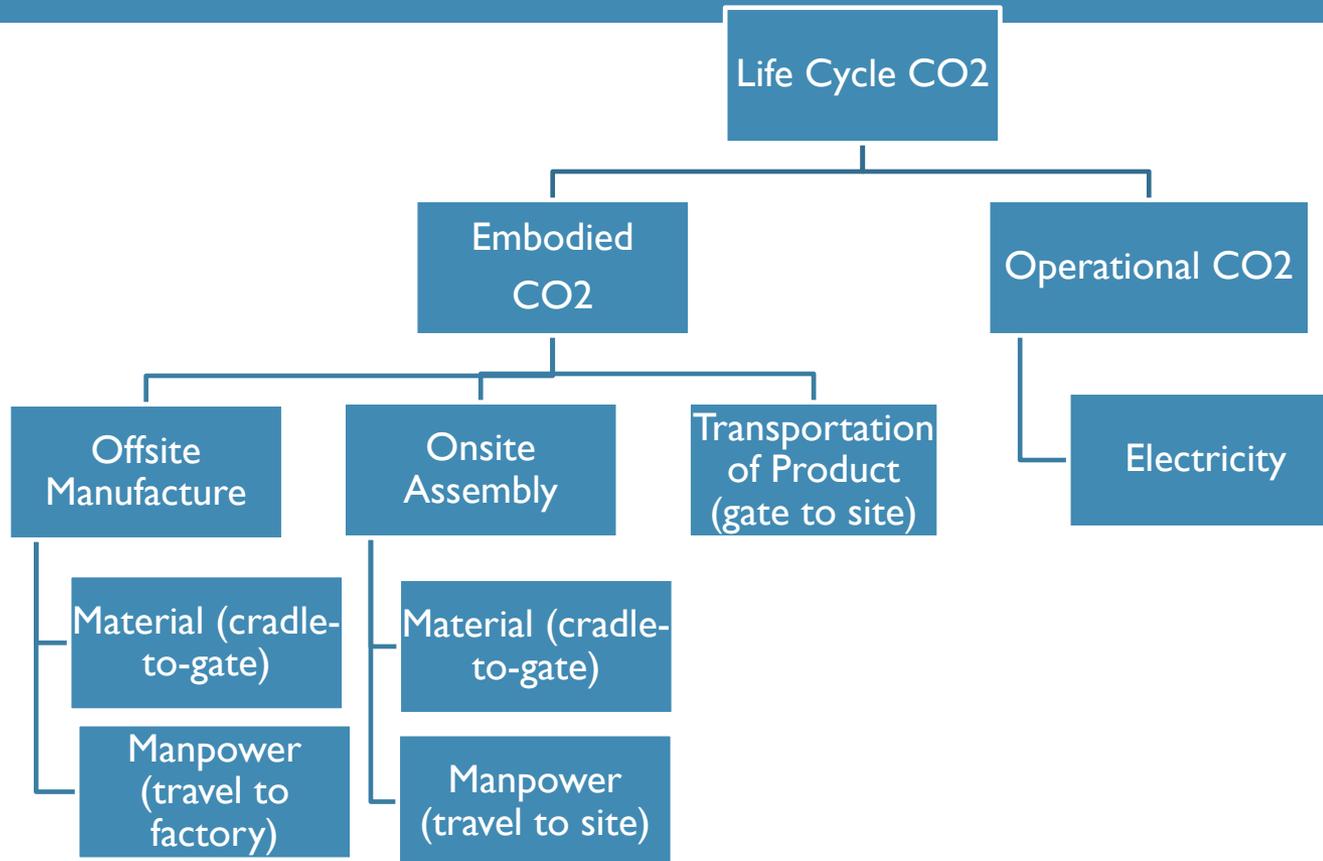 - Sub-activities (Level 4)
  - Resources (Level 5)

DfMA house built by volumetric method comprising 6 pods

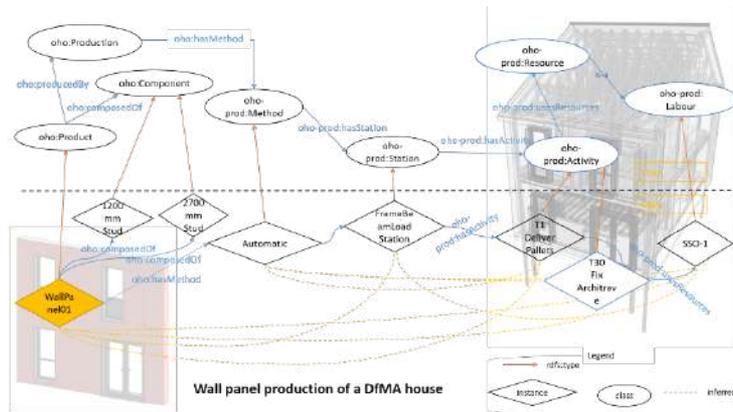# DESIGN FOR MANUFACTURING AND ASSEMBLY

RESOURCE BREAKDOWN OF MANUFACTURE AND ASSEMBLY FOR SUB-ACTIVITIES

LIFE CYCLE CO2 EMISSIONS

SEMANTIC MODELLING OF DFMA

Wall panel production of a DfMA house

- OHO- OFFSITE HOUSING ONTOLOGY

- OHO-PRODUCTION

- OHO-COST

- OHO-LCA

OHO- PRODUCTION

- Classification of production methods
- Time spent in each production activity
- Resources consumed in each activity
- Categorisation of activities i.e. value added activities
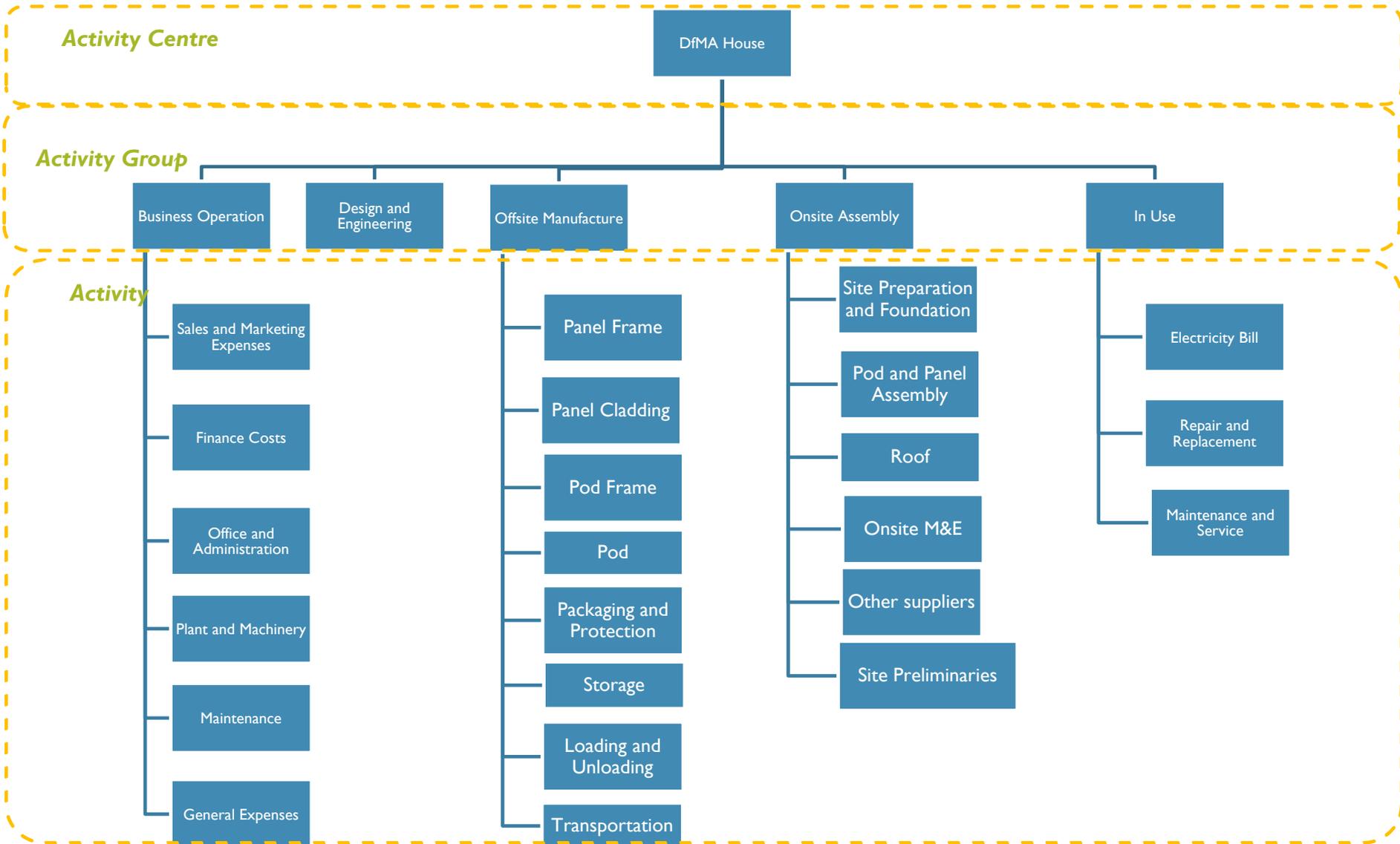- Etc.

Frame Production Line Overview (Source: QM Systems: Modular Housing Assembly Line, 2020)

Property assertions: SemiAutomatedManufacturingMethod

Object property assertions

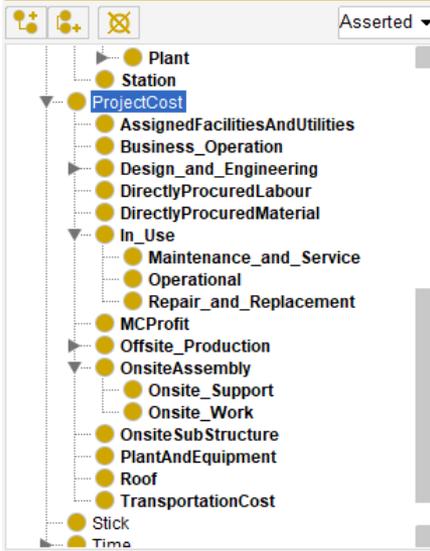- hasStartProcess SemiAutomatedFrameAssemblyLine
- consistOf SemiAutomatedFrameAssemblyLine
- consistOf A5.63_Inspect_quality_of_bonding_and_fixing
- consistOf A5.35_Sort_Steel_Section_and_Load_onto_Tooling
- consistOf Frame_Load_Station
- consistOf A5.30_Start_PMS_System
- consistOf A5.39_Screw_Steel_Section_to_form_Frame
- consistOf A5.65_Install_Cladding_SubFrame
- consistOf CP_Board_Load_Station
- consistOf Frame_Rework_Station
- consistOf A5.38_Transfer_Frame_to_Fixing_Station
- consistOf A5.52_Load_CP_Board_on_Frame
- consistOf Other_Pod_Finishing_Station
- consistOf GF_Pod_Finishing_Station
- consistOf PodFrameAssemblyLine
- consistOf Frame_Inspection_Station
- consistOf A5.37_Clamp_Section_in_Place
- consistOf A5.33_Material_Delivery_to_Work_Station
- consistOf A5.73_Rework_on_Panel_or_Scrap
- consistOf Tooling_SetUp_Station
- consistOf A5.31_Load_BIM_Model
- consistOf A5.71_Install_Window_and_Door
- consistOf A5.36_Verify_and_Inspect_SetUp
- consistOf A5.40_Transfer_Frame_to_Rework_Station
- consistOf A5.58_Rotate_and_Offload_Panel
- consistOf GF_Pod_Frame_Assembly_Station
- consistOf A5.47_Screw_Frame_on_Opposite_Side
- consistOf A5.57_Transfer_Frame_to_Unload_Station
- consistOf A5.45_Transfer_Frame_to_Fixing_Station_2
- consistOf A5.49_Visual_Inspection_on_Frame_Connection
- consistOf A5.70_Install_Cladding
- consistOf A5.34_Tooling_SetUp_for_Batch
- consistOf A5.32_Run_and_Monitor_Process
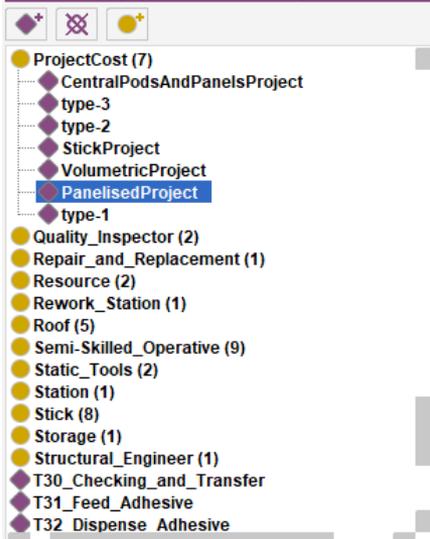- consistOf TEK_Screw1_Station

OHO-COST

DfMA House

Activity Group

Business Operation	Design and Engineering	Offsite Manufacture	Onsite Assembly	In Use

Activity

Business Operation
- Sales and Marketing Expenses
- Finance Costs
- Office and Administration
- Plant and Machinery
- Maintenance
- General Expenses

Offsite Manufacture
- Panel Frame
- Panel Cladding
- Pod Frame
- Pod
- Packaging and Protection
- Storage
- Loading and Unloading
- Transportation

Onsite Assembly
- Site Preparation and Foundation
- Pod and Panel Assembly
- Roof
- Onsite M&E
- Other suppliers
- Site Preliminaries

In Use
- Electricity Bill
- Repair and Replacement
- Maintenance and Service

OHO-COST

OHO-LCA

KBE- TOOL FOR ENGINEERS AND RESEARCHERS

http://dfma.innovationfest.co.uk/
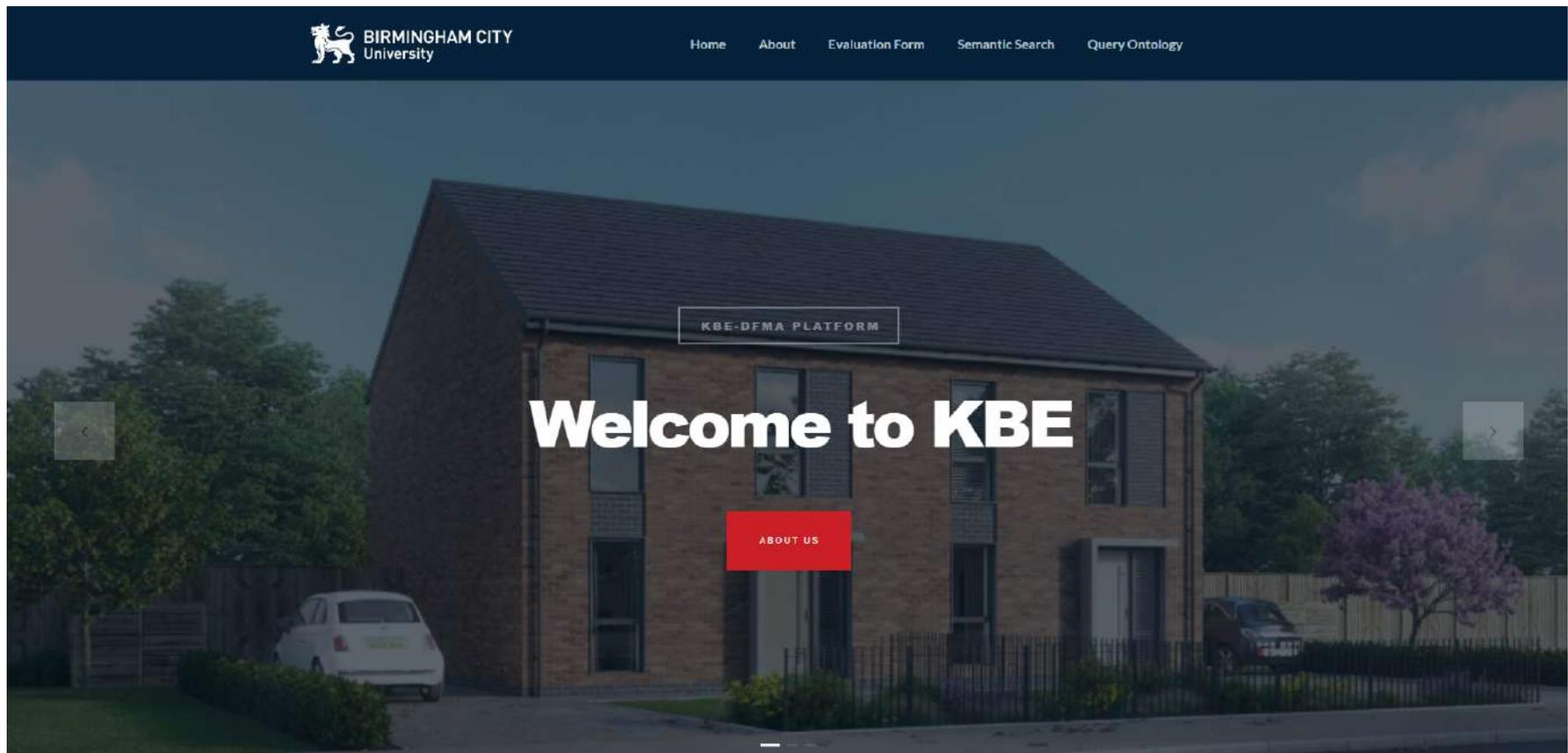
DATA INPUT AND OUTPUT OF KBE TOOL

Data Input: User

Data Output
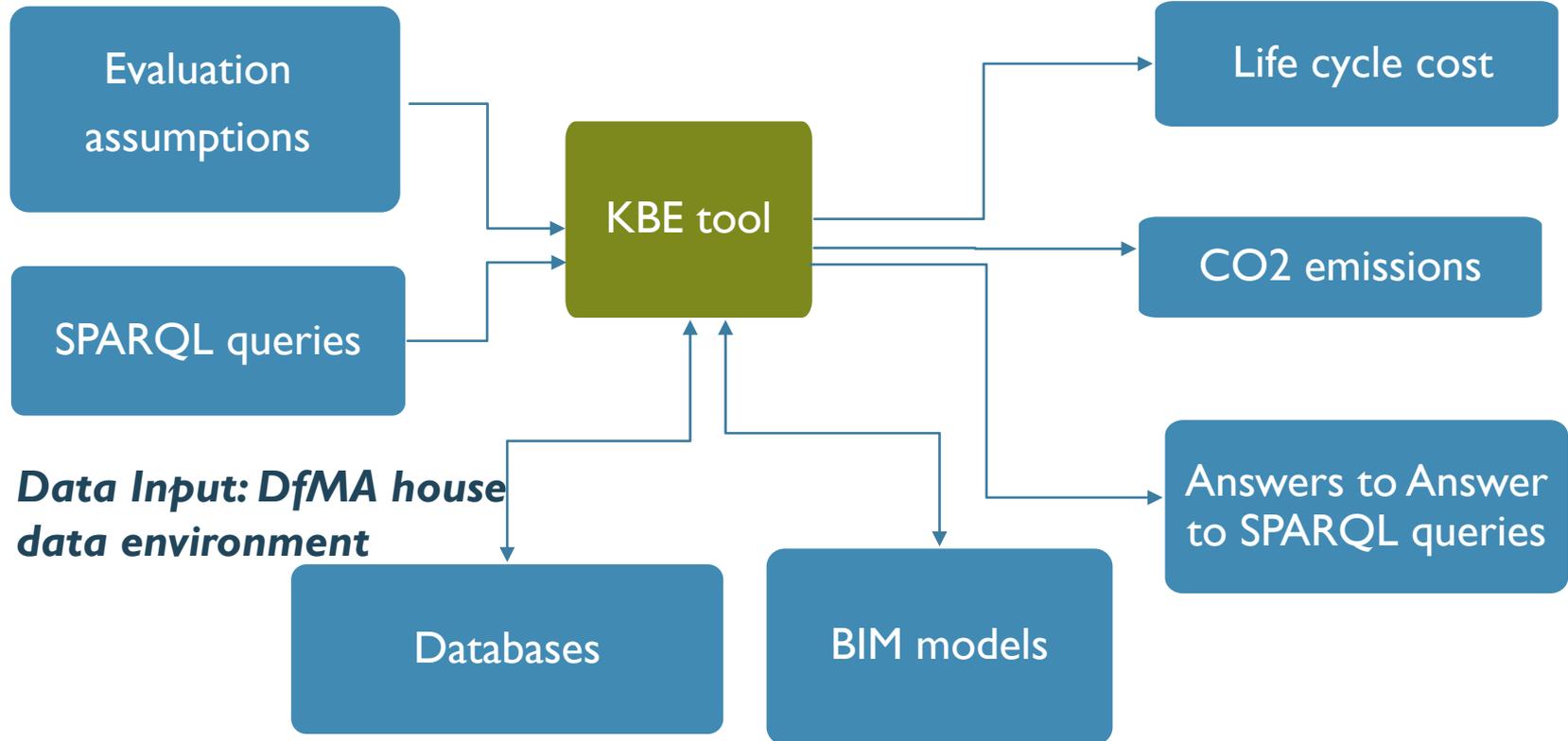
Evaluation assumptions

SPARQL queries

KBE tool

Life cycle cost

CO_2 emissions

Answers to Answer to SPARQL queries

Data Input: DfMA house data environment

Databases

BIM models

KBE TOOL ARCHITECTURE
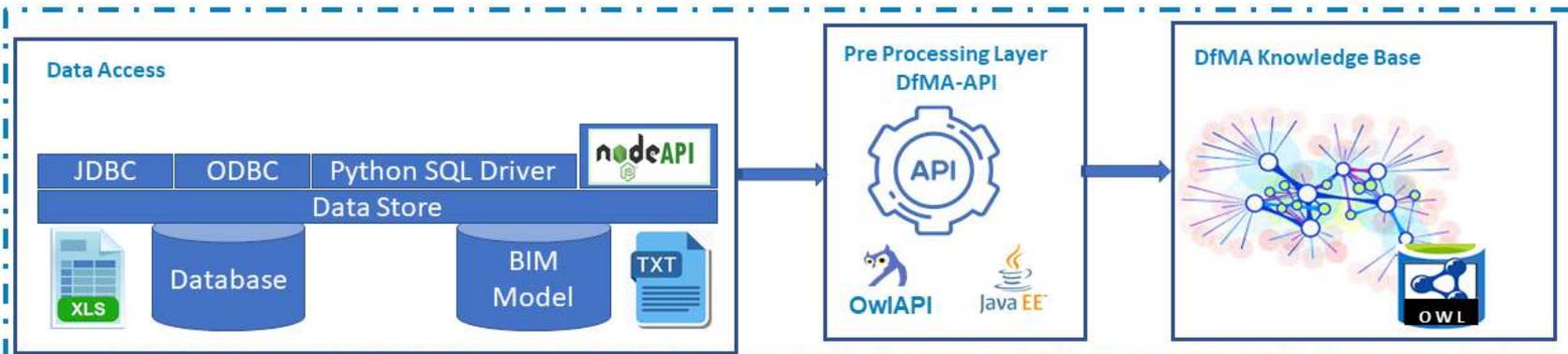
KBE TOOL USE CASE

Project Information

Address (Post Code)

b16 9ju

No. of units for each house type

Detached	Semi-detached	Terrace	Average no. per row
2	2	4	4

Design Choice

External wall finishes	Roof choice	Window frame choice	Services provision standard
Rendering	Sedum green roof	Timber	Silver - Electric panel, mixergy hot water cylinder, Solar PV

Product Assumptions

Batch size within a 12 months period

Offsite System

CO2 Emission per House

Embodied_CO2   Operational_CO2
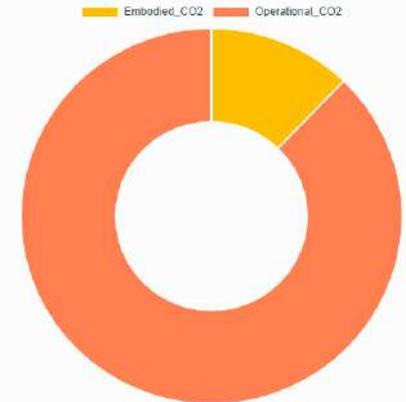
Total Costs

Activity Group	Cost Calculation
Business Operations Costs	£39240
Design and Engineering Costs	£105880
Offsite Manufacturing Costs	£472064
Onsite Assembly Costs	£567744
MC Profits Costs	£118496
In Use Costs	£1463272
totalCost	£1184928

Cost per House Unit

Business Operations Costs   Design and Engineering Costs   Onsite Assembly Costs   Offsite Manufacture Costs   In Use Costs   MC Profits Costs
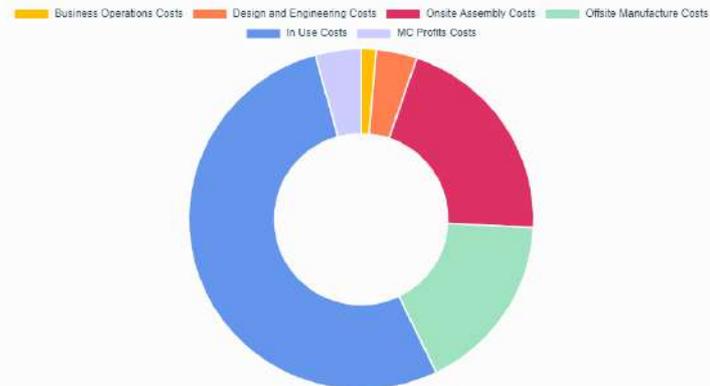
Cost per m^2

PUBLICATIONS

- AYINLA, K., CHEUNG, F. 2020 Development of a generic workflow process model for Offsite Manufacturing (OSM) (under preparation)

- VAKAJ, E., CHEUNG, F., TAWIL, A., PAUWELS, P. PATLAKAS P. 2020. OHO: an Offsite Housing Ontology (under review)

- AYINLA, K., CHEUNG, F. 2020 Process waste analysis for off-site wall panel production methods for house construction (under review)

- KALEMI, E. V., CHEUNG F.. TAWIL A., PATLAKAS, P. & ALYINLA K. 2020. ifcOWL-DfMA a new ontology for the offsite construction domain. LDAC2020 – Proceedings for Linked Data in Architecture and Construction, Trinity College, Dublin

- AYINLA, K., CHEUNG, F. & TAWIL, A. 2019. Towards an ontology-based approach to measuring productivity for offsite manufacturing method. ARCOM 2019 Productivity, Performance and Quality Conundrum, 2nd - 4th September, Leeds Beckett University, Leeds, UK

- AYINLA, K., CHEUNG, F. & TAWIL, A. 2019. Demystifying the concept of offsite manufacturing method: Towards a robust definition and classification system. Construction Innovation, 20 (2), 223-246

- ABANDA, F. H., TAH, J. H. M., & CHEUNG, F. 2017. BIM in off-site manufacturing for buildings. Journal of Building Engineering, 14, 89-102

- PATLAKAS P., A. LIVINGSTONE, HAIRSTANS R. & NEIGHBOUR G. 2018. Automatic code compliance with multi-dimensional data fitting in a BIM context. Advanced Engineering Informatics, 38, 216-231

- OTI, A., KURUL, E., CHEUNG, F. & TAH, J. 2016. A framework for the utilization of Building Management System data in building information models for building design and operation. Automation in Construction, 72 (2), 195-210