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AEC Production Control Room-Role of linked data

LBD CG Meeting October 19, 2021

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Motivation

Success of infrastructure projects depends heavily on completion of construction within planned time and cost while meeting all the project-requirements and standards.

- $114.3billion expected in cost over runs[1] .
- Out of 83 causes in 40+ studies and government audits cause for cost over runs have been ranked[2].

Rank	Cause	
1	Material price fluctuation	
2	Contractor cash flow	
3	Poor site management and supervision	75% is attributed to management factors[3]
4	Inadequate monitoring and control	
5	Inadequate planning and scheduling	

[1]Report McKinsey Global Institute (2013)
[2]Siemiatycki(2009)
[3]Cantarelli et al (2010)

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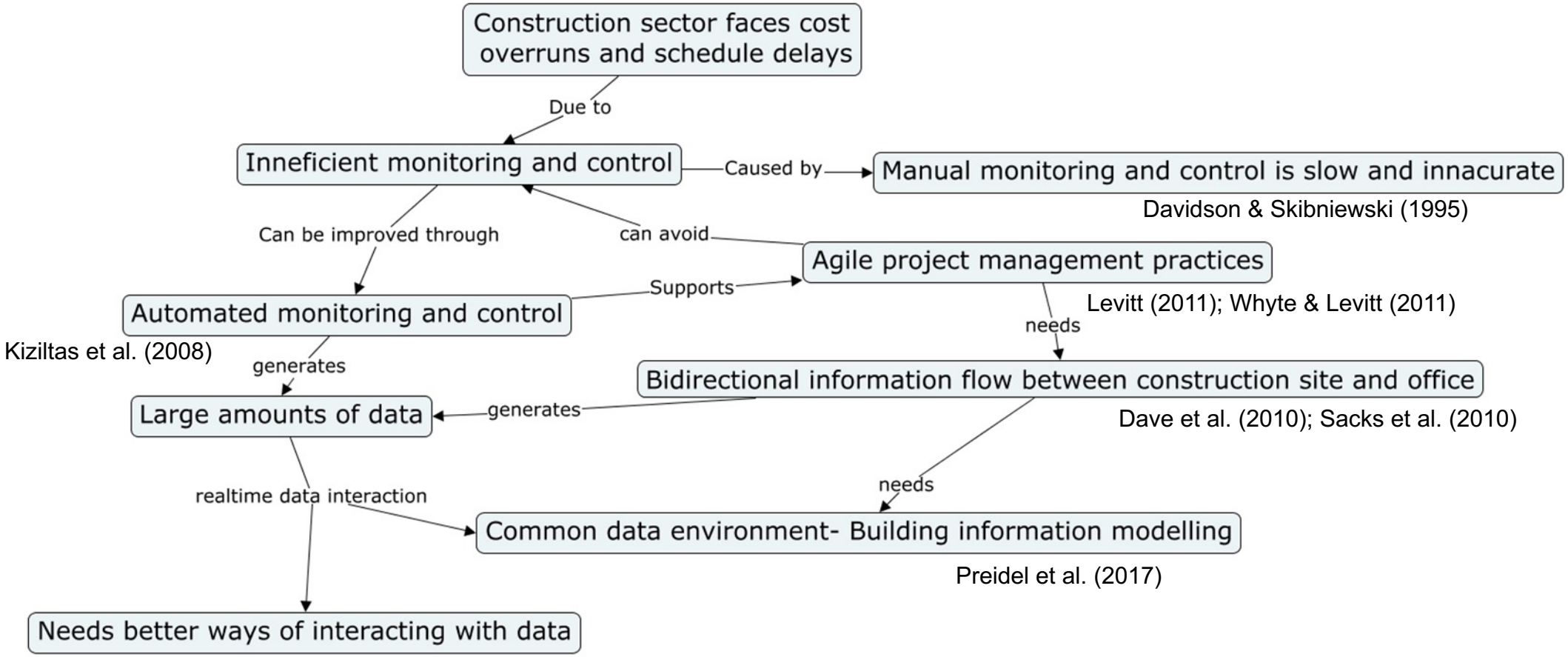
Motivation



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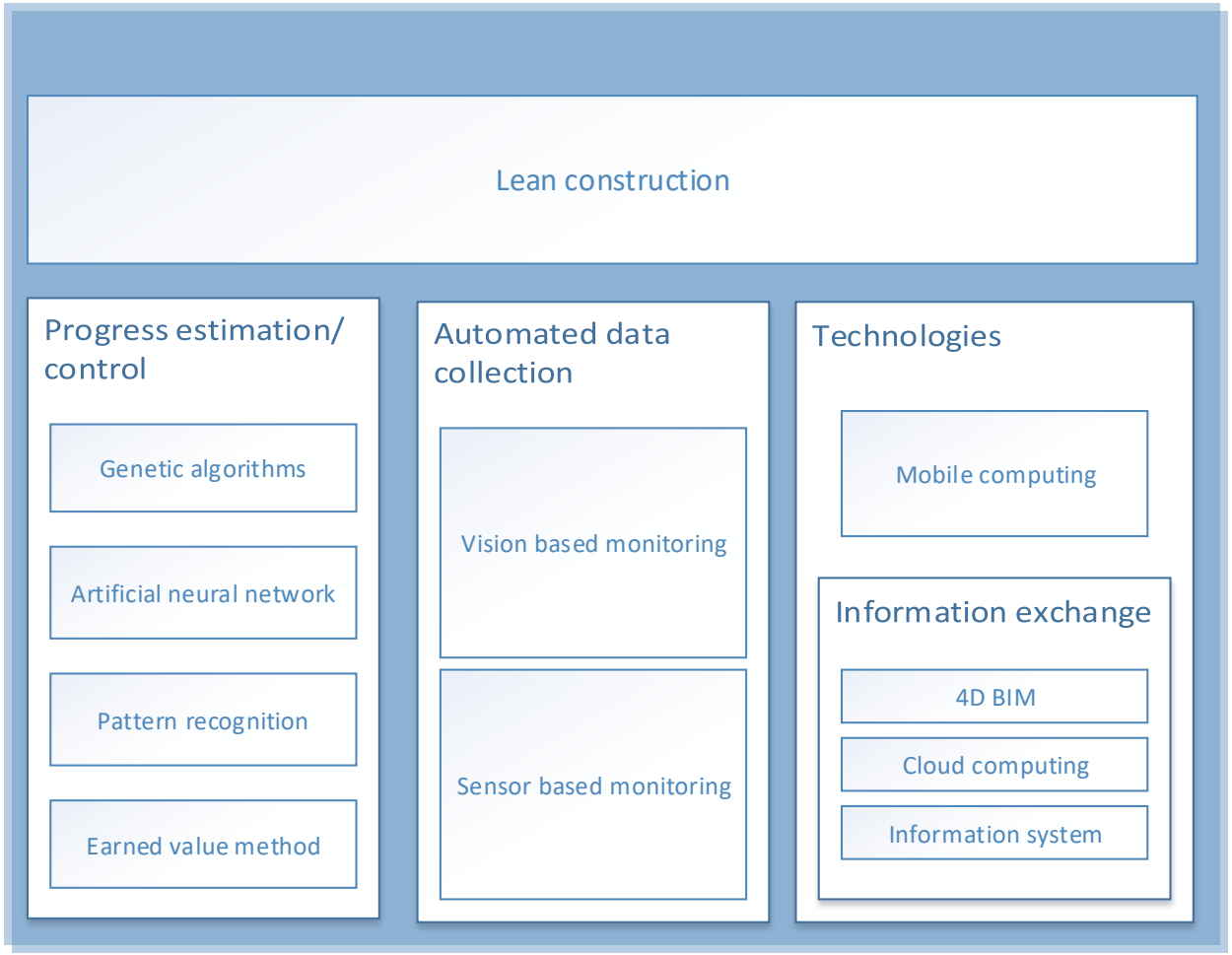
Motivation

- Large amount of information is distributed among multiple BIM databases each with a particular domain focus.

  "There is a lost opportunity to 'instrument' the construction process." (Akanmu et al,2014)

- Lack of a common interface to the 'product and process data' results in a lost opportunity to learn from the data exchange patterns hindering the potential of future automation.



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AEC production control room

- **Why:** Construction stage is known for the fragmentation of data because project stakeholders focus on their individual tasks and data and ignore interdependencies of the tasks and data with other stakeholders resulting in higher emissions, delays, cost overruns and rework.
- **How:** Inspired by the NASA mission control room, the research aimed at developing AEC production control room to visualize and interact with real-time construction information to enable efficient and data-driven construction management.
- **What:** Research involved system requirements analysis, data integration, insight definition and visualization development

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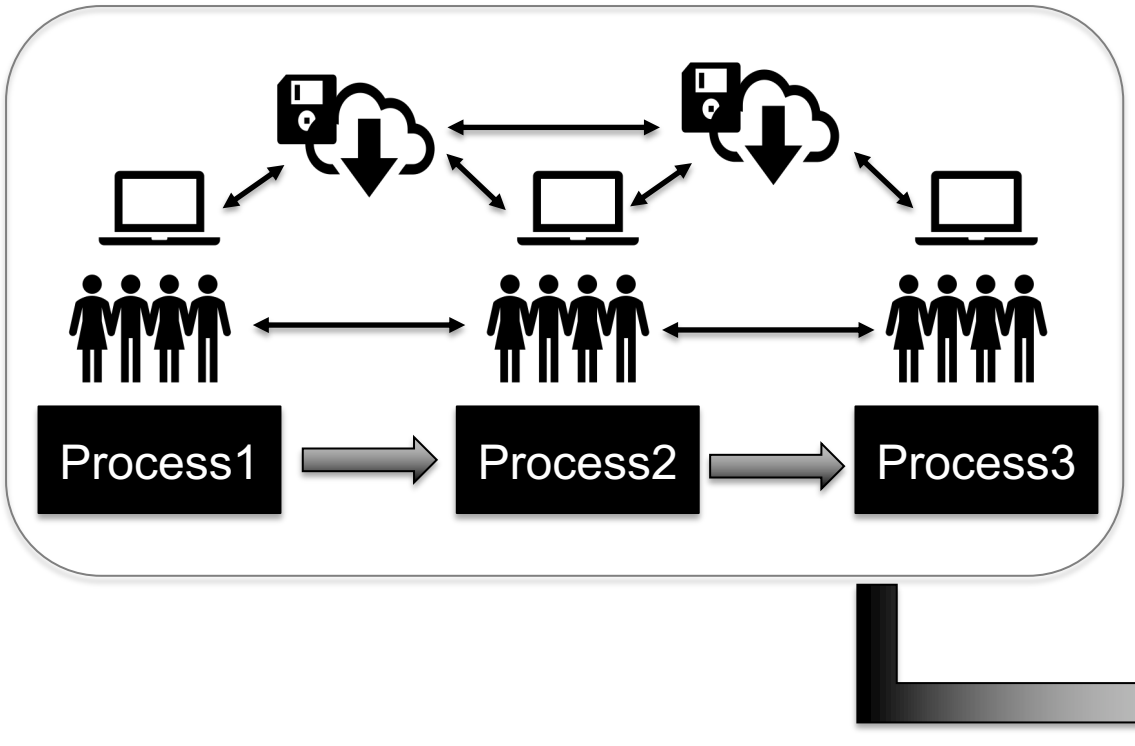
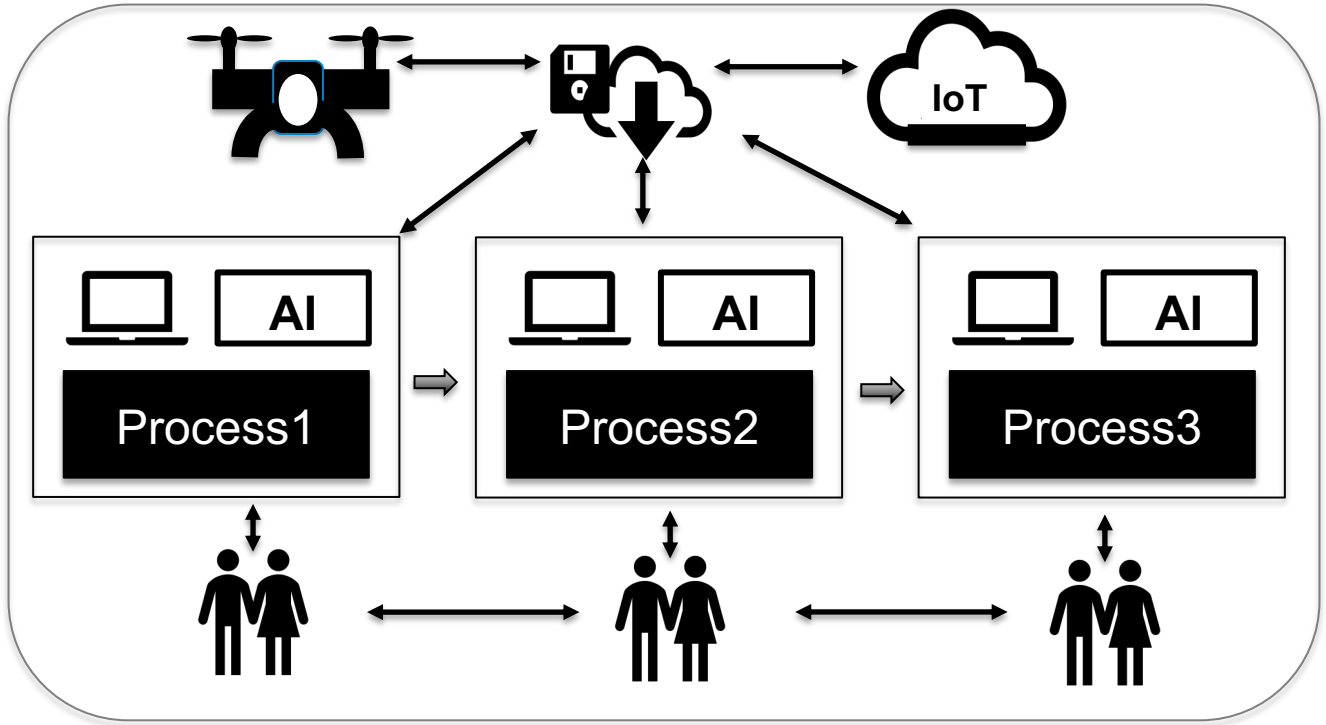


Artificial intelligence + Linked data + Reality capture
+ Internet of things + Robots + Smart contracts



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Digital twin of construction

Typical construction control room – Data recorded on whiteboards resulting in zero traceability and fragmented information

Developed AEC production control room – Data recorded through mobile-app, web-app, touch screens and visualized in large touch screens

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Data collection

Data Source	Count	Total Number
Internal meeting	25	50 hrs
Interviews with stakeholders from the demonstrator projects	8	12 hrs
Look ahead meetings in site	9	9 hrs
Bi-weekly meeting with the demonstrator representatives	20	20 hrs
Accessing utilised platforms/software in the demonstrator projects	7	-
Workshops on site	3	9 hrs

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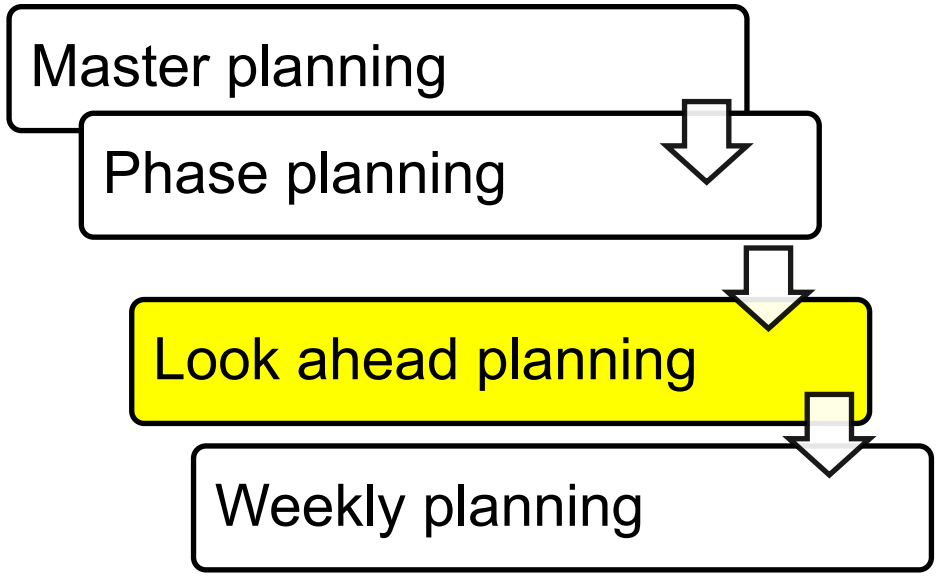
4 main processes

- Planning – Contract programme & Delivery programme
- Look ahead planning
- Document control
- Site logistics



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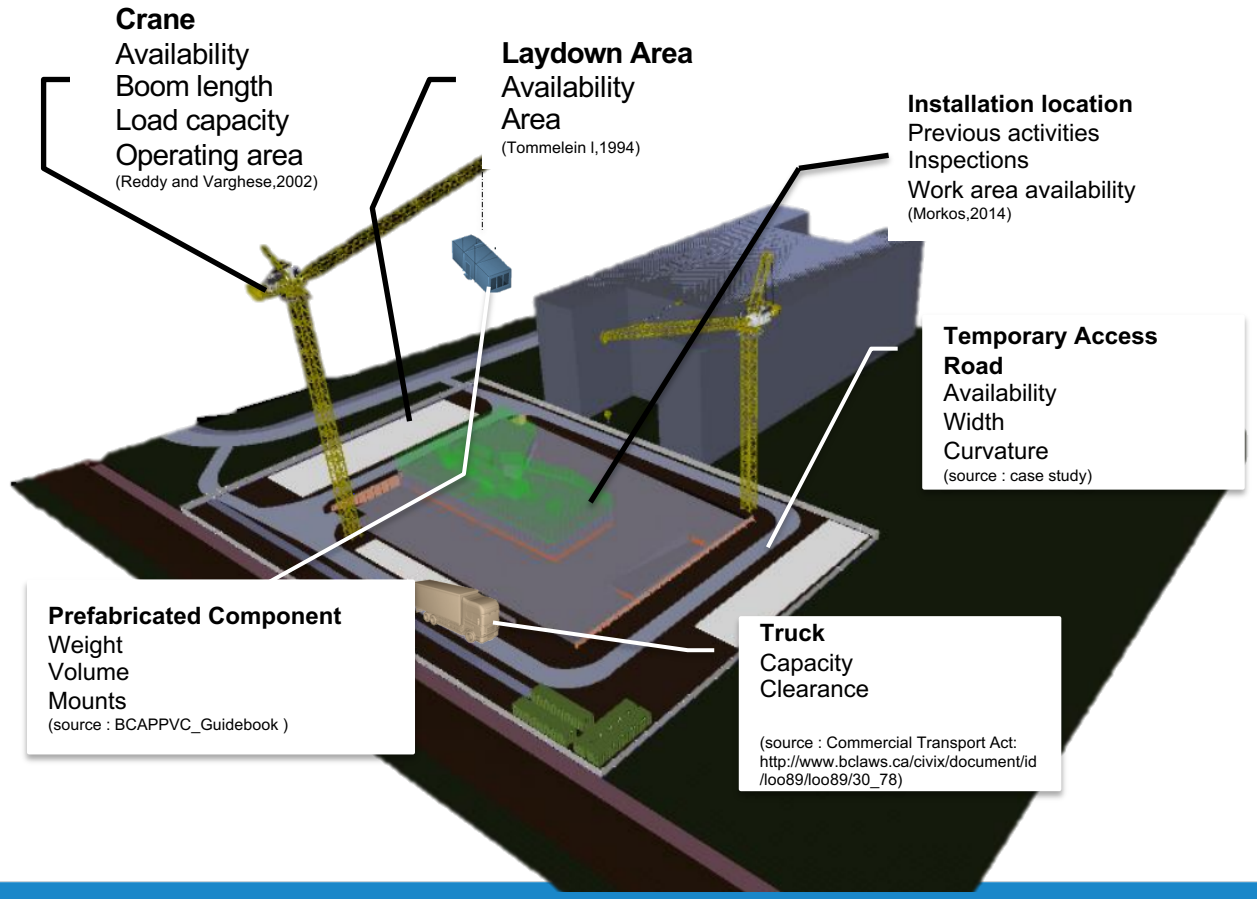
Information is not connected

1. Truck enters site with prefabricated component
2. Truck moves to laydown area through temporary access road
3. Unloads prefabricated component to laydown area
4. Crane lifts component from laydown area
5. Crane places component in the installation location



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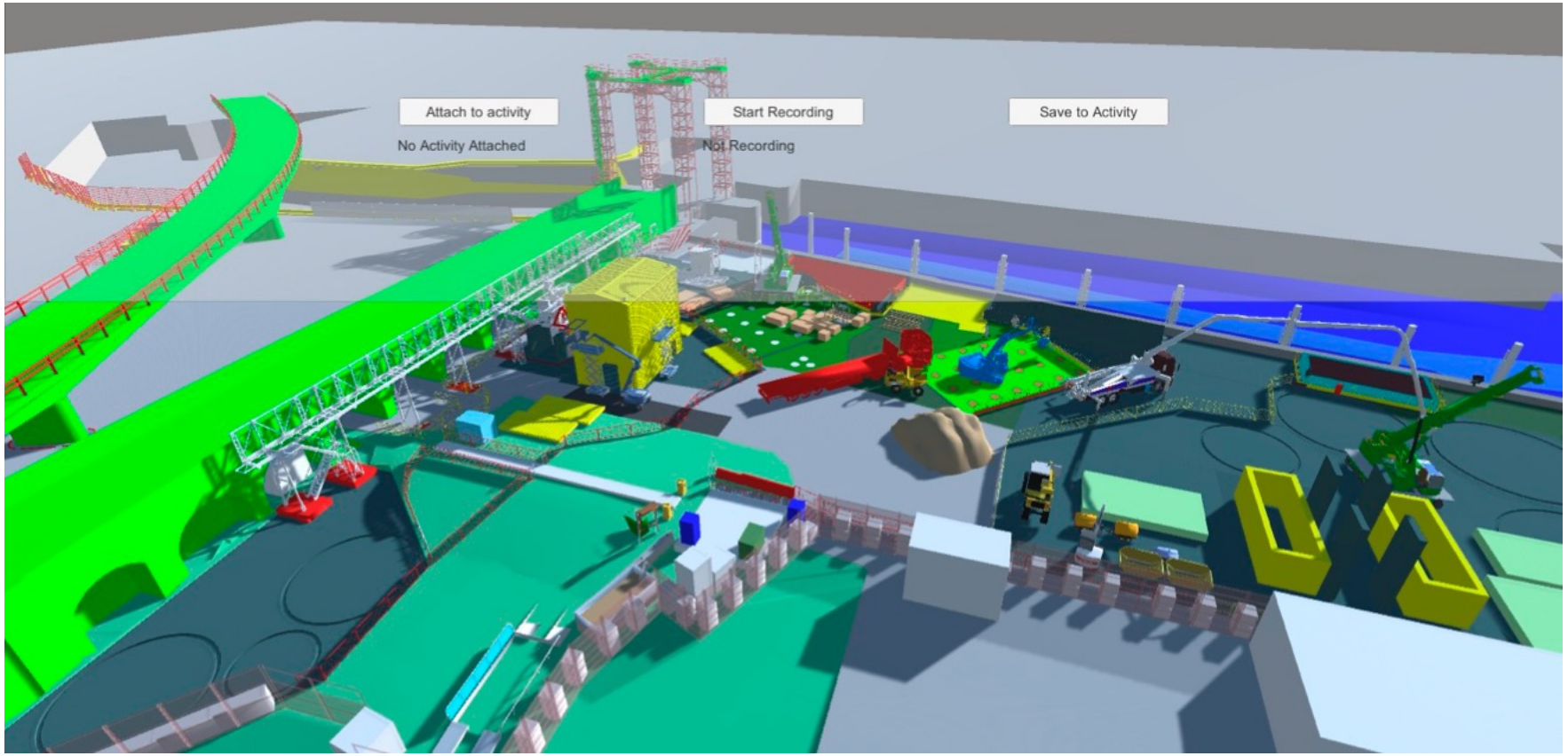

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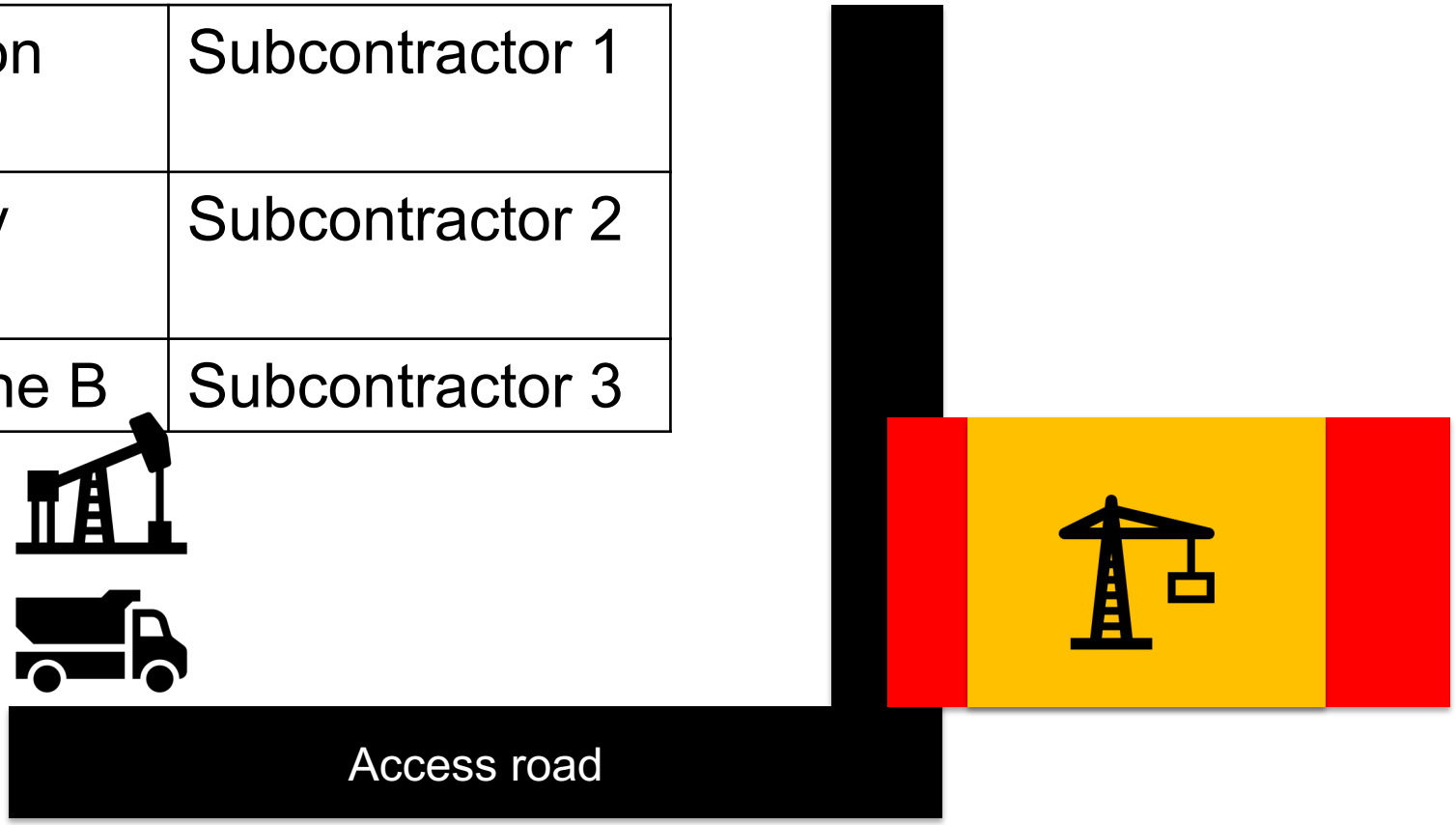
Week 1	Excavation Zone A	Subcontractor 1
Week 2	Assembly Zone A	Subcontractor 2
Week 3	Piling Zone B	Subcontractor 3



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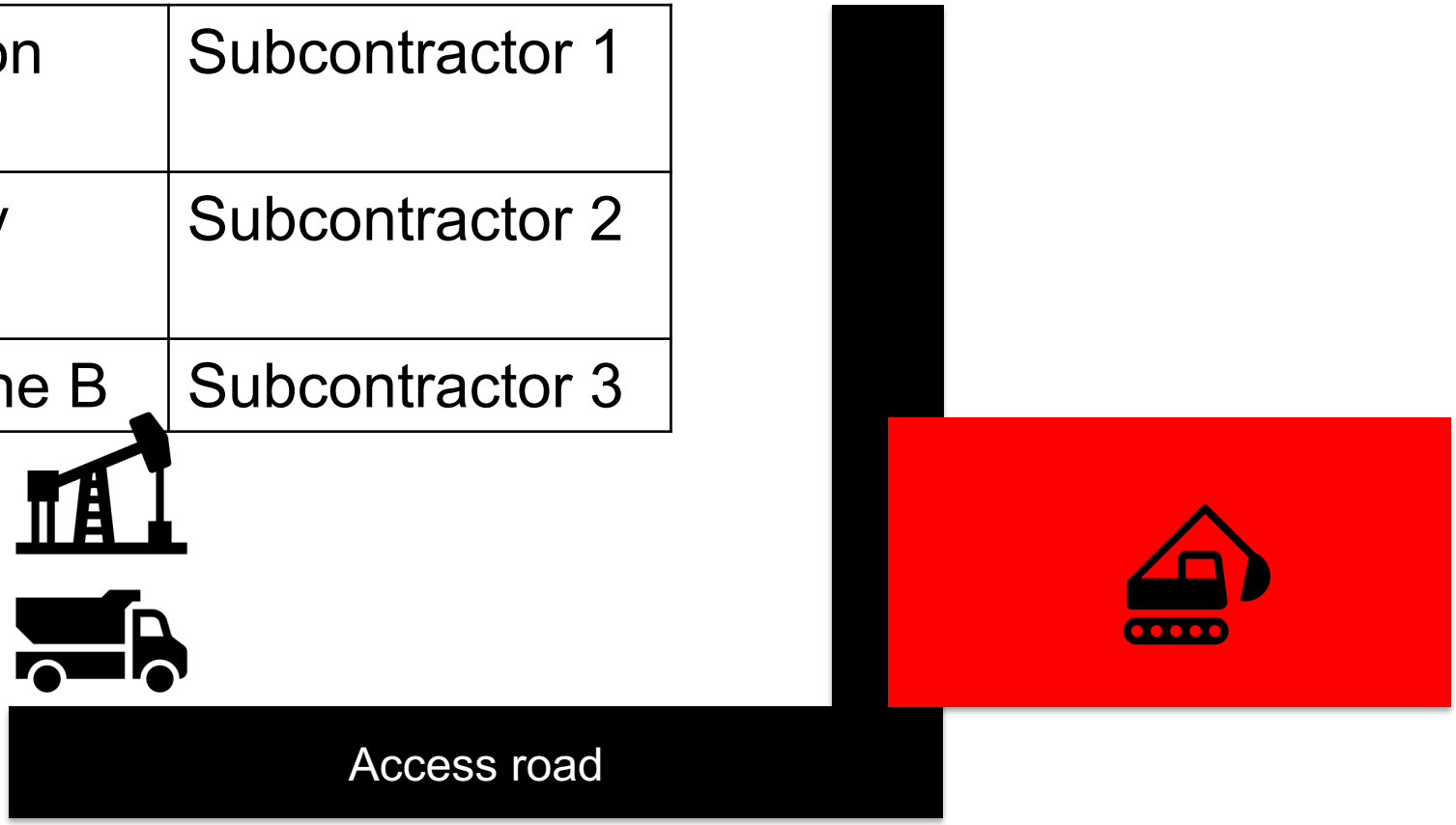
Week 1	Excavation Zone A	Subcontractor 1
Week 2	Assembly Zone A	Subcontractor 2
Week 3	Piling Zone B	Subcontractor 3



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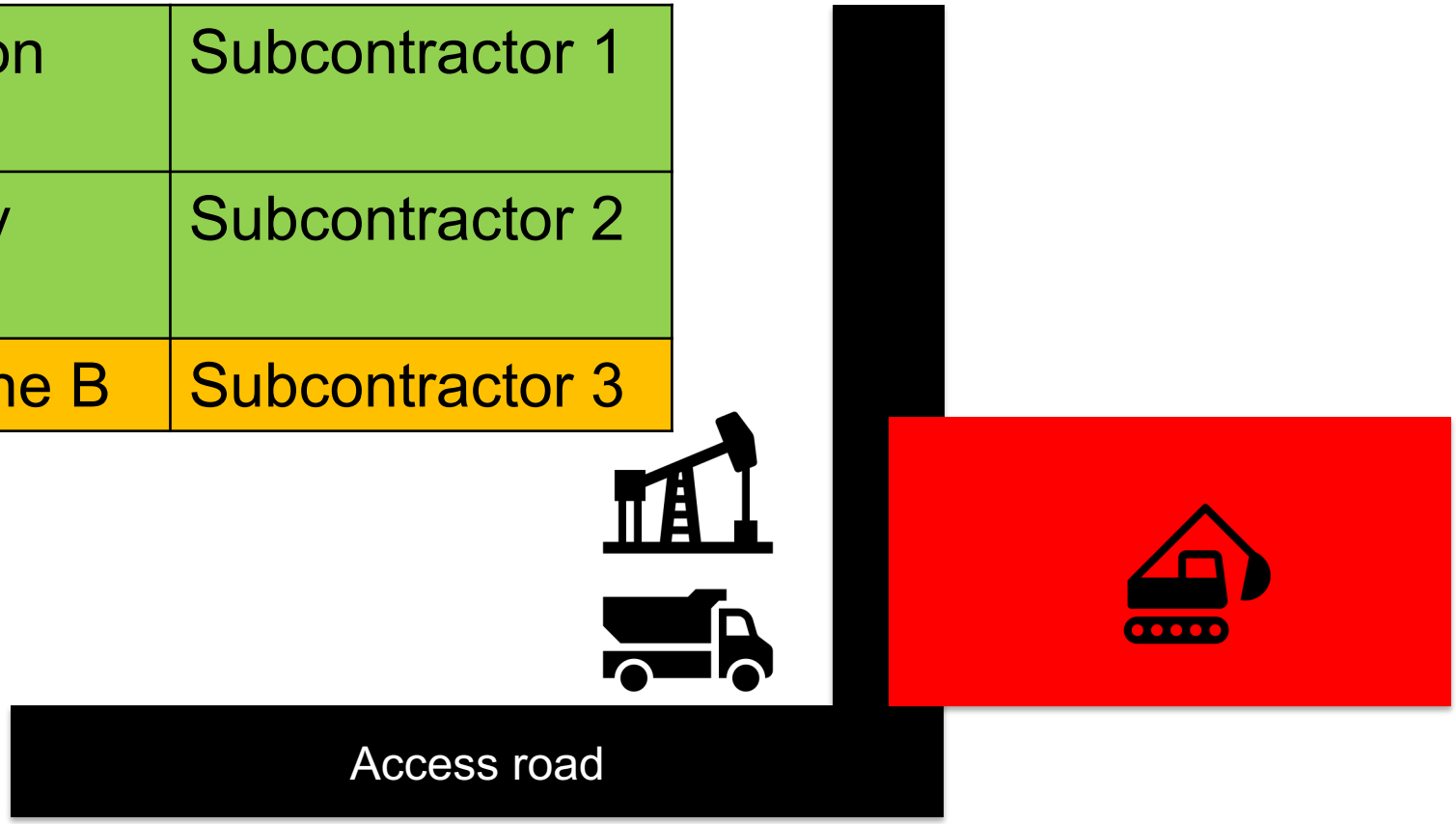
Week 1	Excavation Zone A	Subcontractor 1
Week 2	Assembly Zone A	Subcontractor 2
Week 3	Piling Zone B	Subcontractor 3



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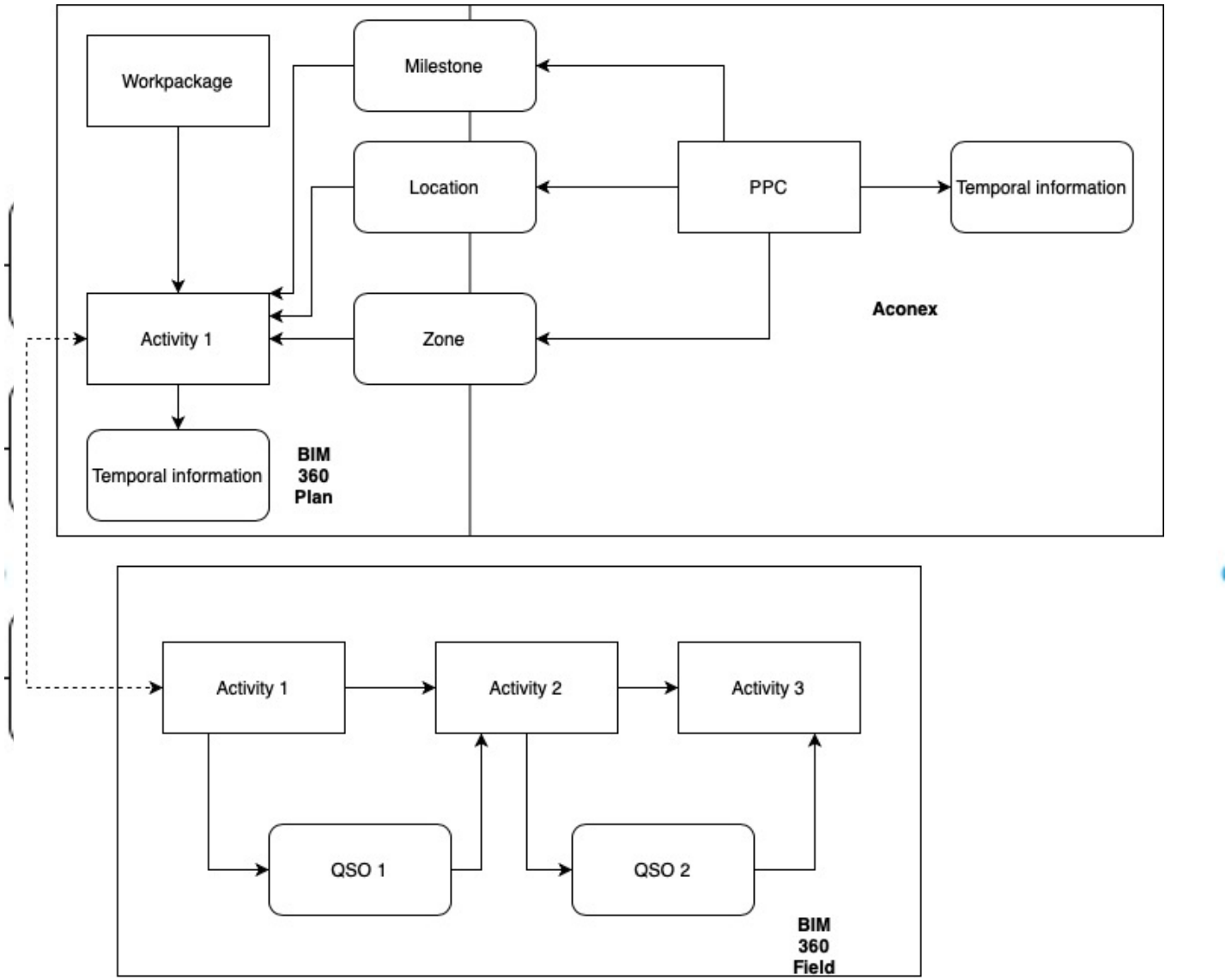

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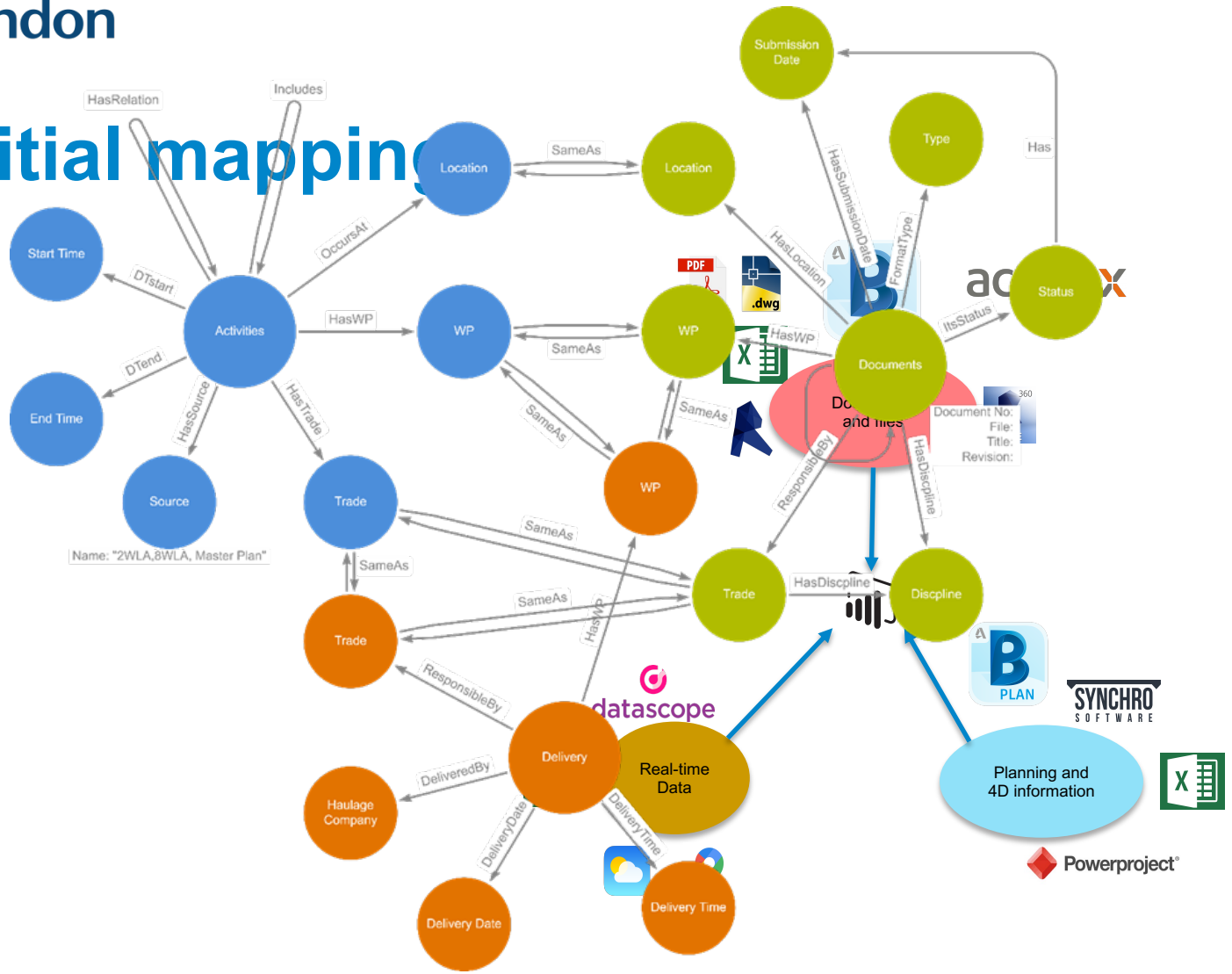
Initial mapping



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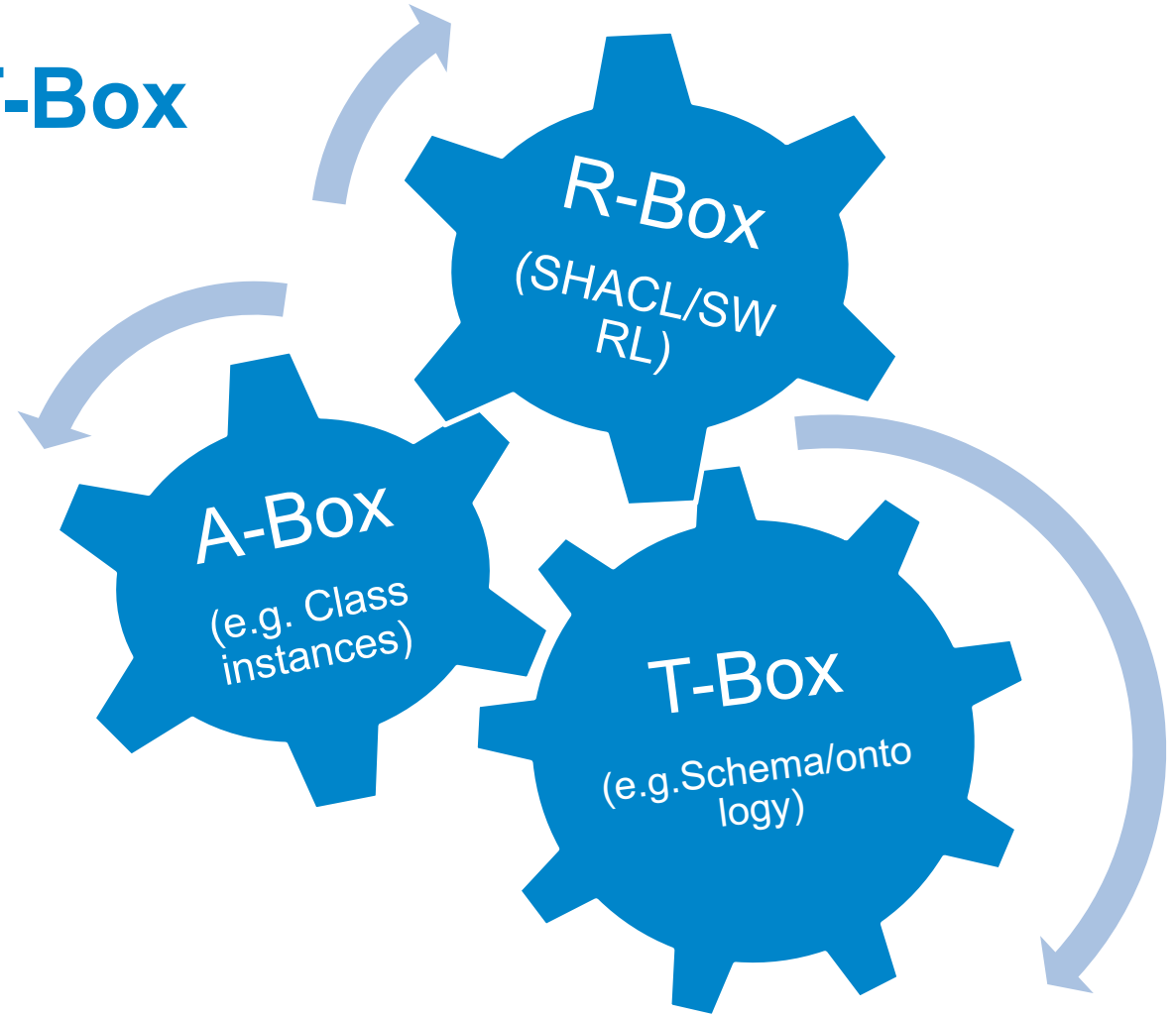
T-Box, A-box & T-Box



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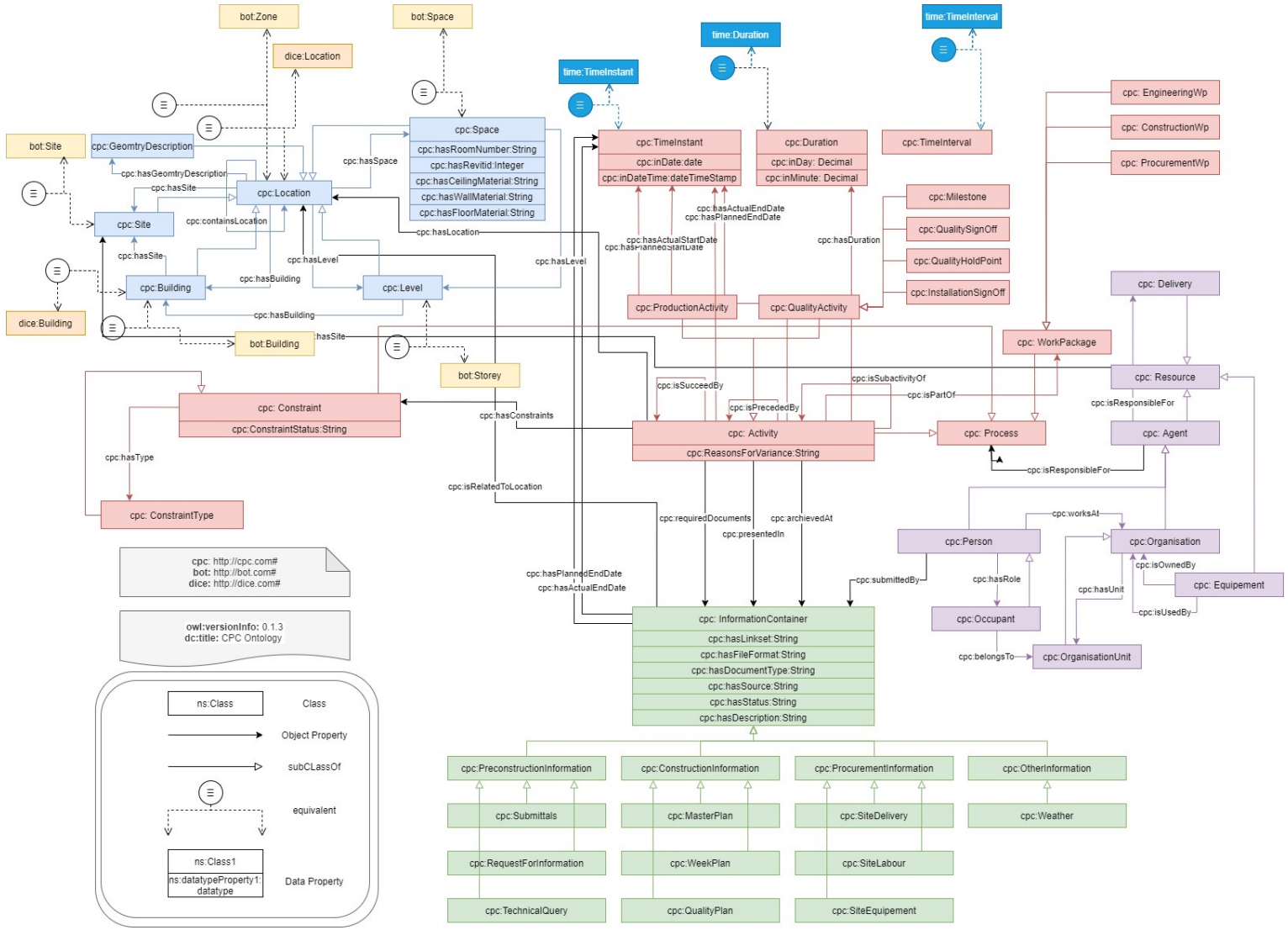

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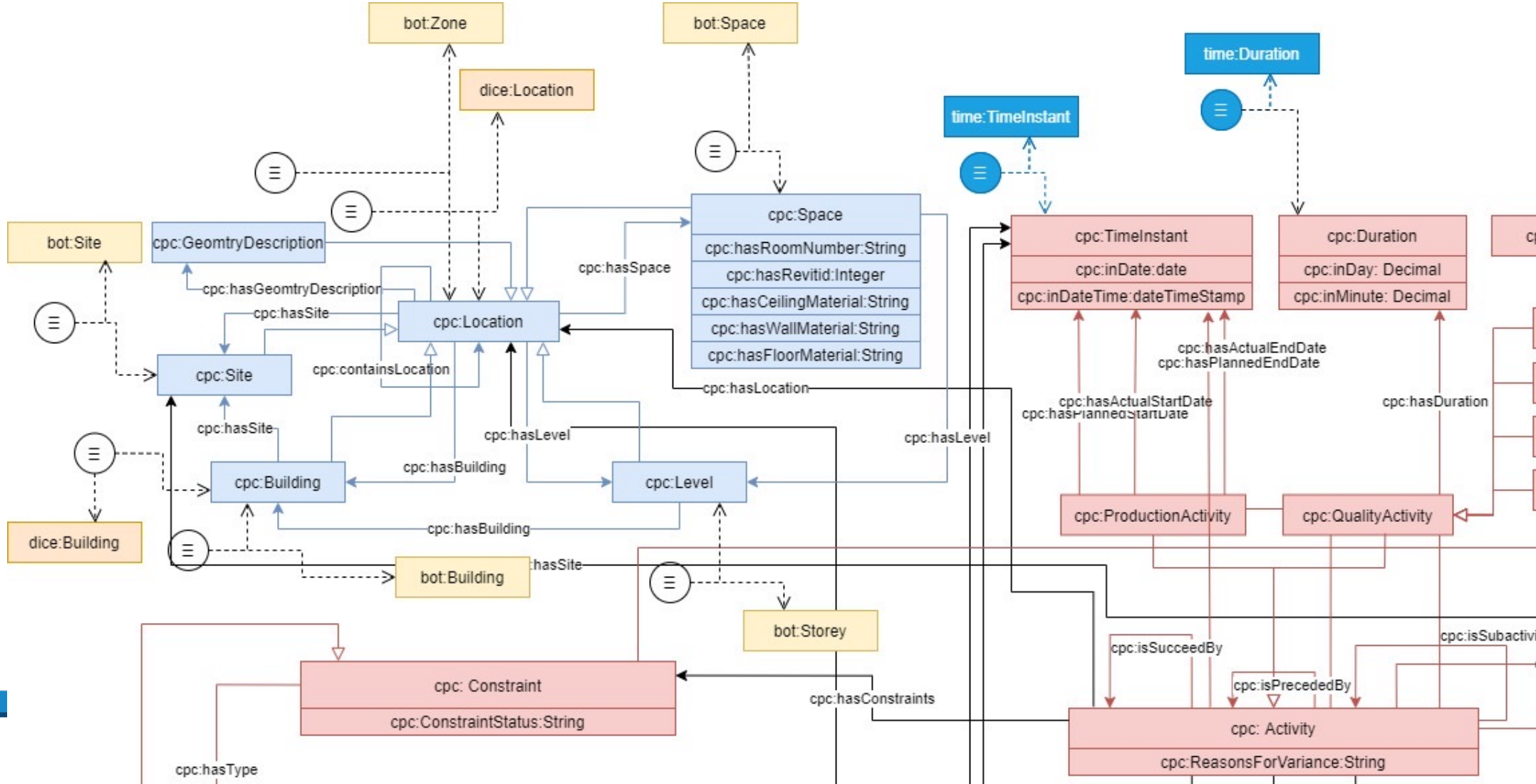

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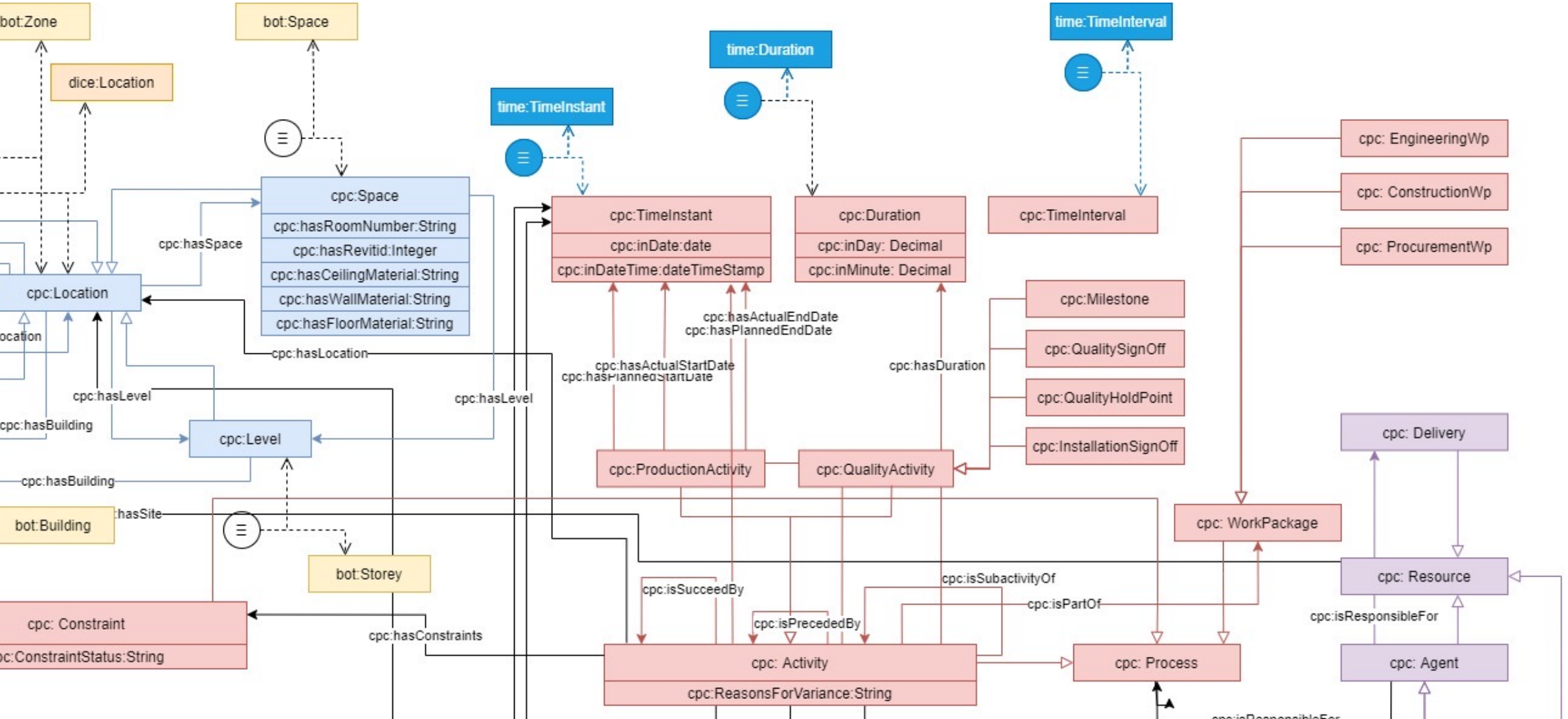

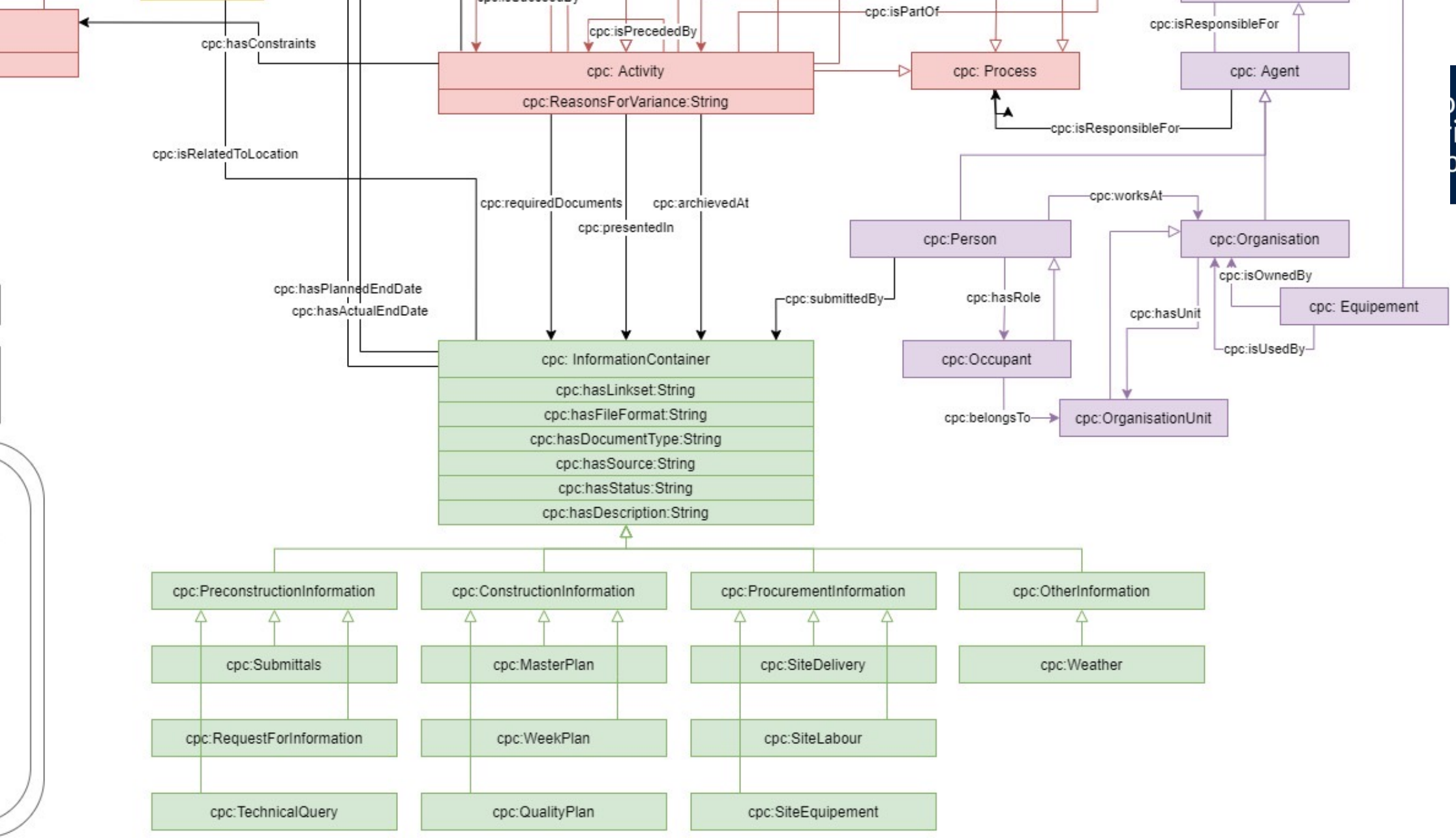
cpc:hasConstraints
cpc:isPrecededBy
cpc:isPartOf
cpc:isResponsibleFor
cpc: Activity
cpc:ReasonsForVariance:String
cpc: Process
cpc: Agent
cpc:isResponsibleFor
cpc:isRelatedToLocation
cpc:requiredDocuments
cpc:archievedAt
cpc:presentedIn
cpc:worksAt
cpc:Person
cpc:Organisation
cpc:isOwnedBy
cpc: Equipement
cpc:hasPlannedEndDate
cpc:hasActualEndDate
cpc:submittedBy
cpc:hasRole
cpc:hasUnit
cpc:isUsedBy
cpc: InformationContainer
cpc:hasLinkset:String
cpc:hasFileFormat:String
cpc:hasDocumentType:String
cpc:hasSource:String
cpc:hasStatus:String
cpc:hasDescription:String
cpc:Occupant
cpc:belongsTo
cpc:OrganisationUnit
cpc:PreconstructionInformation
cpc:ConstructionInformation
cpc:ProcurementInformation
cpc:OtherInformation
cpc:Submittals
cpc:MasterPlan
cpc:SiteDelivery
cpc:Weather
cpc:RequestForInformation
cpc:WeekPlan
cpc:SiteLabour
cpc:TechnicalQuery
cpc:QualityPlan
cpc:SiteEquipement

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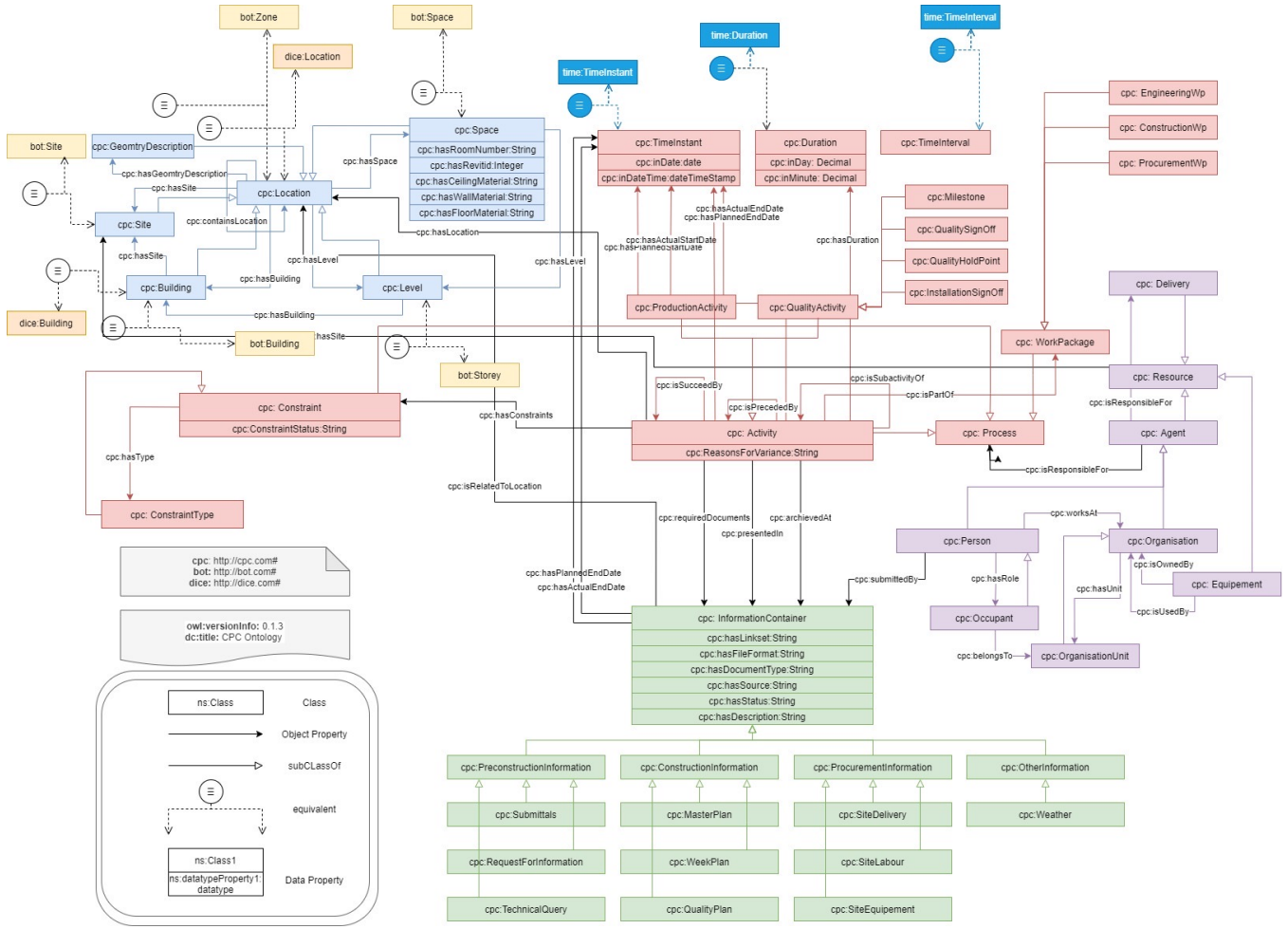

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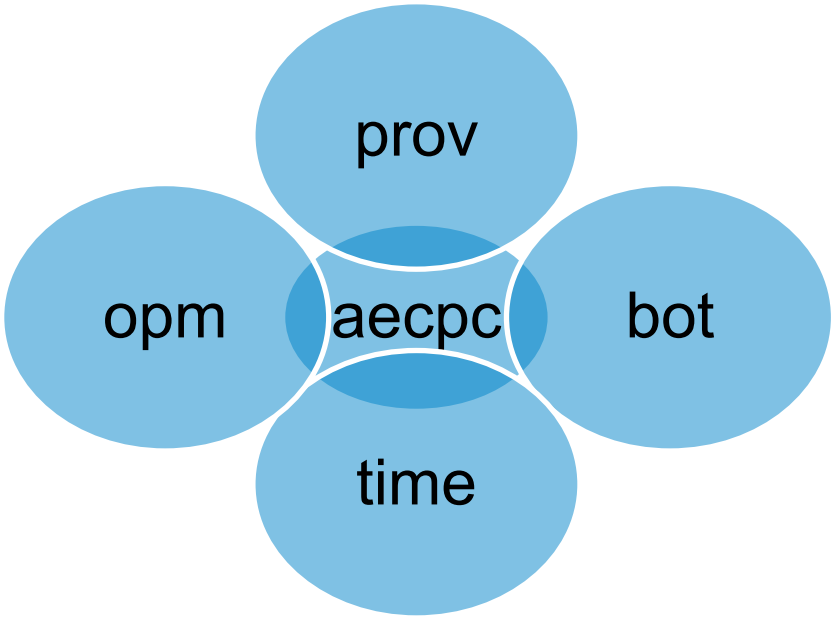
AEC PCR Ontology

aecpcr	http://www.semanticweb.org/ranjithsoman/ontologies/2021/9/AECPCR#
bot	https://w3id.org/bot#
owl	http://www.w3.org/2002/07/owl#
prov	http://www.w3.org/ns/prov#Agent
rdf	http://www.w3.org/1999/02/22-rdf-syntax-ns#
rdfs	http://www.w3.org/2000/01/rdf-schema#
time	http://www.w3.org/2006/time#
xml	http://www.w3.org/XML/1998/namespace
xsd	http://www.w3.org/2001/XMLSchema#
opm	http://www.w3id.org/opm#



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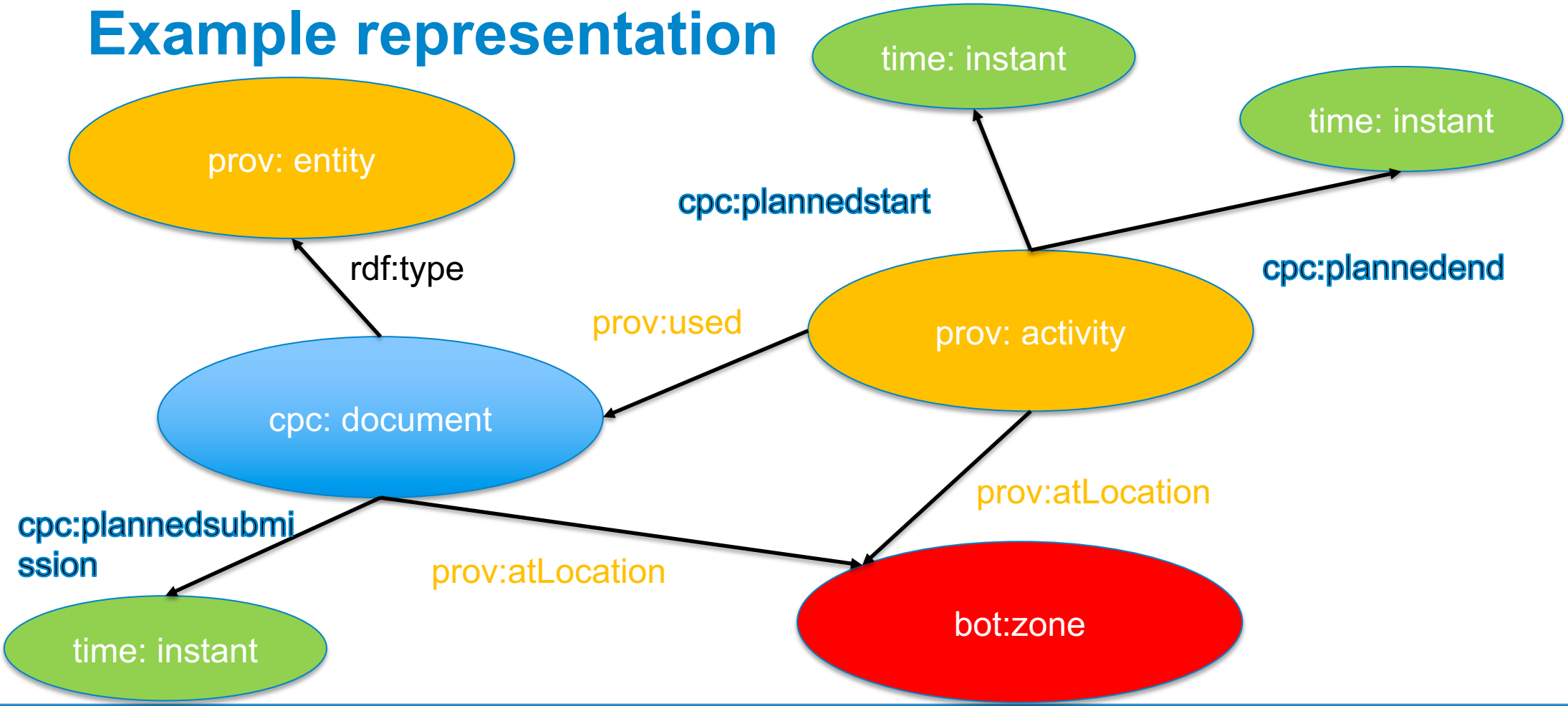
Example representation



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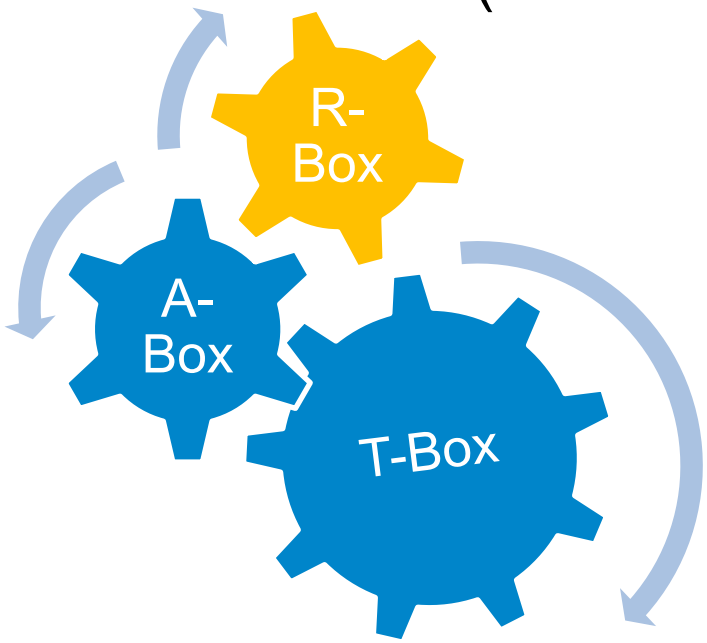
Shapes Constraint Language (SHACL)

- Data modelling language developed by the W3C working group to model constraints against which RDF data could be validated (Knublauchet al., 2017)
- 2 Inputs
  - Data graph
  - Shapes graph



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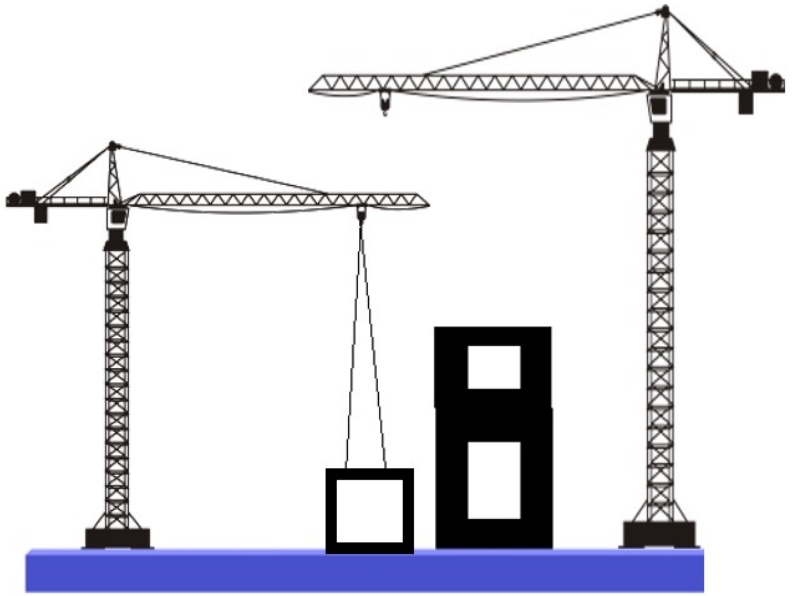
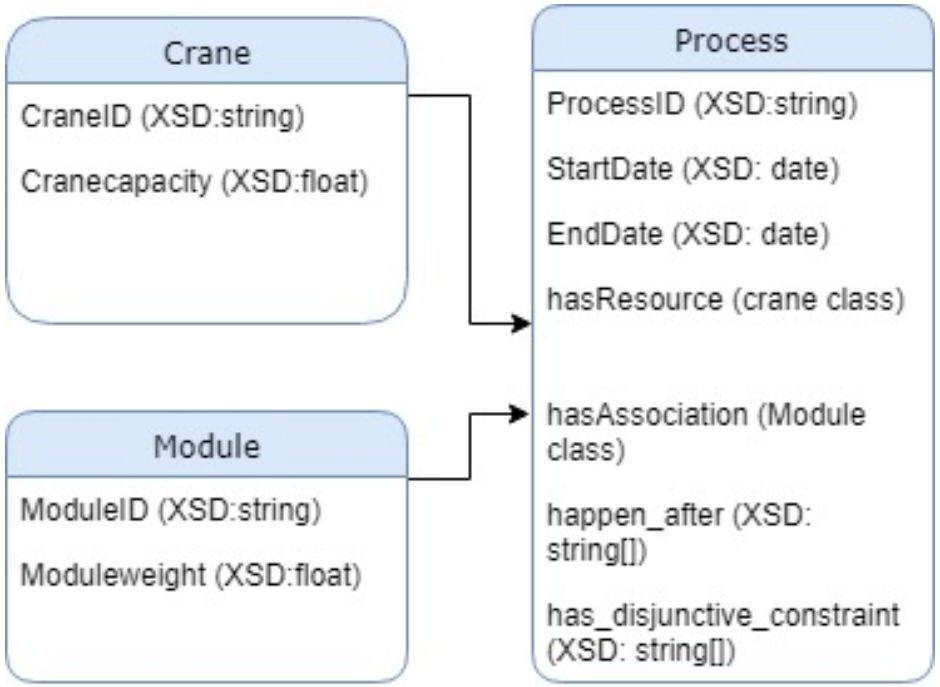
Simple implementation





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Modelling SHACL shapes

```
OntProcess:Process
  rdf:type rdfs:Class ;
  rdf:type sh:NodeShape ;
  rdfs:subClassOf owl:Class ;
  sh:sparql [
      sh:message "Crane capacity should be greater than module weight" ;
      sh:prefixes <http://semanticprocess.x10host.com/Ontology/OntProcess> ;
      sh:select """SELECT $this
WHERE {
      $this  rdf:type OntProcess:Process.
      $this OntProcess:hasResource ?crane.
      $this OntProcess:hasAssociation ?module.
      ?crane OntProcess:Cranecapacity ?cc.
      ?module OntProcess:Moduleweight ?mw.
          FILTER (?cc <= ?mw).
}""" ;
    ]
```

```
OntProcess:Process
  rdf:type rdfs:Class ;
  rdf:type sh:NodeShape ;
  rdfs:subClassOf owl:Class ;
sh:sparql [
      sh:message "Precedence condition is violated" ;
      sh:prefixes <http://semanticprocess.x10host.com/Ontology/OntProcess> ;
      sh:select """SELECT $this
WHERE {
$this  rdf:type OntProcess:Process.
$this owl:happen_after ?process2.
$this owl:hasStartDate ?sd1.
?process2 owl:hasEndDate ?ed2.
FILTER( ?sd1 <?ed2)
}
```

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Data input

Process	Crane	Crane capacity (metric ton)	Module	Module Weight (metric ton)	Start date	End date	Precedence Constraint	Disjunctive constraint
Process_1	Crane_1	12	Module_1	15	01/01/2019	02/01/2019		
Process_2	Crane_2	18	Module_2	15	02/01/2019	03/01/2019	Process 1	
Process_3	Crane_2	18	Module_3	15	01/01/2019	05/01/2019	Process 1	Process 1,Process 2

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Output from SHACL

Process 3	Constraint Violation in SPARQLConstraintComponent (http://www.w3.org/ns/shacl#SPARQLConstraintComponent): Severity: sh:Violation Source Shape: OntProcess:Process Focus Node: OntProcess:Process_3 Value Node: OntProcess:Process_3 Source Constraint: [sh:message Literal("Precedence condition is violated") ; sh:prefixes <http://semanticprocess.x10host.com/Ontology/OntProcess> ; sh:select Literal("SELECT $this WHERE { $this rdf:type OntProcess:Process. $this owl:happen_after ?process2. $this owl:hasEndDate ?ed1. $this owl:hasStartDate ?sd1. ?process2 owl:hasEndDate ?ed2. ?process2 owl:hasStartDate ?sd2. FILTER(?sd1 <?ed2) }")] **Message: Precedence condition is violated** Constraint Violation in SPARQLConstraintComponent (http://www.w3.org/ns/shacl#SPARQLConstraintComponent): Severity: sh:Violation Source Shape: OntProcess:Process Focus Node: OntProcess:Process_3 Value Node: OntProcess:Process_3 Source Constraint: [sh:message Literal("Disjunctive constraint is violated ") ; sh:prefixes <http://semanticprocess.x10host.com/Ontology/OntProcess> ; sh:select Literal("SELECT $this WHERE { $this rdf:type OntProcess:Process. $this owl:has_disjunctive_constraint ?process2. $this owl:hasEndDate ?ed1. $this owl:hasStartDate ?sd1. ?process2 owl:hasEndDate ?ed2. ?process2 owl:hasStartDate ?sd2. FILTER((?sd2<?ed1&&?sd1<?ed2)||(?sd1=?sd2 && ?ed1=?ed2)) }")] **Message: Disjunctive constraint is violated**

Crane 1	No violation
Crane 2	Constraint Violation in SPARQLConstraintComponent (http://www.w3.org/ns/shacl#SPARQLConstraintComponent): Severity: sh:Violation Source Shape: OntProcess:Crane Focus Node: OntProcess:Crane_2 Value Node: OntProcess:Crane_2 Source Constraint: [sh:message Literal("Discrete constrsint for the resource not satisfied") ; sh:prefixes <http://semanticprocess.x10host.com/Ontology/OntProcess> ; sh:select Literal("SELECT $this WHERE { $this rdf:type OntProcess:Crane . ?process1 rdf:type OntProcess:Process. ?process2 rdf:type OntProcess:Process. ?process1 OntProcess:hasResource $this. ?process2 OntProcess:hasResource $this. ?process1 owl:hasEndDate ?ed1. ?process1 owl:hasStartDate ?sd1. ?process2 owl:hasEndDate ?ed2. ?process2 owl:hasStartDate ?sd2. FILTER (!(?process1=?process2)) FILTER((?sd2<?ed1&&?sd1<?ed2)||(?sd1=?sd2 && ?ed1=?ed2)) }")] **Message: Discrete constraint for the resource not satisfied**

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Output

Instances	Output
Process 1	Constraint violation
Process 2	No Violation
Process 3	Constraint Violation
Crane 1	No violation
Crane 2	Constraint Violation

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Advantages of SHACL to model constraints

- Modular
- Acts as unit testing environment
- Can be reused across projects
- Towards parametric planning

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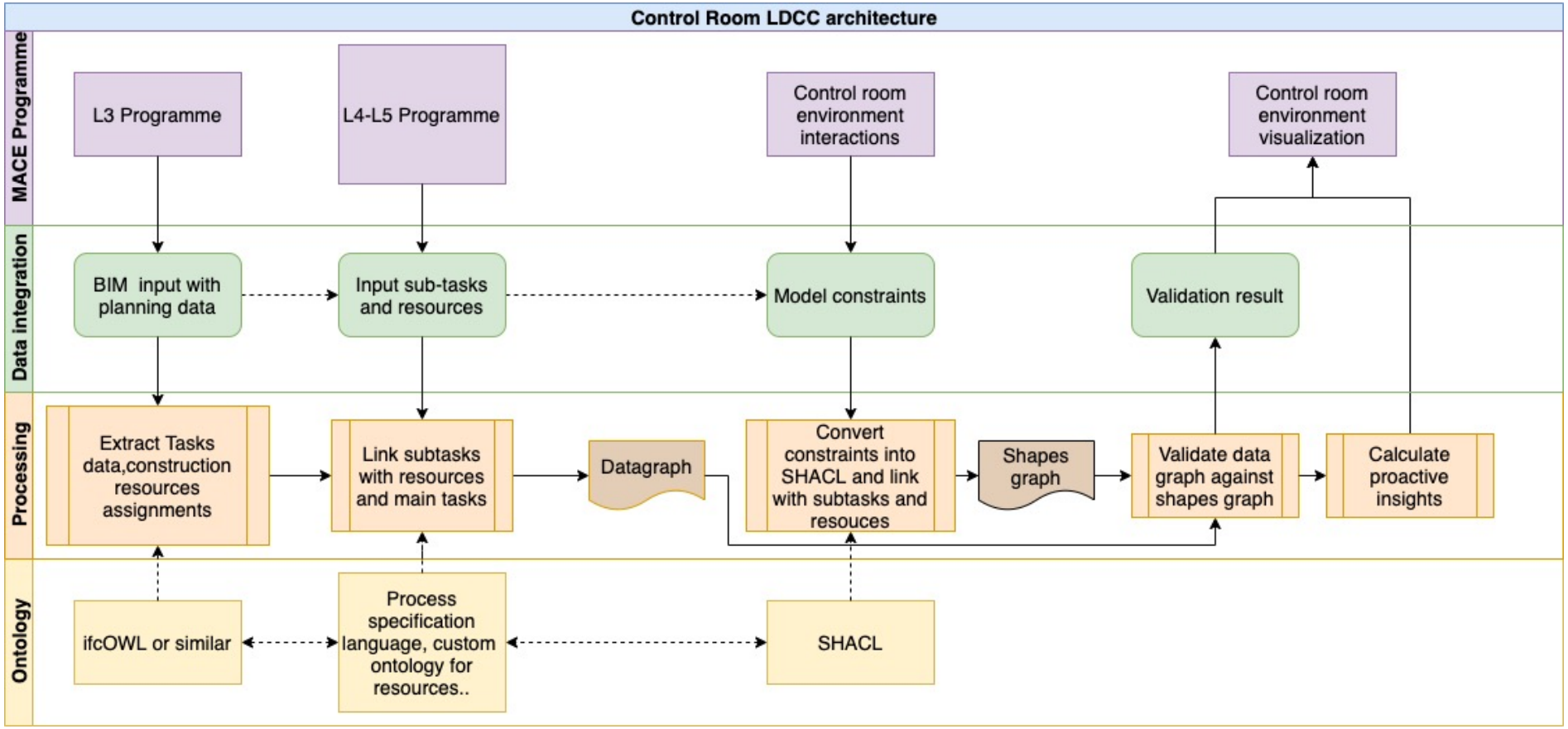

https://www.sciencedirect.com/science/article/pii/S0926580520309493

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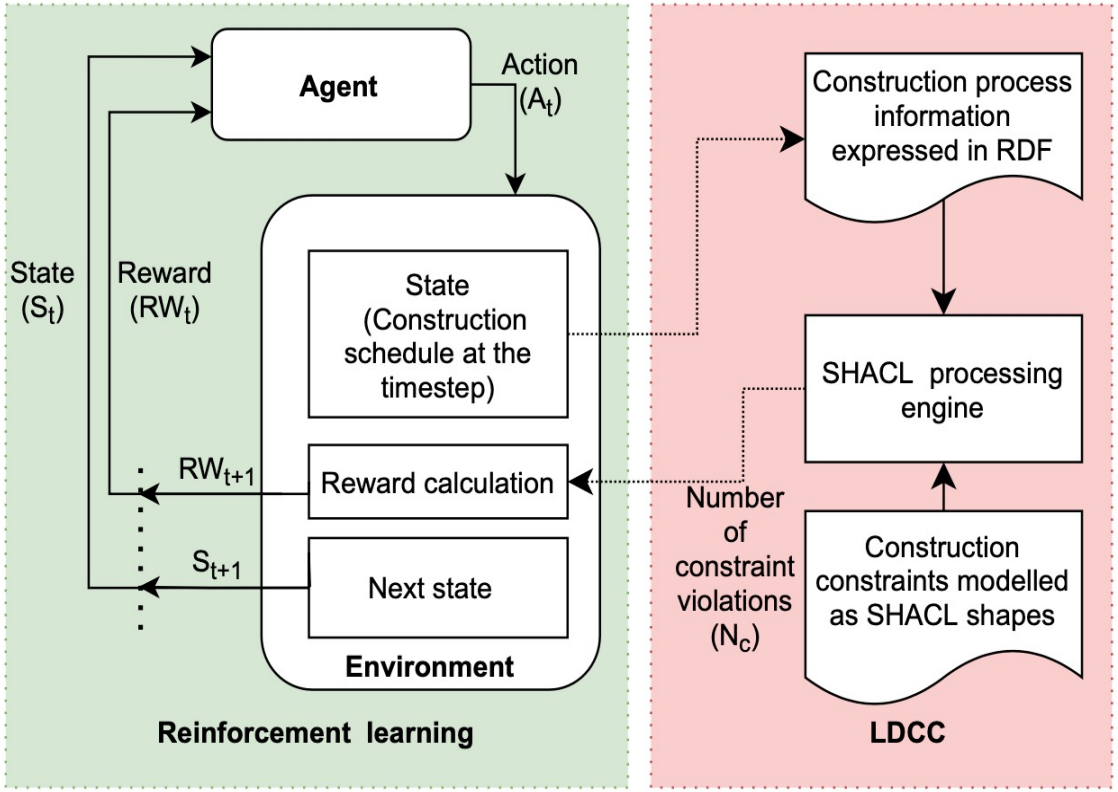
Look ahead schedule generation



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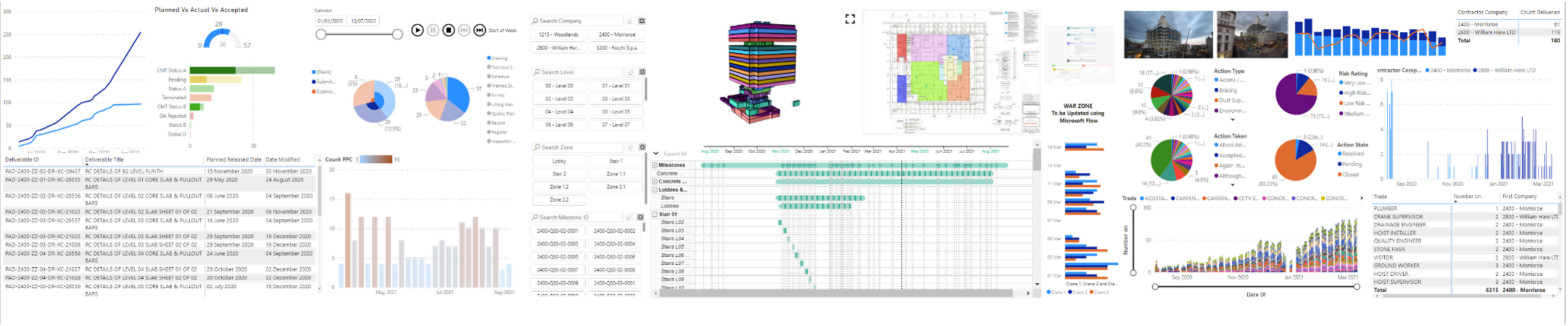

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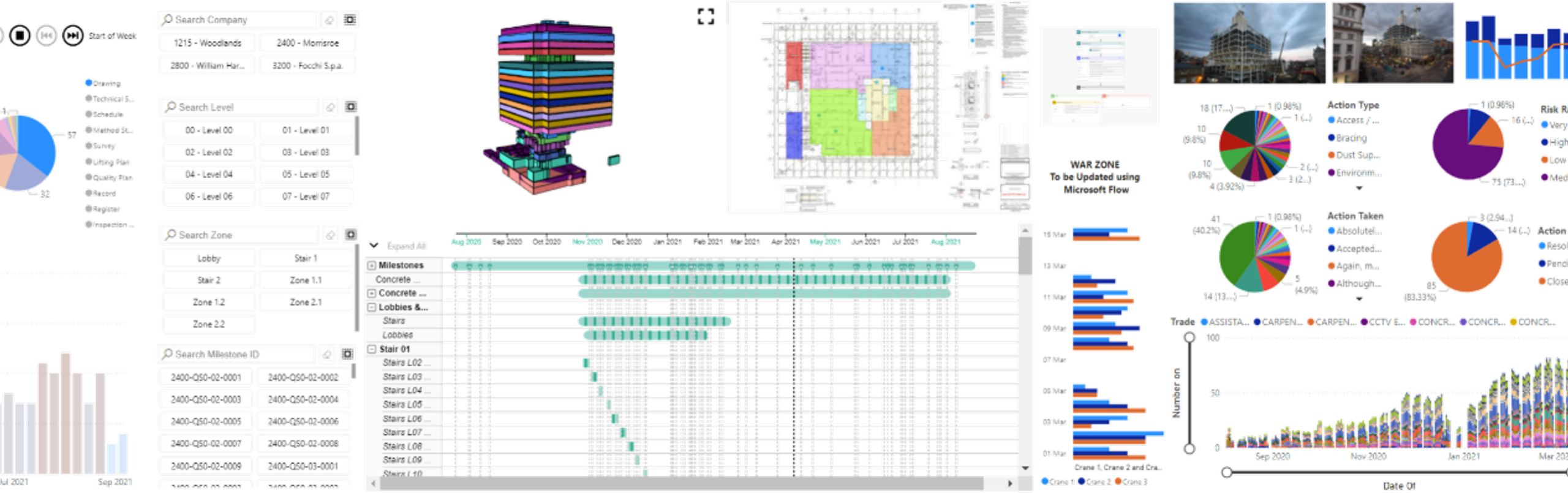

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Deliverable ID	Deliverable Title	Planned Released Date	Date Modified
PAD-2400-ZZ-B2-DR-XC-20437	RC DETAILS OF B2 LEVEL PLINTH	15 November 2020	30 November 2020
PAD-2400-ZZ-01-DR-XC-20555	RC DETAILS OF LEVEL 01 CORE SLAB & PULLOUT BARS	29 May 2020	24 August 2020
PAD-2400-ZZ-02-DR-XC-20556	RC DETAILS OF LEVEL 02 CORE SLAB & PULLOUT BARS	08 June 2020	04 September 2020
PAD-2400-ZZ-02-DR-XC-21023	RC DETAILS OF LEVEL 02 SLAB SHEET 01 OF 02	21 September 2020	06 November 2020
PAD-2400-ZZ-03-DR-XC-20557	RC DETAILS OF LEVEL 03 CORE SLAB & PULLOUT BARS	16 June 2020	04 September 2020
PAD-2400-ZZ-03-DR-XC-21025	RC DETAILS OF LEVEL 03 SLAB SHEET 01 OF 02	29 September 2020	16 December 2020
PAD-2400-ZZ-03-DR-XC-21026	RC DETAILS OF LEVEL 03 SLAB SHEET 02 OF 02	29 September 2020	16 December 2020
PAD-2400-ZZ-04-DR-XC-20558	RC DETAILS OF LEVEL 04 CORE SLAB & PULLOUT BARS	24 June 2020	04 September 2020
PAD-2400-ZZ-04-DR-XC-21027	RC DETAILS OF LEVEL 04 SLAB SHEET 01 OF 02	20 October 2020	02 December 2020
PAD-2400-ZZ-04-DR-XC-21028	RC DETAILS OF LEVEL 04 SLAB SHEET 02 OF 02	20 October 2020	02 December 2020
PAD-2400-ZZ-05-DR-XC-20559	RC DETAILS OF LEVEL 05 CORE SLAB & PULLOUT BARS	02 July 2020	16 December 2020

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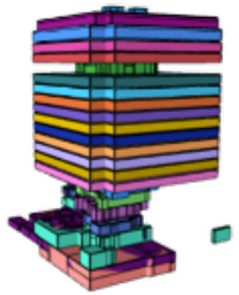
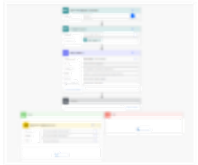
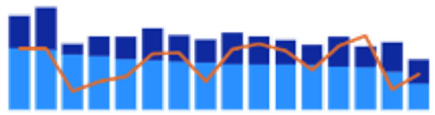
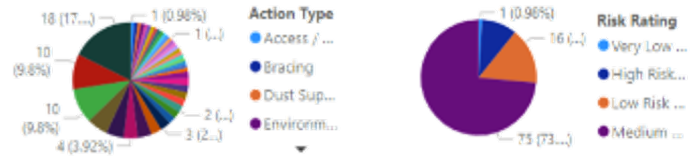


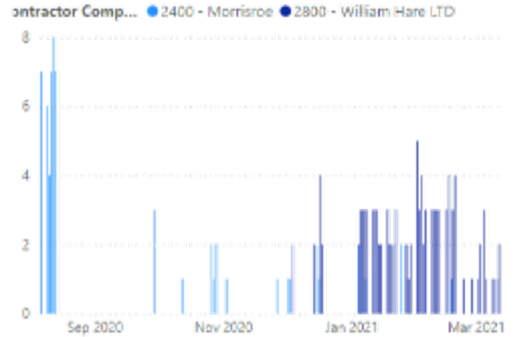


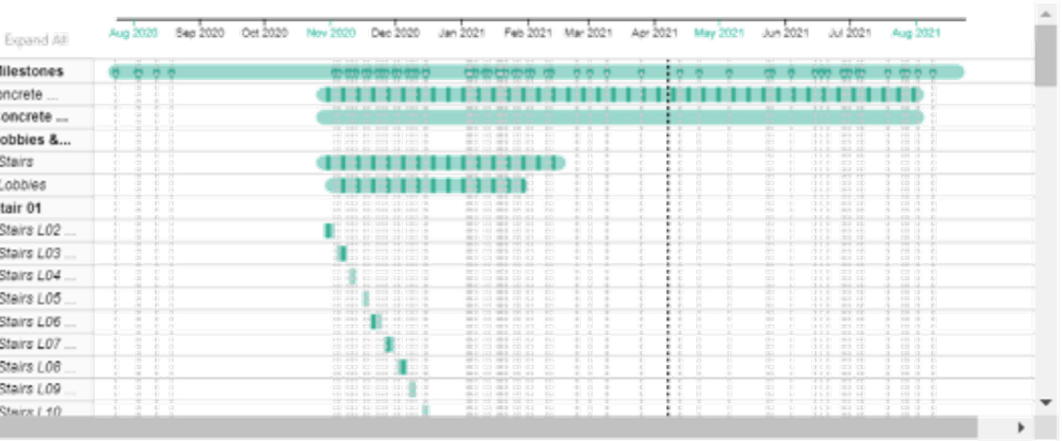
WAR ZONE
To be Updated using Microsoft Flow

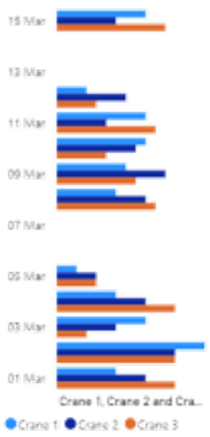


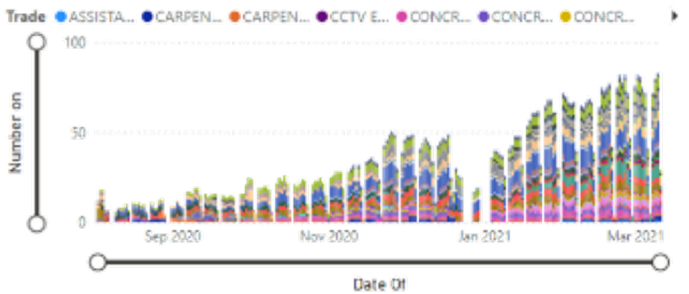
Contractor Company	Count Deliveries
2400 - Morrisroe	61
2800 - William Hare LTD	119
Total	180











Trade	Number on	First Company
PLUMBER	1	2400 - Morrisroe
CRANE SUPERVISOR	2	2800 - William Hare LTD
DRAINAGE ENGINEER	2	2400 - Morrisroe
HOIST INSTALLER	2	2400 - Morrisroe
QUALITY ENGINEER	2	2400 - Morrisroe
STONE FIXER	2	2400 - Morrisroe
VISITOR	2	2800 - William Hare LTD
GROUND WORKER	3	2400 - Morrisroe
HOIST DRIVER	3	2400 - Morrisroe
HOIST SUPERVISOR	3	2400 - Morrisroe
Total	6315	2400 - Morrisroe

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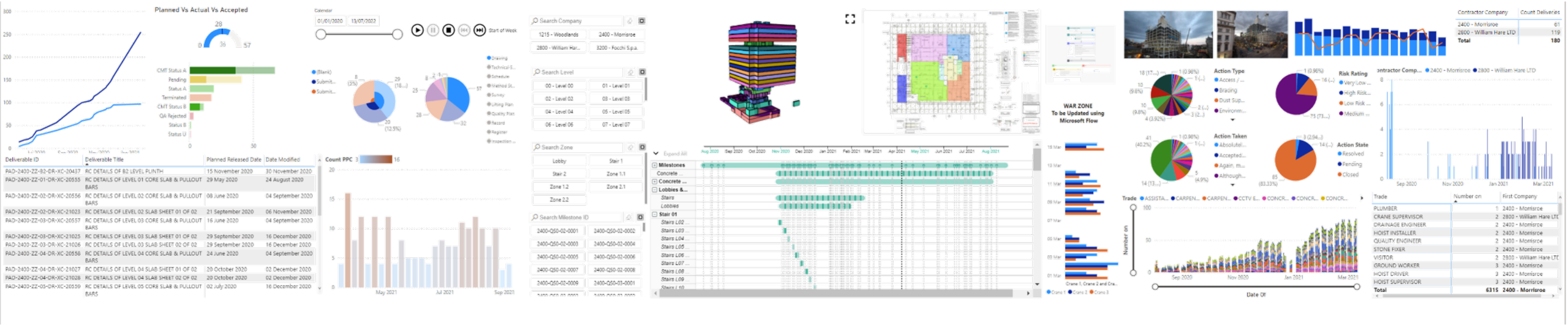

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Proactive insights

Predict task confidence levels

Identify workspace conflicts

Generate look-ahead schedule

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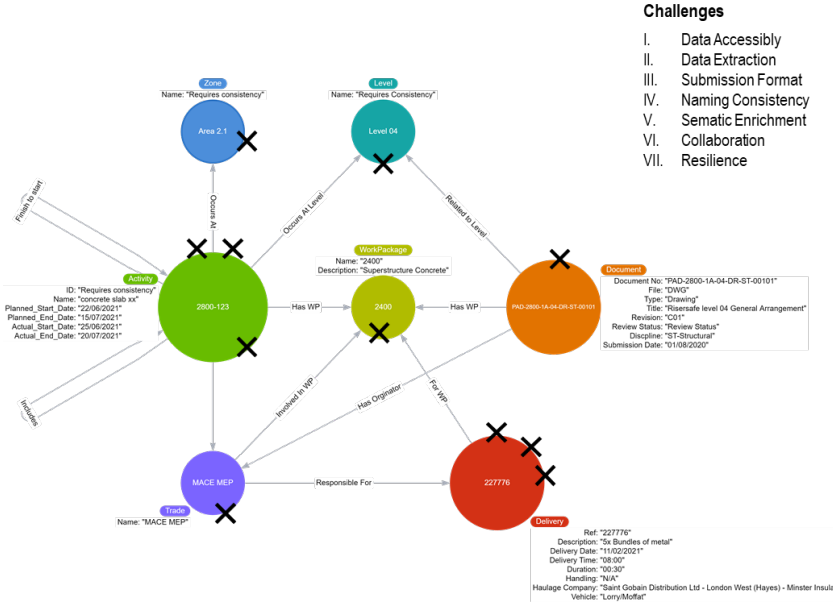
Case Study



Challenges

I. Data Accessibly
II. Data Extraction
III. Submission Format
IV. Naming Consistency
V. Sematic Enrichment
VI. Collaboration
VII. Resilience

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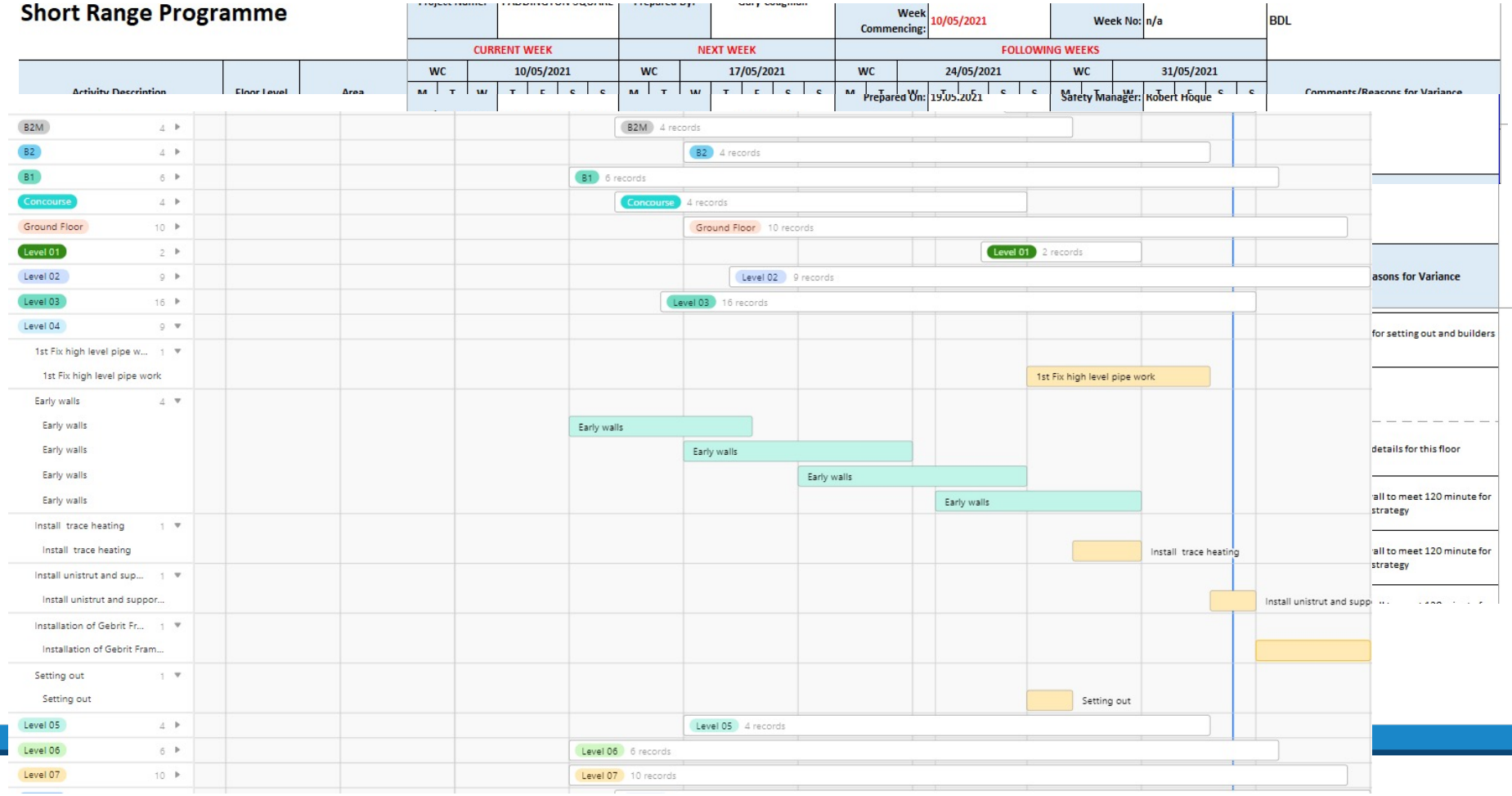
Case Study



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Conclusion

- Construction monitoring and control will not be achieved unless alleviating
  - unclear end-users requirements,
  - insufficient visibility and traceability of real-time information,
  - poor interoperability among different systems and heterogenous stakeholder,
  - ineffective environment for collaboration between humans and data.
- Production control room is seen as the space where real-time data can be integrated with digital models and visualised for supporting decision making in real-time.
- This research contributes in this area by developing a production control room process/framework to develop an effective scalable and reproduceable control room for construction projects. The framework is implemented and evaluated in a real-world case study.

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Key publications

- Farghaly, K., Soman, R., & Whyte, J. (2021). Visualizing real-time information through a construction production control room, 2021 European Conference on Computing in Construction, Rhodes, Greece
- Soman, R. K., Molina-Solana, M., & Whyte, J. K. (2020). Linked-Data based Constraint-Checking (LDCC) to support look-ahead planning in construction. *Automation in Construction*, *120*, 103369.
- K Soman, R. (2019). Modelling construction scheduling constraints using shapes constraint language (SHACL), 2019 European Conference on Computing in Construction, Chania , Greece.