

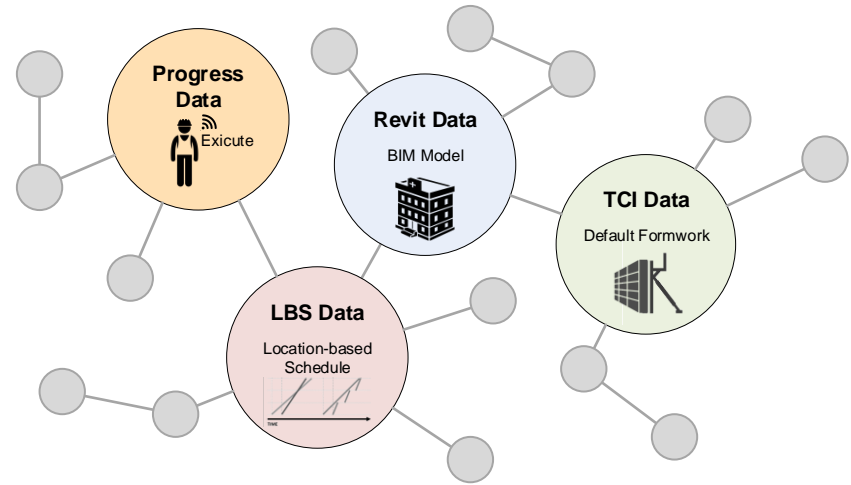


Lean and integrated management process of temporary construction items (TCIs)

Alex Schlachter
MSc. Architectural Engineering, DTU

Agenda

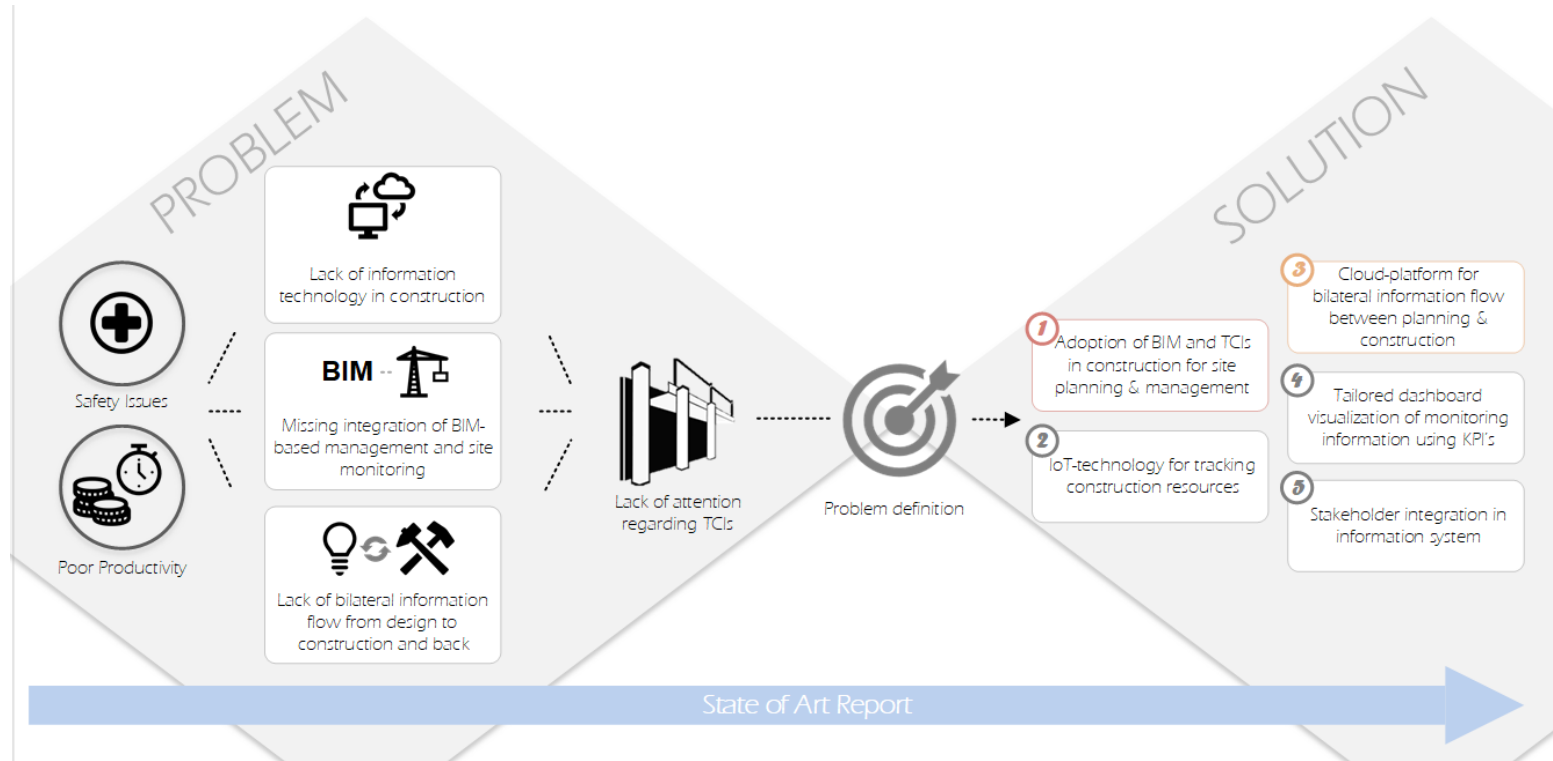
- I. Problem & Solution Space
- II. Propose specific Solution
- III. Linked Data Introduction
- IV. Linked Building Data Example
- V. Demo Project
 - Data Sources & Extraction
 - Data Management
 - Data Processing & Querying
 - Data Visualization & Distribution
- VI. Further Development/ Improvements





I. Problem & Solution Space

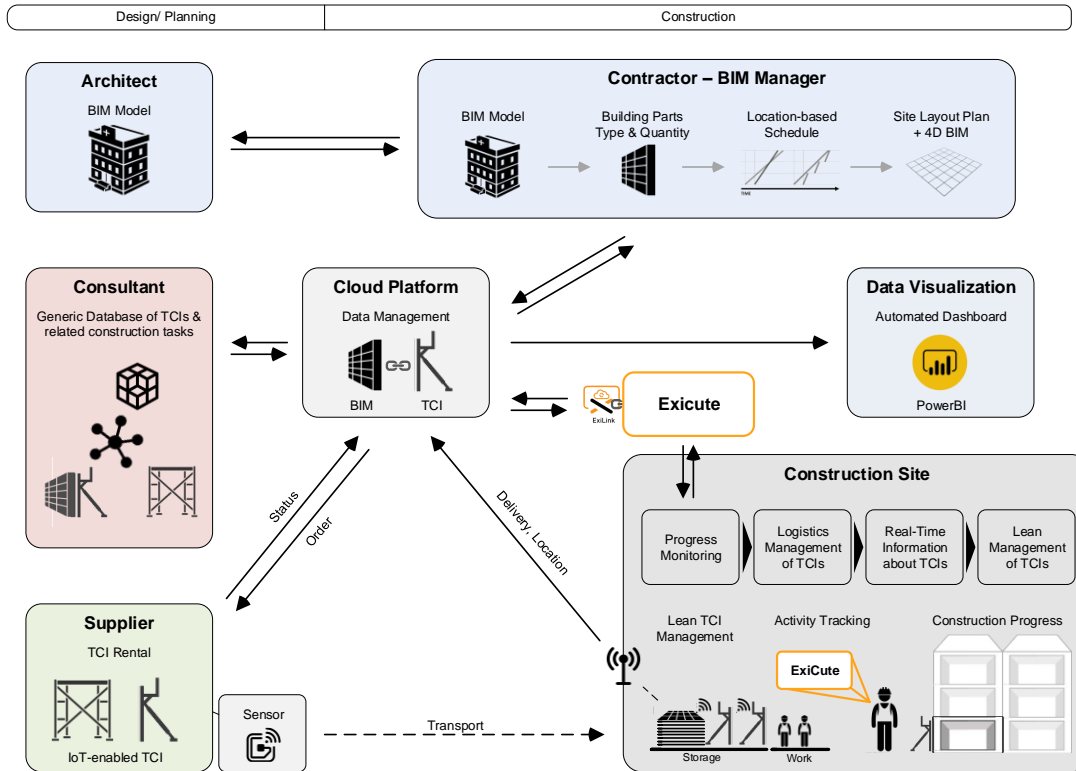
State of Art - Problem & Solution Space





II. Propose specific Solution

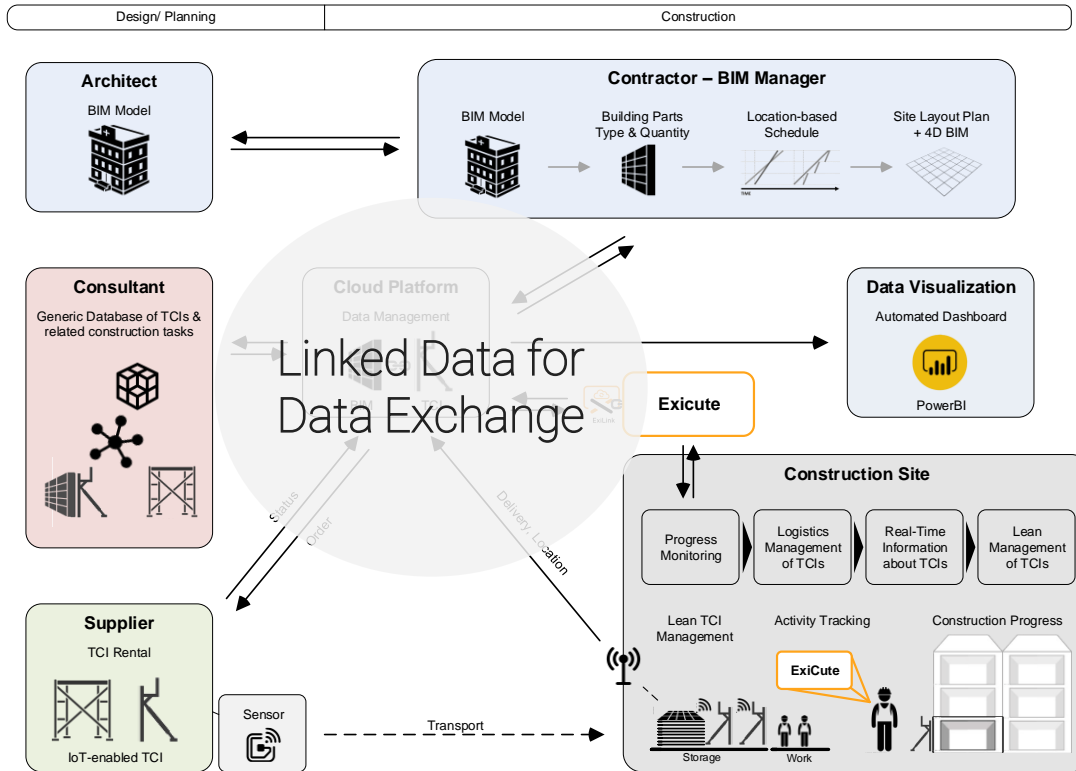
Proposed Solution



Benefits

- Automatic planning of TCIs
- Goal to generate a TCI utilization plan
- Direct link of TCIs to permanent building elements supporting their construction
- Passive scheduling and monitoring of TCIs
- No additional planning effort
- Lean management of TCIs possible due to precise and updated data about TCI-utilization
- Possible extension with supplier software, product catalogues and IoT-tracking

Proposed Solution



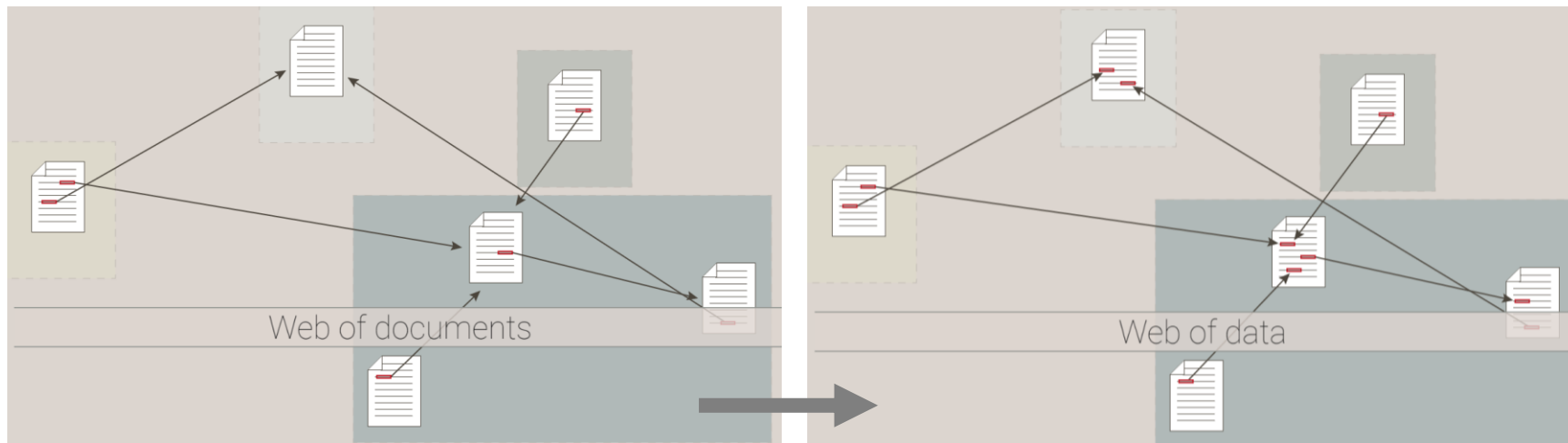
Benefits

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III. Linked Data Introduction

Linked Data



Linked Data principles

1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names
3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)
4. Include links to other URIs. so that they can discover more things

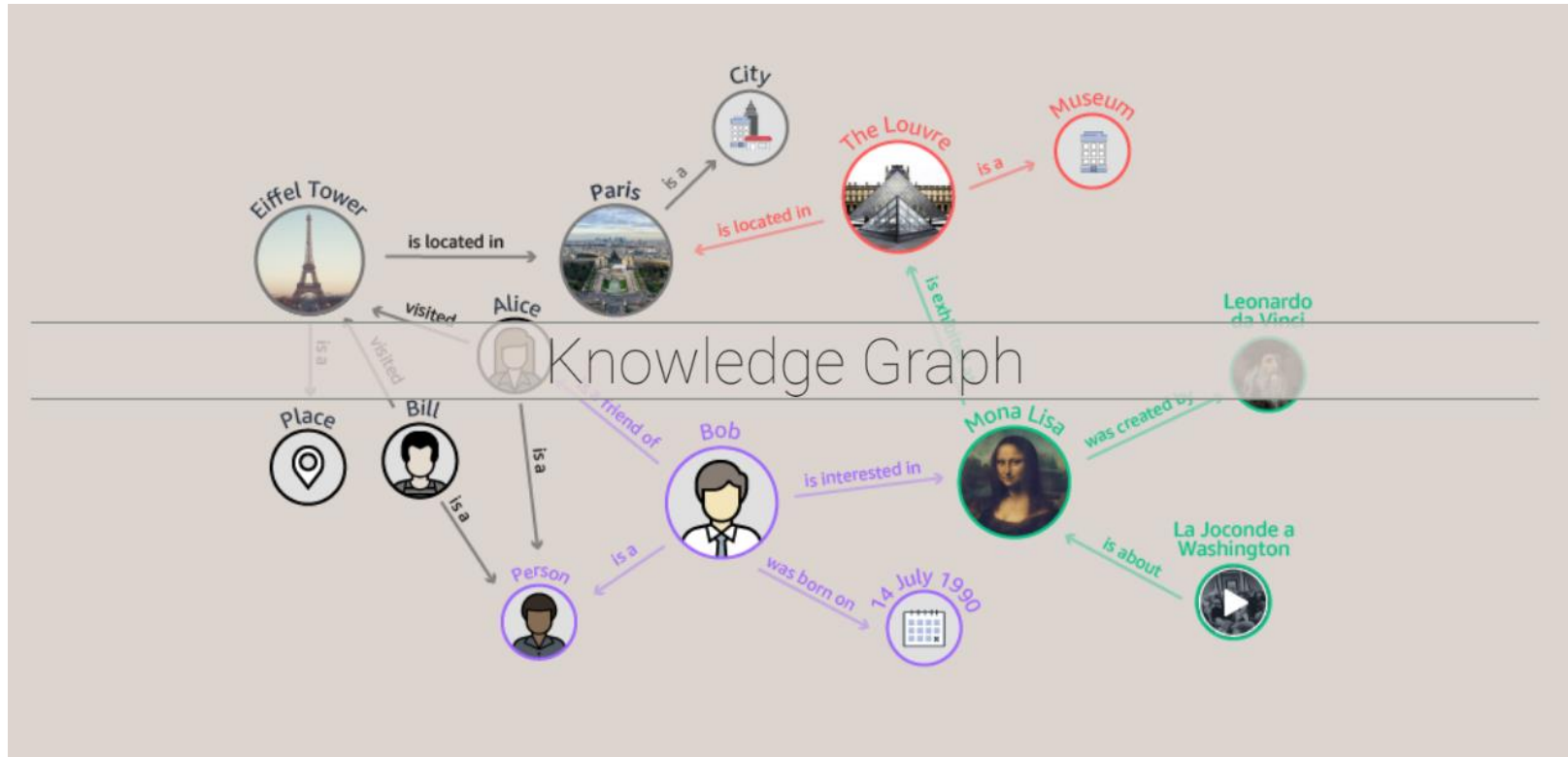
Linked Data



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Linked Data



Linked Data

RDF (Resource
Description Framework)

Query Data Graphs with
SPARQL Queries
(Similar to SQL Queries)

```
@prefix inst: <https://my-awesome-knowledge-graph.org/resources/> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix schema: <http://schema.org/> .
```

```
inst:Eiffel_Tower    rdf:type    schema:Place .
inst:Paris           rdf:type    schema:City .
inst:Bill            rdf:type    schema:Person .
inst:Alice           rdf:type    schema:Person .
inst:Bob             rdf:type    schema:Person .
inst:The_Louvre     rdf:type    schema:Museum .
```

Assign Subjects
to Classes

```
@prefix inst: <https://my-awesome-knowledge-graph.org/resources/> .
@prefix xx: <https://my-awesome-knowledge-graph.org/ontology/xx#> .
```

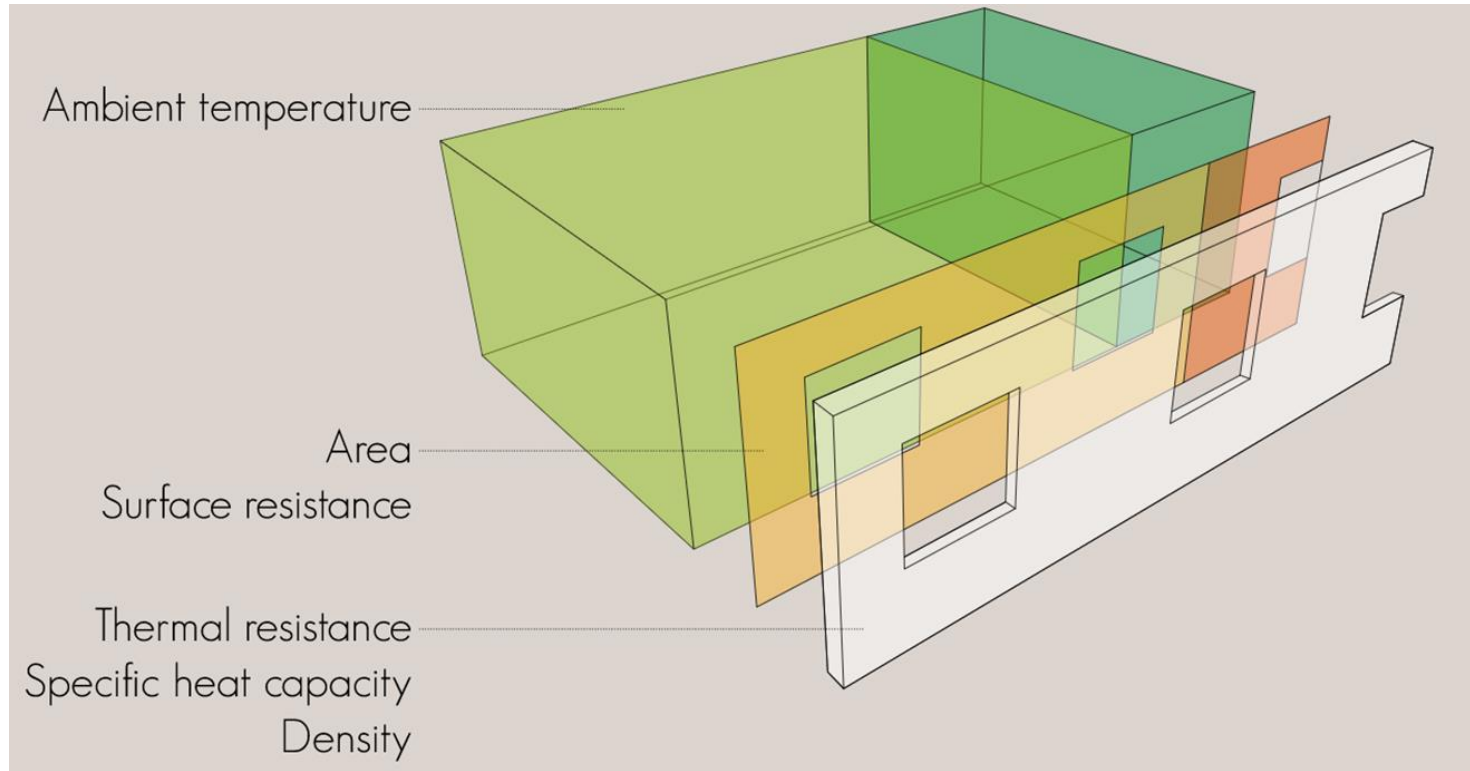
```
# RELATIONSHIPS
inst:Eiffel_Tower    xx:is_located_in    inst:Paris .
inst:Alice           xx:visited           inst:Eiffel_Tower .
inst:Bill            xx:visited           inst:Eiffel_Tower .
inst:Bob             xx:is_a_friend_of    inst:Alice .
inst:Bob             xx:is_interested_in  inst:Person .
inst:Bob             xx:was_born_on       "14 July 1990" .
inst:Mona_Lisa       xx:is_exhibited_at   ints:The_Louvre .
ints:Mona_Lisa       xx:was_created_by    ints:Leonardo_da_Vinci .
ints:La_Joconde_a_Washington xx:is_about    ints:Mona_Lisa .
```

Define relations
between Subjects

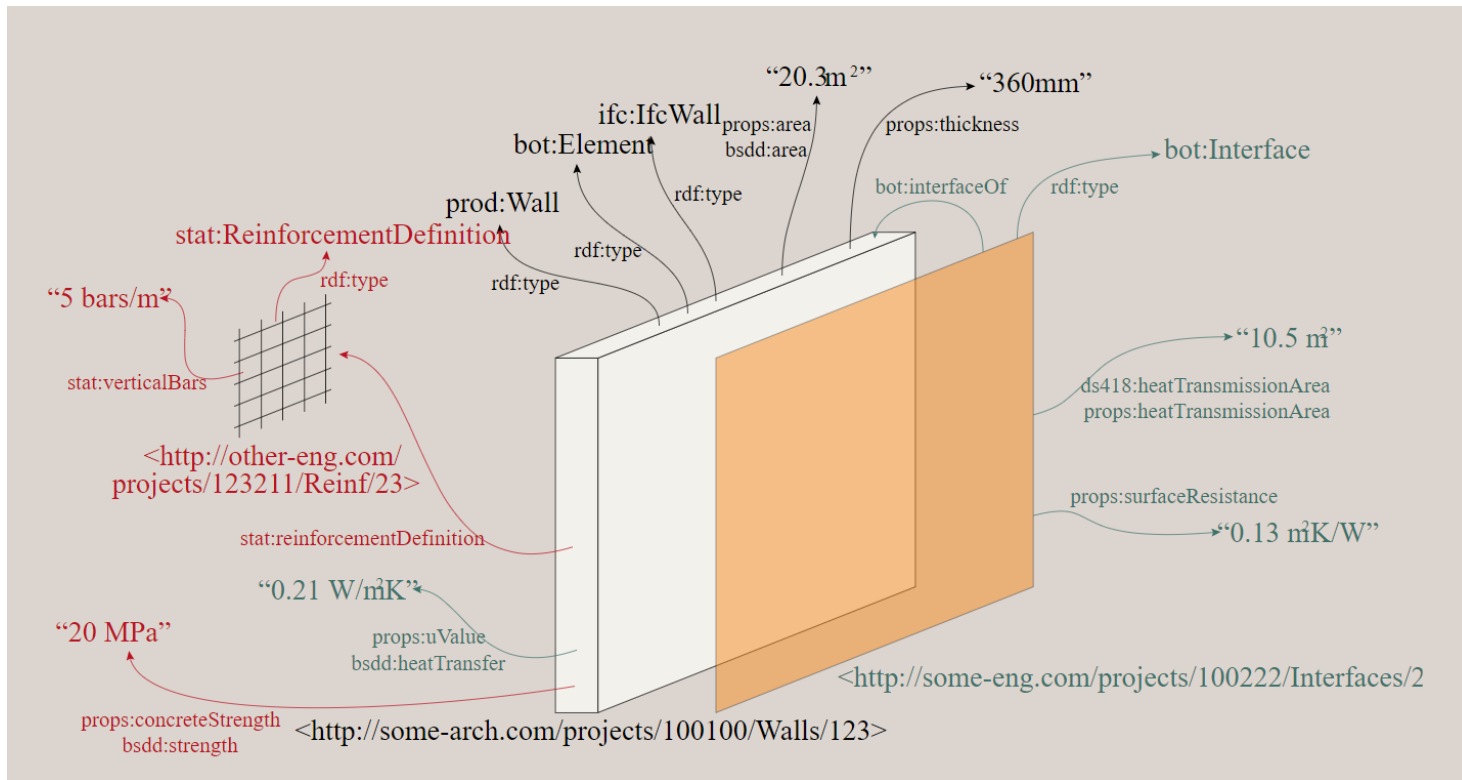


IV. Linked Building Data

Linked Building Data (LBD) - Example



Linked Building Data (LBD) - Example



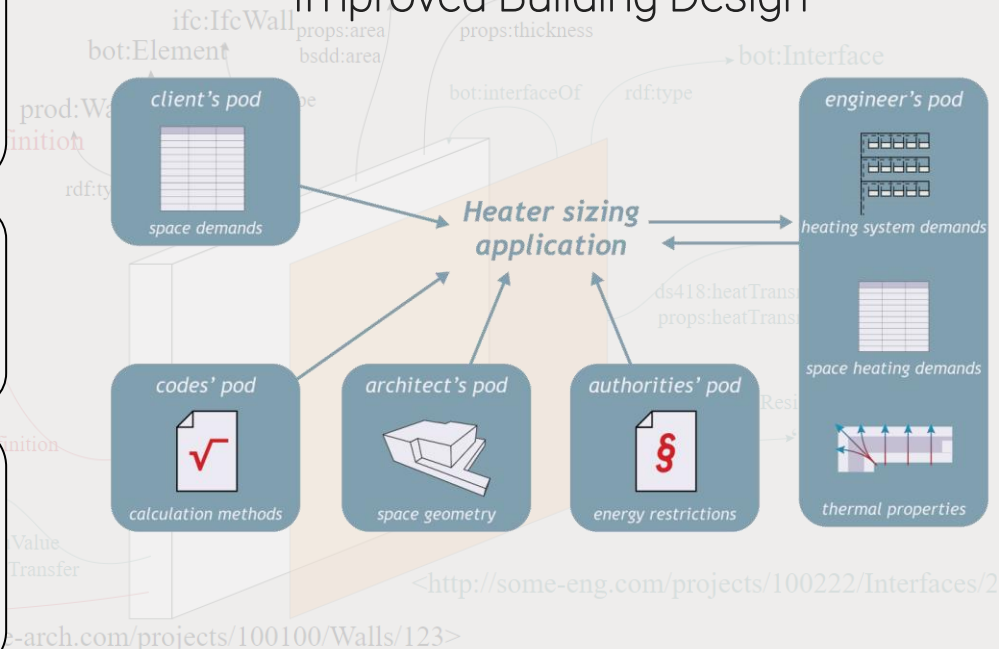
Linked Building Data (LBD) - Example

Data is stored and hosted by the stakeholder who generated it and is responsible for it

Data can be shared with authenticated people or be made publicly available

The model data can be extended with Linked Open Data (products, material properties, IoT, GIS)

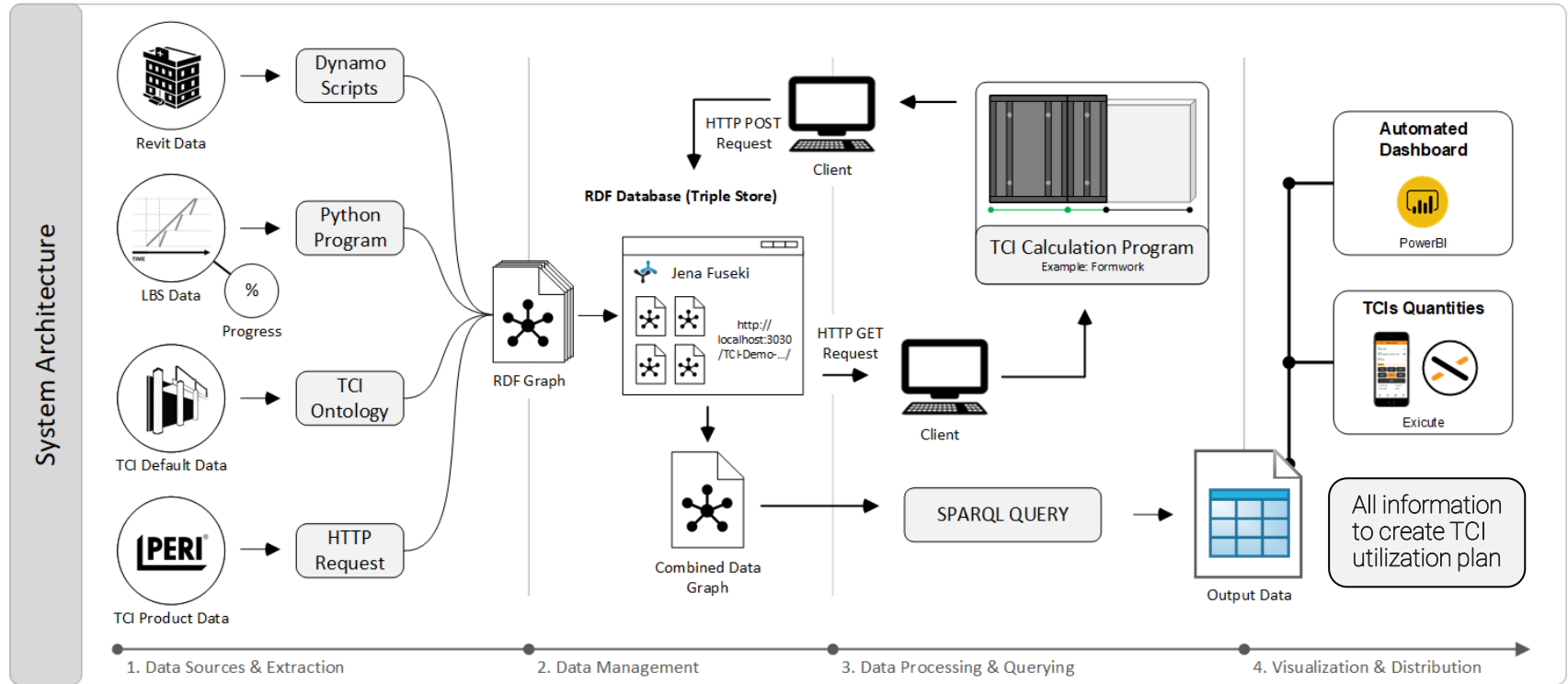
Improved Building Design





V. Demo Project

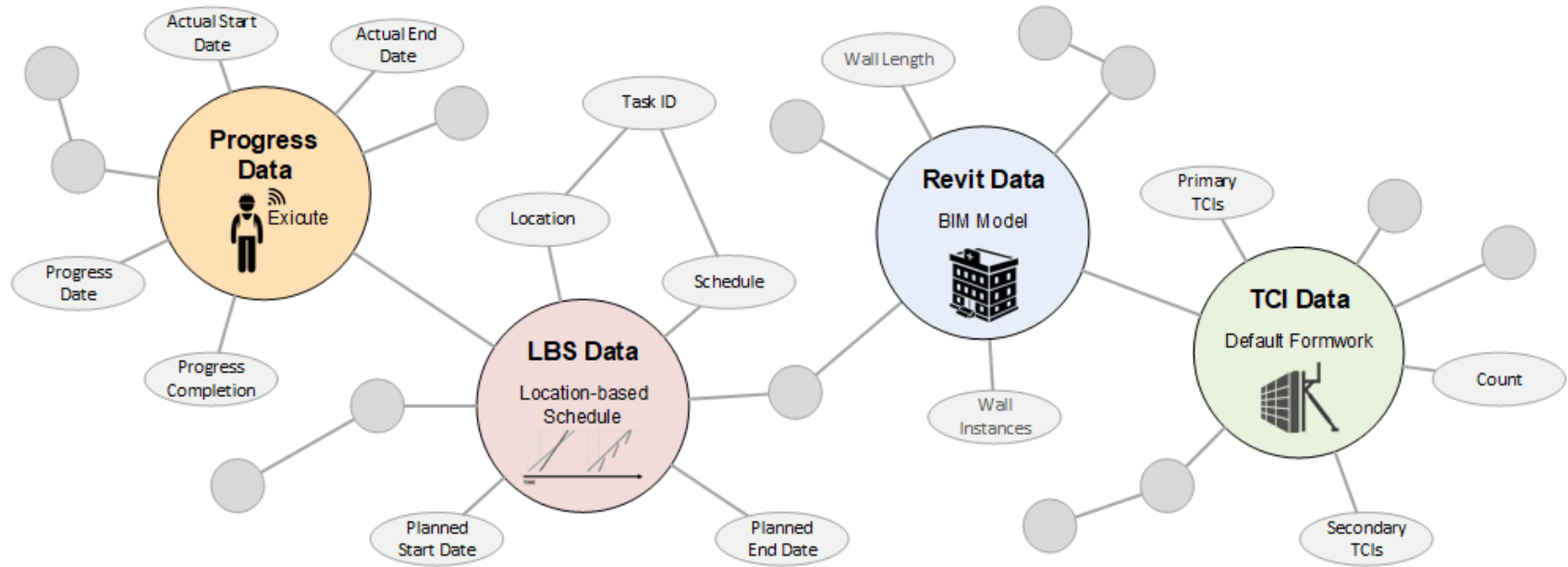
System Architecture



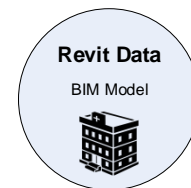
Data Sources

Formwork Example

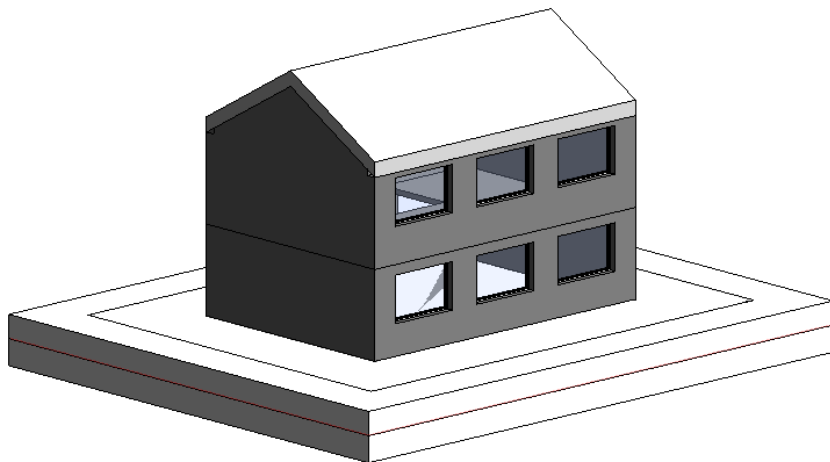
... Important parameter for TCI utilization



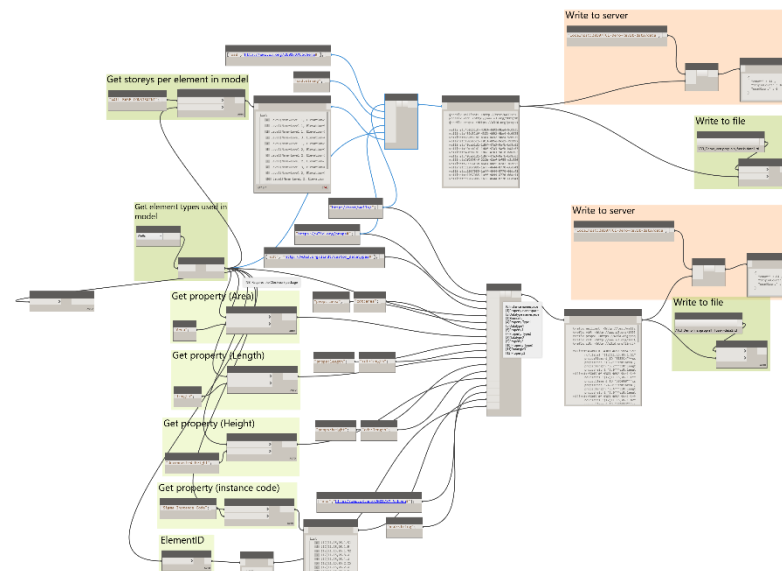
Building Model - Revit



Data Generation in Revit



Data Extraction in Dynamo



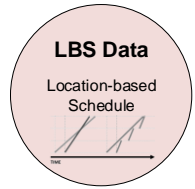
Building Model - Revit

Revit Data Graph

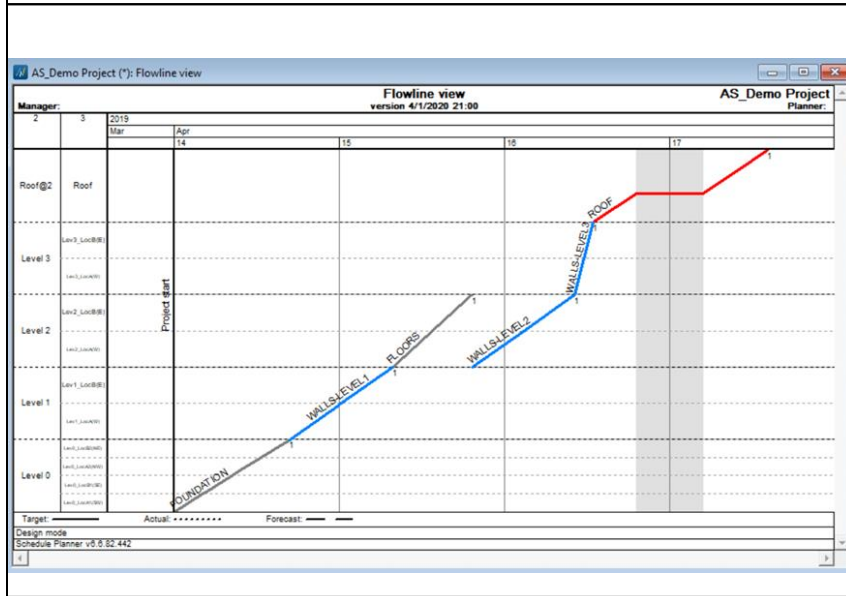
```
wallinst:450d31df-4383-4692-9be4-9c0935e083ef-0008f0ba
  a      product:Wall , ont:Concrete400MmCastInPlace ;
  rdf:label      "(12)11.15,05.1.S1" ;
  bot:adjacentElement wallinst:40cab1d1-1d6f-47a3-9afb-bd8c6300ff7e-0009c504 , wallinst:c1037085-1aff-4644-8770-66dc41edbf0b-0009d67e ;
  props:Element_ID      "585914" ;
  props:Revit_GUID      "450d31df-4383-4692-9be4-9c0935e083ef-0008f0ba" ;
  props:angle      0.0 ;
  props:area      19.2 ;
  props:height      3.0 ;
  props:length      6.2 ;
  props:level_simple      "Level1" .

wallinst:450d31df-4383-4692-9be4-9c0935e083ef-0008f0f0
  a      product:Wall , ont:Concrete400MmCastInPlace ;
  rdf:label      "(12)11.15,05.1.E" ;
  bot:adjacentElement wallinst:450d31df-4383-4692-9be4-9c0935e083ef-0008f14f , wallinst:c1037085-1aff-4644-8770-66dc41edbf0b-0009d67e ;
  props:Element_ID      "585968" ;
  props:Revit_GUID      "450d31df-4383-4692-9be4-9c0935e083ef-0008f0f0" ;
  props:angle      90.0 ;
  props:area      24.0 ;
  props:height      3.0 ;
  props:length      8.4 ;
  props:level_simple      "Level1" .
```

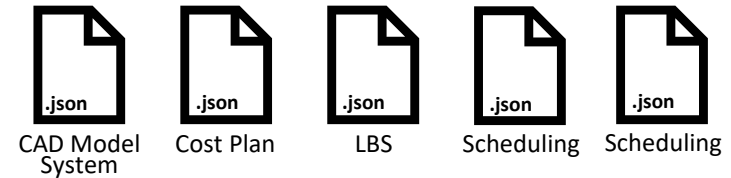
Location-Based Schedule – VICO Office



Data Generation in VICO



Data Extraction in ExiLink/ Program



Data Mapping and
Conversion in RDF triples

Location-Based Schedule – VICO Office

LBS Data Graph

```
inst:1000.0.145882  a      lbs:CompLoid , product:Wall ;
    lbs:hasCompLoid      "1000.0.145882" ;
    lbs:hasLocation      "Lev1_loca(w)" ;
    lbs:haslocLoid       "1000.0.355001" ;
    lbs:hasschedLoid     "1000.0.321768" ;
    lbs:hastaskLoid      "1000.0.358588" ;
    lbs:taskActualEndDate "NULL"^^xsd:dateTime ;
    lbs:taskActualStartDate "NULL"^^xsd:dateTime ;
    lbs:taskPlannedEndDate "2019-04-08 07:28:48.000"^^xsd:dateTime ;
    lbs:taskPlannedStartDate "2019-04-04 11:00:00.000"^^xsd:dateTime ;
    lbs:taskProgressCompletion "0.0"^^xsd:nonNegativeInteger ;
    lbs:taskProgressDate "NULL"^^xsd:dateTime ;
    props:Element_ID      "585914" ;
    props:Revit_GUID      "450d31df-4383-4692-9be4-9c0935e083ef-0008f0ba" .
```

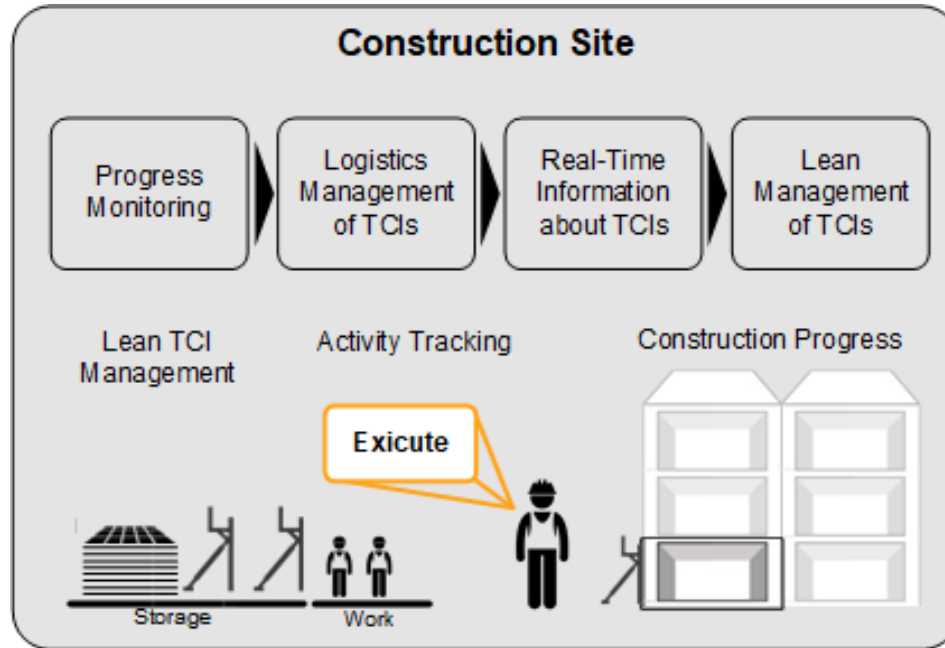
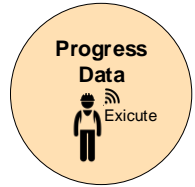
Location-Based Schedule – VICO Office

LBS Data Graph

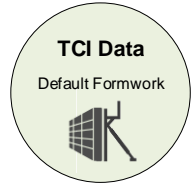
```
inst:1000.0.145882  a      lbs:CompLoid , product:Wall ;
    lbs:hasCompLoid      "1000.0.145882" ;
    lbs:hasLocation      "Lev1_loca(w)" ;
    lbs:haslocLoid       "1000.0.355001" ;
    lbs:hasschedLoid     "1000.0.321768" ;
    lbs:hastaskLoid      "1000.0.358588" ;
    lbs:taskActualEndDate "NULL"^^xsd:dateTime ;
    lbs:taskActualStartDate "NULL"^^xsd:dateTime ;
    lbs:taskPlannedEndDate "2019-04-08 07:28:48.000"^^xsd:dateTime ;
    lbs:taskPlannedStartDate "2019-04-04 11:00:00.000"^^xsd:dateTime ;
    lbs:taskProgressCompletion "0.0"^^xsd:nonNegativeInteger ;
    lbs:taskProgressDate      "NULL"^^xsd:dateTime ;
    props:Element_ID         "585914" ;
    props:Revit_GUID         "450d31df-4383-4692-9be4-9c0935e083ef-0008f0ba" .
```

Exicute

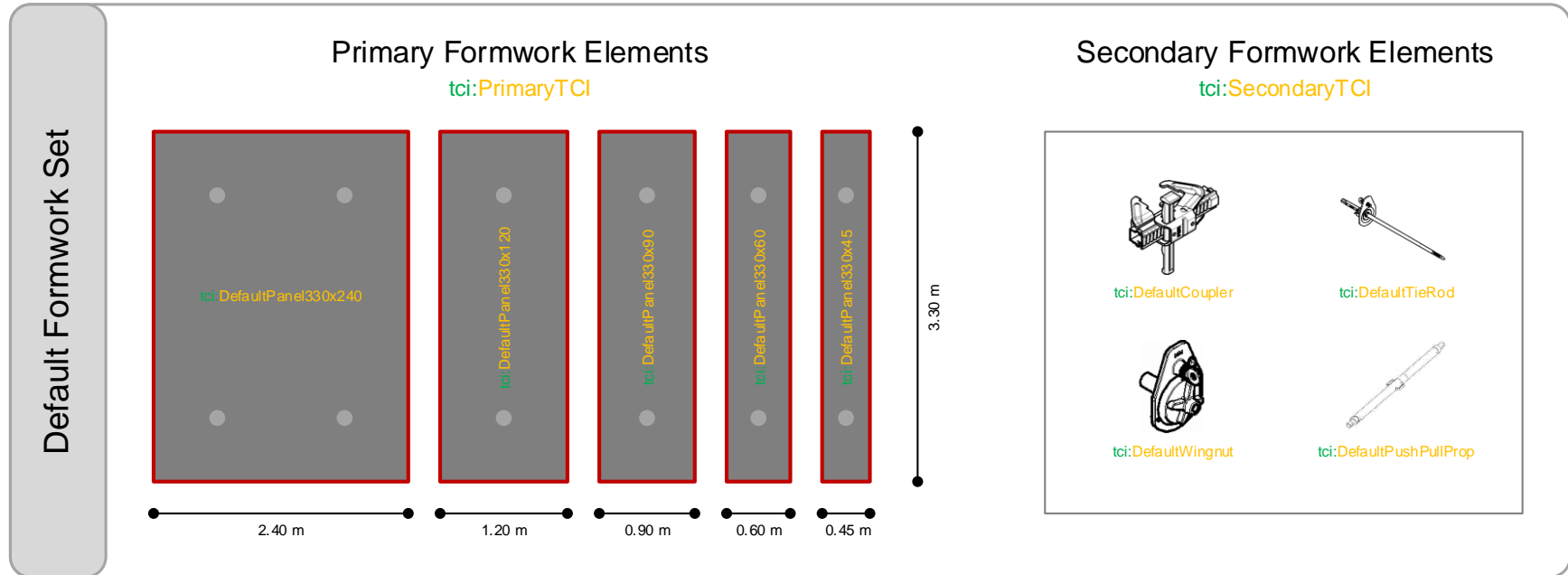
Progress Monitoring – Exicute



Temporary Construction Items – TCI



- TCI Ontology Creation describing the TCI context



Temporary Construction Items – TCI

TCI Data Graph

```
tci:PrimaryTCI a owl:Class ;
  rdfs:subClassOf tci:TCI ;
  owl:disjointWith tci:SecondaryTCI .

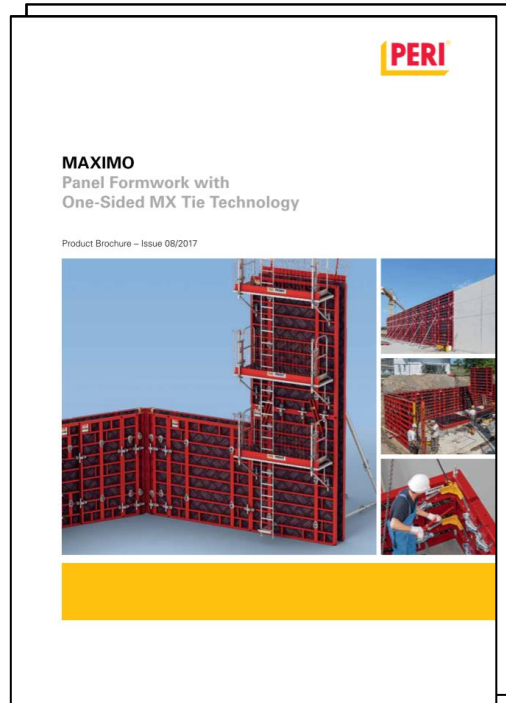
tci:SecondaryTCI a owl:Class ;
  rdfs:subClassOf tci:TCI .

tci:DefaultPanel330x240
  a owl:NamedIndividual , tci:DefaultFormwork , tci:FormworkVertical , tci:Panel ;
  rdf:label "Default Panel 330x240" ;
  props:area 7.29 ;
  props:height 3.30 ;
  props:length 2.40 ;
  props:weight 408.0 ;
  props:width 0.12 .

tci:DefaultCoupler a tci:SecondaryTCI , owl:NamedIndividual , tci:DefaultFormwork , tci:Coupler ;
  rdf:label "Default Coupler" ;
  props:weight 4.58 .
```

Specific Product – PERI MAXIMO MX15

- Product Catalogue



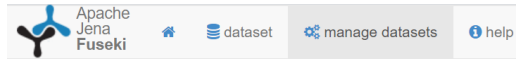
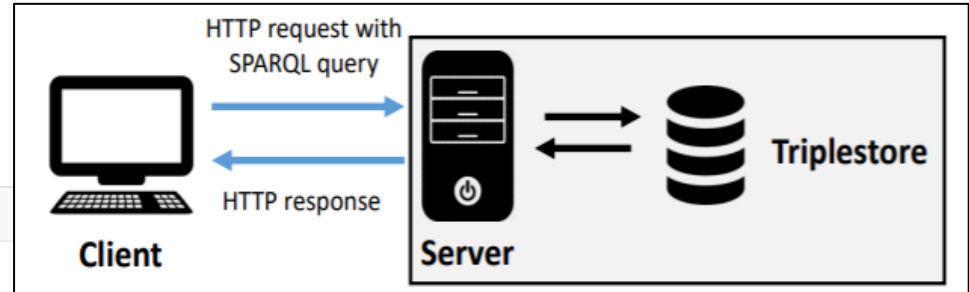
```
peri:MAXIMO_MX15 a peri:PERIProduct ,
    tci:FormworkVertical ;
rdf:label "MAXIMO MX15 Panel Formwork"^^xsd:string ;
tci:hasProducer "PERI GmbH"^^xsd:string ;
tci:hasProductCatalogue "MAXIMO MX 15, 270 _ 330 Instructions for Assembly and Use"^^xsd:string ;
tci:consistsof peri:PERI_MXM330x60, peri:PERI_MXI330x60, peri:PERI_MXI330x50x20, peri:PERI_MXA330x45,
peri:PERI_MX330x90, peri:PERI_MX330x60, peri:PERI_MX330x45, peri:PERI_MX330x30, peri:PERI_MX330x240,
peri:PERI_MX330x120, peri:PERI_MXA330x35, peri:WDAMX330x10, peri:PERI_WingnutMX15, peri:PERI_WingnutDW15_Pivot,
peri:PERI_WalerMAR853, peri:PERI_Waler85, peri:PERI_TieTS_TrioBulkhead, peri:PERI_TieMX15_3040,
peri:PERI_AlignmentCouplerBFD .

peri:PERI_MX330x240 rdf:type owl:NamedIndividual ,
    peri:MAXIMO_MX15 ,
    tci:Panel ;
tci:hasArtNo "114426"^^xsd:string ;
rdf:label "PERI MX 330x240"^^xsd:string ;
props:length "2.40"^^xsd:decimal ;
props:height "3.30"^^xsd:decimal ;
props:area "7.29"^^xsd:decimal ;
props:width "0.12"^^xsd:decimal ;
props:weight "408.0"^^xsd:decimal .

peri:PERI_MX330x120 rdf:type owl:NamedIndividual ,
    peri:MAXIMO_MX15 ,
    tci:Panel ;
tci:hasArtNo "114248"^^xsd:string ;
rdf:label "PERI MX 330x120"^^xsd:string ;
props:length "1.20"^^xsd:decimal ;
props:height "3.30"^^xsd:decimal ;
props:area "3.96"^^xsd:decimal ;
props:width "0.12"^^xsd:decimal ;
props:weight "226.0"^^xsd:decimal .
```

Data Management

- Storage in triple store Jena Fuseki
- Access through localhost:3030



Manage datasets

Perform management actions on existing datasets, including backup, or add a new dataset.

existing datasets + add new dataset			
Name			
/TCI-Demo	remove	backup	upload data
/TCI-Demo-LBS	remove	backup	upload data
/TCI-Demo-PERI	remove	backup	upload data
/TCI-Demo-Revit+LBS	remove	backup	upload data
/TCI-Demo-Revit-data	remove	backup	upload data
/TCI-Demo-Revit-file	remove	backup	upload data
/TCI-Demo-TCI	remove	backup	upload data

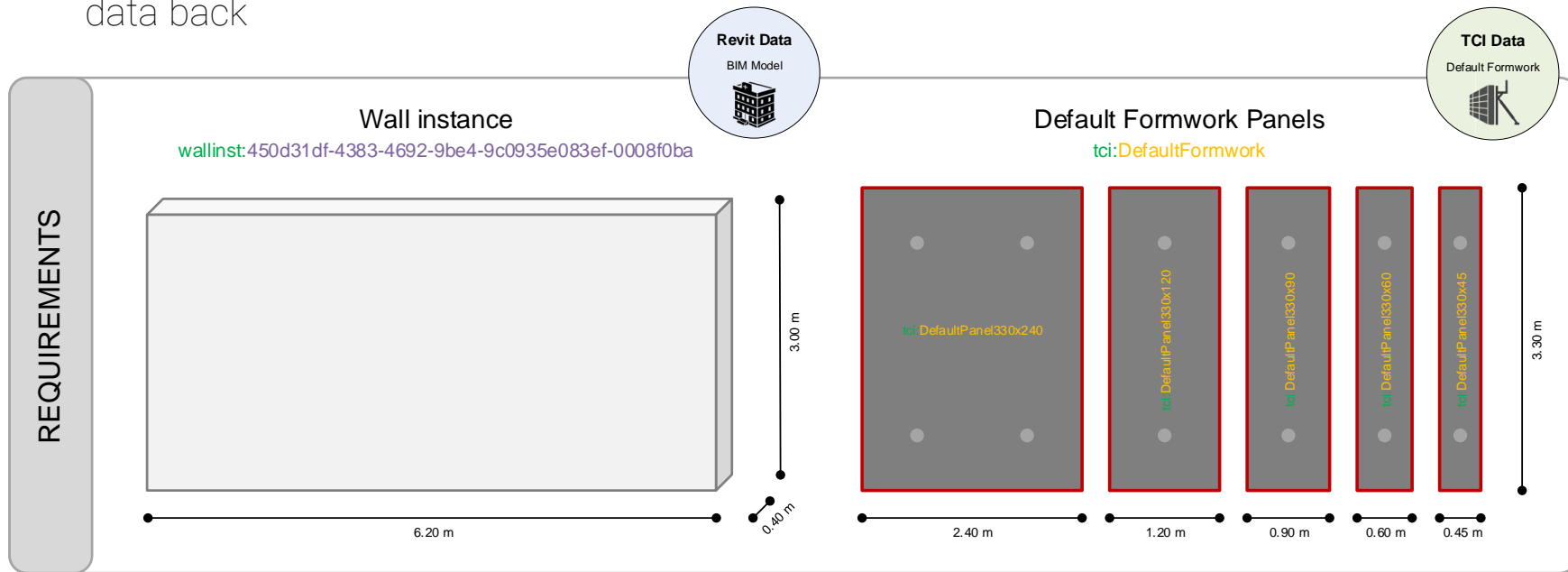
Data Processing & Querying



Revit		TCI					VICO		Exicute			
ElementID	props: length	Primary Formwork	Count	props: length	Secondary Formwork	Count	taskPlanned StartDate	taskPlanned EndDate	taskProgress Date	taskProgress Completion	taskActual StartDate	taskActual EndDate
string	m	string	integer	m	string	integer	DateTime	DateTime	DateTime	%	DateTime	DateTime
585914	6.20	Default Panel 330x240	4	2.40	Default Wingnut	12	2019-04-04 11:00	2019-04-08 07:28	2019-04-06 11:00	70.0	2019-04-04 11:00	NULL
		Default Panel 330x120	2	1.20	Default Tie Rod	12						
		Wooden filling material	2	0.20	Default Coupler	16						
				Default PushPull Prop	6							
				Default Waler	0							
644734	6.20	Default Panel 330x240	4	2.40	Default Wingnut	12	2019-04-08 07:28	2019-04-09 11:57	2019-04-08 16:00	100.0	2019-04-08 11:00	2019-04-08 16:00
		Default Panel 330x120	2	1.20	Default Tie Rod	12						
		Wooden filling material	2	0.20	Default Coupler	16						
				Default PushPull Prop	6							
				Default Waler	0							

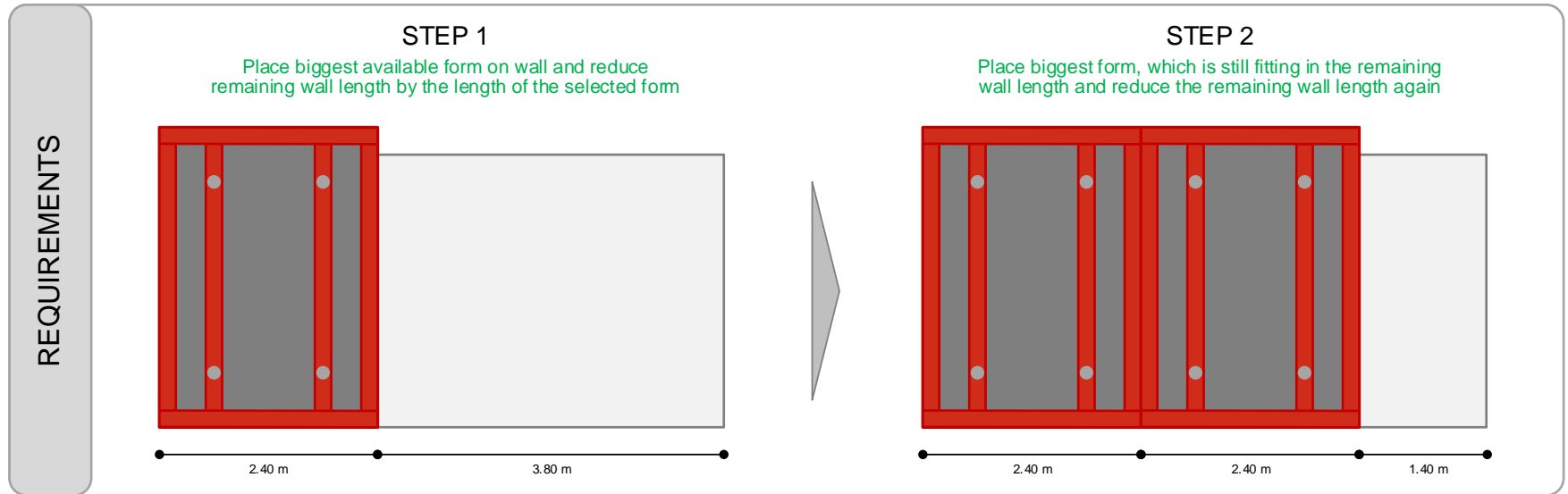
Data Processing & Querying

- Demo project for the calculation of formwork layout on wall elements
- Formwork calculation program that receives data from triple store and write processed data back



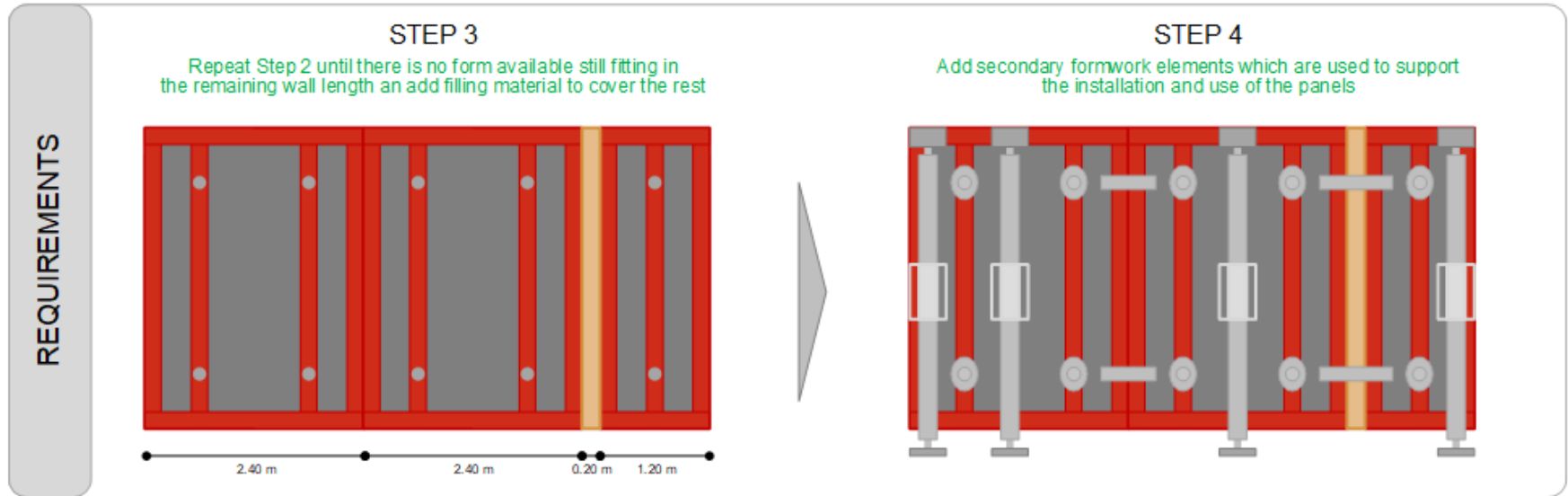
Data Processing & Querying

- Logic of Formwork Calculation Program



Data Processing & Querying

- Logic of Formwork Calculation Program



Data Processing & Querying

Output Data of Program

```
{
  "wallInst": "http://test/walls/450d31df-4383-4692-9be4-9c0935e083ef-0008f0ba",
  "length": 6.2,
  "TCIsIn": [
    {
      "TCIInst": "http://test/tci/DefaultPanel330x240_0",
      "length": 2.4
    },
    {
      "TCIInst": "http://test/tci/DefaultPanel330x240_1",
      "length": 2.4
    },
    {
      "TCIInst": "http://test/tci/DefaultPanel330x120_0",
      "length": 1.2
    }
  ],
  "TCIsOut": [
    {
      "TCIInst": "http://test/tci/DefaultPanel330x240_0",
      "length": 2.4
    },
    {
      "TCIInst": "http://test/tci/DefaultPanel330x240_1",
      "length": 2.4
    },
    {
      "TCIInst": "http://test/tci/DefaultPanel330x120_0",
      "length": 1.2
    }
  ],
  "secTCIs": [
    {
      "TCIInst": "http://test/tci/DefaultCoupler",
      "weight": 4.58
    },
    {
      "TCIInst": "http://test/tci/DefaultTieRod",
      "weight": 4.43
    },
    {
      "TCIInst": "http://test/tci/DefaultWingnut",
      "weight": 2.58
    },
    {
      "TCIInst": "http://test/tci/DefaultPushPullProp",
      "weight": 22.8
    }
  ],
  "TCIsCount": [
    {
      "TCIInst": "http://test/tci/DefaultPanel330x240",
      "Count": 4
    },
    {
      "TCIInst": "http://test/tci/DefaultPanel330x120",
      "Count": 2
    },
    {
      "TCIInst": "http://test/tci/TimberFilling",
      "Count": 2
    },
    {
      "TCIInst": "http://test/tci/DefaultCoupler",
      "Count": 4
    },
    {
      "TCIInst": "http://test/tci/DefaultTieRod",
      "Count": 8
    },
    {
      "TCIInst": "http://test/tci/DefaultWingnut",
      "Count": 8
    },
    {
      "TCIInst": "http://test/tci/DefaultPushPullProp",
      "Count": 8
    }
  ],
  "TimberFilling": [
    {
      "TCIInst": "http://test/tci/TimberFilling",
      "Length": 0.2
    },
    {
      "TCIInst": "http://test/tci/TimberFilling",
      "Length": 0.2
    }
  ]
}
```

Data Processing & Querying

Combined Data Graph

Dataset: /TCI-Demo

query upload files edit info

graph: http://localhost:3030/TCI-Demo/data/Combined

Available graphs [list current graphs](#)

- default graph (1230 triples)
- <http://localhost:3030/TCI-Demo/data/RevitLBS> (458 triples)
- <http://localhost:3030/TCI-Demo/data/TCI> (466 triples)
- <http://localhost:3030/TCI-Demo/data/LBS> (254 triples)
- <http://localhost:3030/TCI-Demo/data/Revit> (204 triples)
- <http://localhost:3030/TCI-Demo/data/Combined> (1230 triples)

```
80 wallinst:40cab1d1-1d6f-47a3-9afb-bd8c6300ff7e-0009c7fb
81   a
82   rdf:label
83   tci:countDefaultCoupler
84   tci:countDefaultPanel1330x120
85   tci:countDefaultPanel1330x240
86   tci:countDefaultPushPullProp
87   tci:countDefaultTieRod
88   tci:countDefaultWingnut
89   tci:countTimberFilling
90   tci:hasTCIs
91   tci:hasTCIsIn
92   tci:hasTCIsOut
93   tci:hasTimberFillinglength
94   tci:hassecTCIs
95   owl:sameAs
96   bot:adjacentElement
97   props:Element_ID
98   props:Revit_GUID
99   props:angle
100  product:Wall , ont:Concrete400MmCastInPlace ;
    "(12)11.15,05.2.E" ;
    8 ;
    2 ;
    6 ;
    10 ;
    12 ;
    12 ;
    2 ;
    tci:DefaultPanel1330x120 , tci:DefaultPanel1330x240
    tci:DefaultPanel1330x240_0 , tci:DefaultPanel1330x2
    tci:DefaultPanel1330x240_0 , tci:DefaultPanel1330x2
    "0"^^xsd:decimal ;
    tci:DefaultCoupler , tci:DefaultTieRod , tci:Defa
    inst:1000.0.146034 ;
    wallinst:40cab1d1-1d6f-47a3-9afb-bd8c6300ff7e-000
    "641019" ;
    "40cab1d1-1d6f-47a3-9afb-bd8c6300ff7e-0009c7fb" ;
    90.0 ;
```

[✕ discard changes](#) [✓ save](#)

Data Processing & Querying

Querying Output Data to
create desired Data Table

```
SELECT ?Element_ID ?length ?PrimaryTCIs ?TCIsCount ?SecondaryTCIs ?2TCIsCount  
?Location ?PlannedStartDate ?PlannedEndDate ?ActualStartDate ?ActualEndDate ?P  
rogressDate ?ProgressCompletion
```

```
WHERE {GRAPH <http://localhost:3030/TCI-Demo/data/Combined>  
{  
  ?Revitinst a product:Wall ;  
    props:Element_ID ?Element_ID ;  
    props:length ?length ;  
    tci:hasTCIs ?PrimaryTCIs;  
    tci:hassecTCIs ?SecondaryTCIs .
```

```
  ?1Countprop tci:iscounting ?PrimaryTCIs .  
  ?Revitinst ?1Countprop ?TCIsCount .  
  ?2Countprop tci:iscounting ?SecondaryTCIs .  
  ?Revitinst ?2Countprop ?2TCIsCount .
```

```
  ?VICOinst a lbs:CompLoid ;  
    props:Element_ID ?Element_ID ;  
    lbs:hasLocation ?Location;  
    lbs:taskPlannedStartDate ?PlannedStartDate;  
    lbs:taskPlannedEndDate ?PlannedEndDate;  
    lbs:taskActualStartDate ?ActualStartDate;  
    lbs:taskActualEndDate ?ActualEndDate;  
    lbs:taskProgressDate ?ProgressDate ;  
    lbs:taskProgressCompletion ?ProgressCompletion .
```

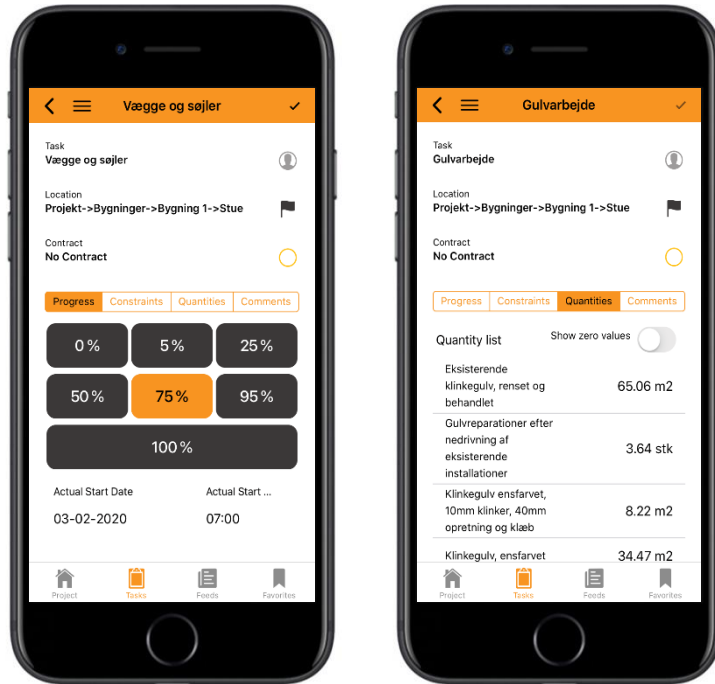
```
FILTER (?VICOinst != ?Revitinst)  
}}
```

Data Processing & Querying

Revit		TCI					VICO		Exicute			
Element_ID	length	PrimaryTCIs	TCIs Count	SecondaryTCIs	2TCIs Count	Location	PlannedStartDate	PlannedEndDate	ActualStartDate	ActualEndDate	Progress Date	%
"645092"	"6.2"	"tci:DefaultPanel330x120"	"2"	"tci:DefaultCoupler"	"4"	"Lev1_loca(w)"	"2019-04-04 11:00:00.000"	"2019-04-08 07:28:48.000"	"NULL"	"NULL"	"NULL"	"0.0"
				"tci:DefaultTieRod"	"8"							
		"tci:DefaultPanel330x240"	"4"	"tci:DefaultWingnut"	"8"							
		"tci:TimberFilling"	"0.2"	"tci:DefaultPushPullProp"	"8"							
"585914"	"6.2"	"tci:DefaultPanel330x120"	"2"	"tci:DefaultCoupler"	"4"	"Lev1_loca(w)"	"2019-04-04 11:00:00.000"	"2019-04-08 07:28:48.000"	"NULL"	"NULL"	"NULL"	"0.0"
				"tci:DefaultTieRod"	"8"							
		"tci:DefaultPanel330x240"	"4"	"tci:DefaultWingnut"	"8"							
		"tci:TimberFilling"	"0.2"	"tci:DefaultPushPullProp"	"8"							
"640260"	"8.4"	"tci:DefaultPanel330x120"	"2"	"tci:DefaultCoupler"	"8"	"Lev1_loca(w)"	"2019-04-04 11:00:00.000"	"2019-04-08 07:28:48.000"	"NULL"	"NULL"	"NULL"	"0.0"
				"tci:DefaultTieRod"	"12"							
		"tci:DefaultPanel330x240"	"6"	"tci:DefaultWingnut"	"12"							
		"tci:TimberFilling"	"0"	"tci:DefaultPushPullProp"	"10"							

Data Visualization & Distribution

Excute Cloud Platform

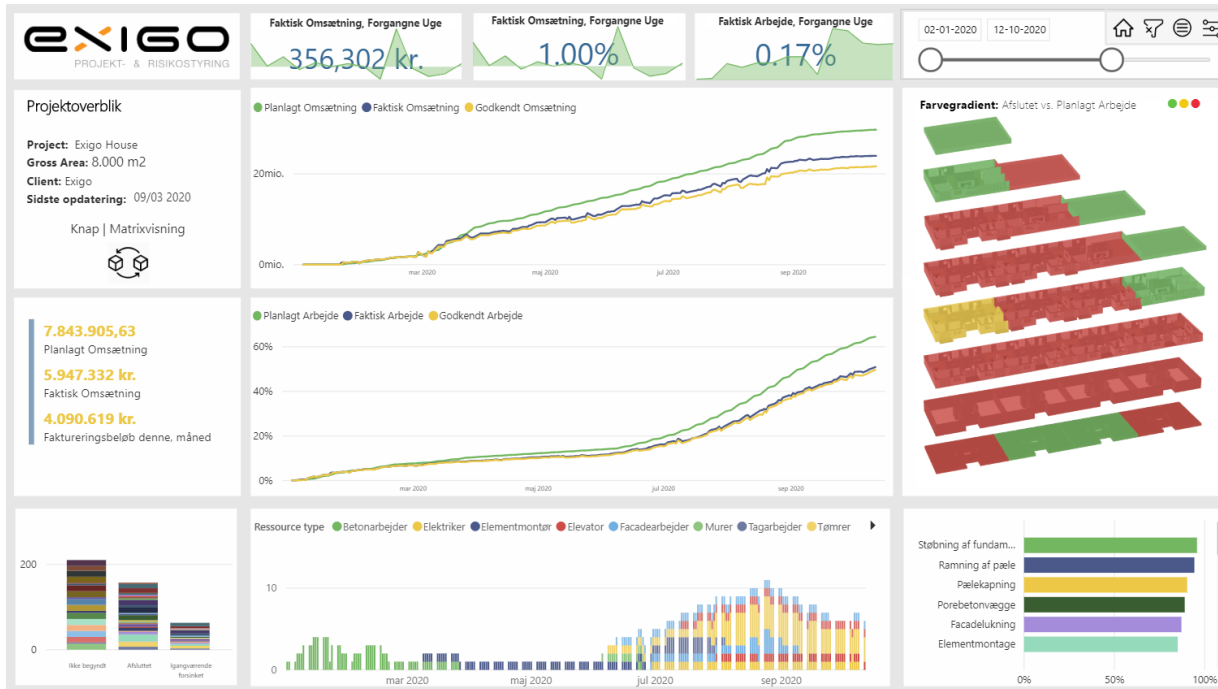


Integration in existing App

- Implementation of the proposed solution in practice
- Extension of the existing application
- New tab "TCI Quantities"
 - TCI quantities per task
 - Parameters of TCIs (weight etc.)
 - Installation time
 - Storage location before and after use
 - Safety Risk Factor
- Conversion of output data into SQL format in order to implement it in Excute
- Could be an additional feature that can be sold to contractors

Data Visualization & Distribution

Power BI Dashboard Visualization



Automated Dashboards

- Direct link between triple store and Power BI
- TCI utilization plan over time
- Utilization of exploded model view to locate tasks
- Quantities & Types for upcoming tasks
- Current stock on site
- Etc.



VI. Further Development/ Improvements

Further Development/ Improvements

Improving formwork
calculation program

Data Visualization &
Distribution with
Excute & Power BI

IoT-Implementation for
active resource
tracking

Validate solution with
case study on SDU
project

Develop Program to
export VICO data as an
RDF data graph

Create business case
for stakeholder to publish
their information as
Linked Open Data

Questions/
Feedback?