International Council on Systems Engineering
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# Integrating Concept of Operations in Prefabrication Processes for Effective Construction Projects: A Case Study on Plumbing Systems

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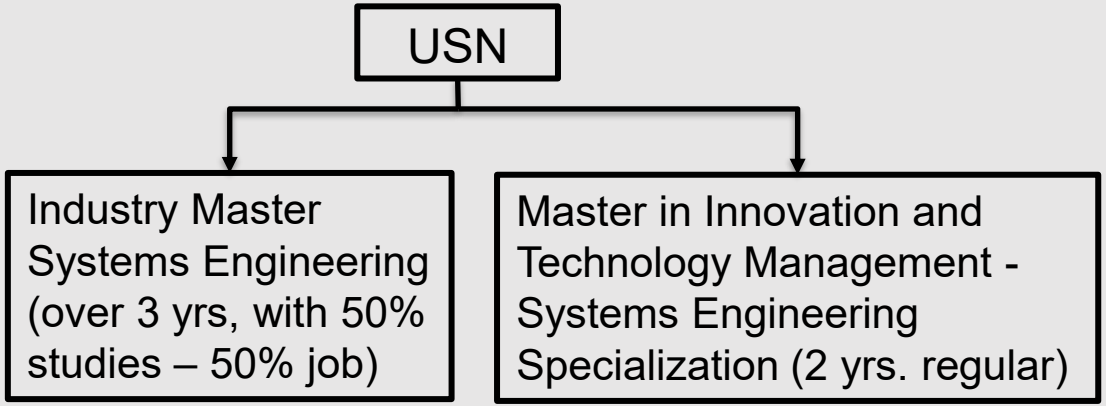
# Context

- University of South-Eastern Norway (USN) offers Master Programs in





- Master thesis project is worth 30 ECTS, executed in the FINAL semester
  - Students have to show they can apply the theory in practice

# Today's Agenda

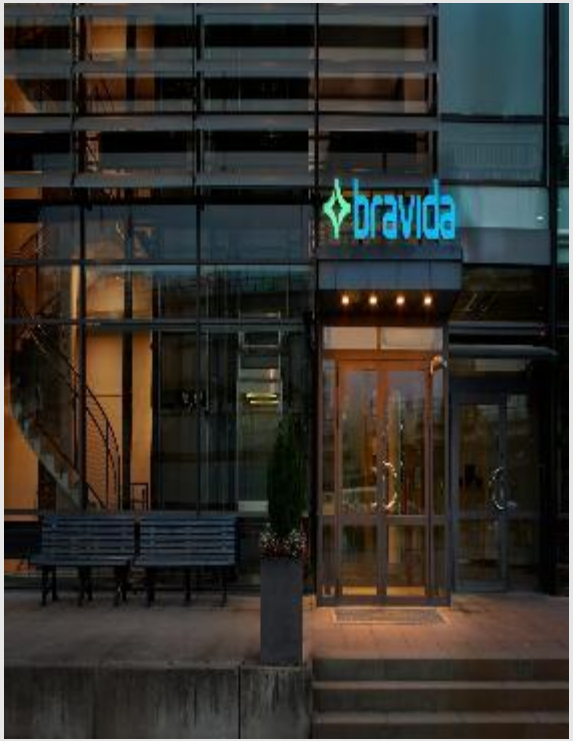
- Background
- Research Questions
- Research methodology
- Case site
- Research findings
- Conclusion
- Future Research

# Background

**Industrial Context and Needs**: Bravida AS is a Nordic technical construction company offering solutions in the technical lifecycle of a building.

**Mechanical, electrical, and plumbing (MEP)** are the technical aspects of construction

**Industry practice:** The current industry practice is the traditional on-site assembly of building materials, also known as the conventional or site-built method.

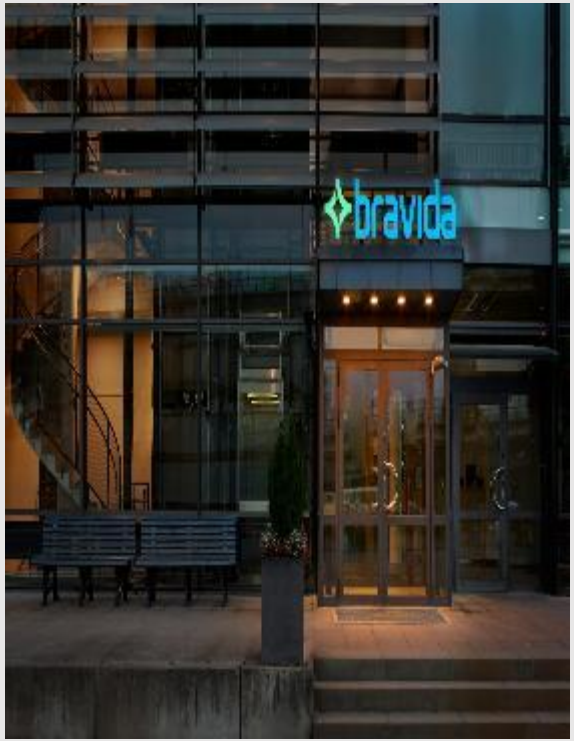


# Problem

- Bravida AS faces multifaceted challenges in project planning and execution phases of plumbing operations. The challenges include project delays, cost overruns, and logistics management.

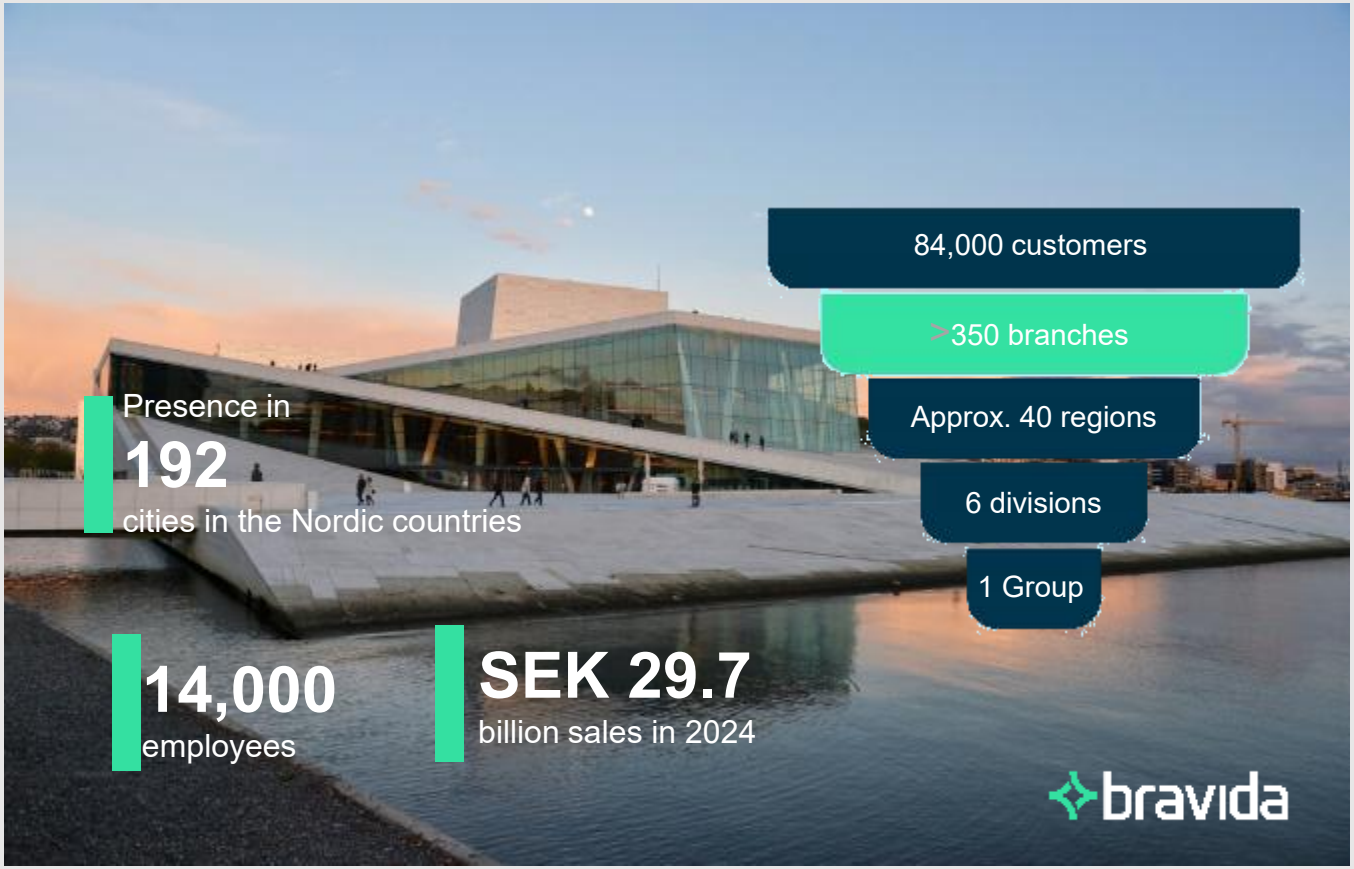
**Goal:**

- ✓ The study aims to investigate a method to streamline processes, reduce project costs, and shorten delivery times in plumbing operations.



# BRAVIDA VISION

# BRAVIDA


84,000 customers
>350 branches
Approx. 40 regions
6 divisions
1 Group
Presence in
192
cities in the Nordic countries
14,000
employees
SEK 29.7
billion sales in 2024
bravida

# BRAVIDA


Bravida helps create a resilient society.
Today and beyond.
Automation that provides energy efficient buildings
Energy saving measures in buildings
Hospital buildings with operational certainty
Energy efficient technology solutions for industrial customers
Future infrastructure projects
Reliable security systems
bravida

# Case

In the current project, we have:

**Customer - OBOS**

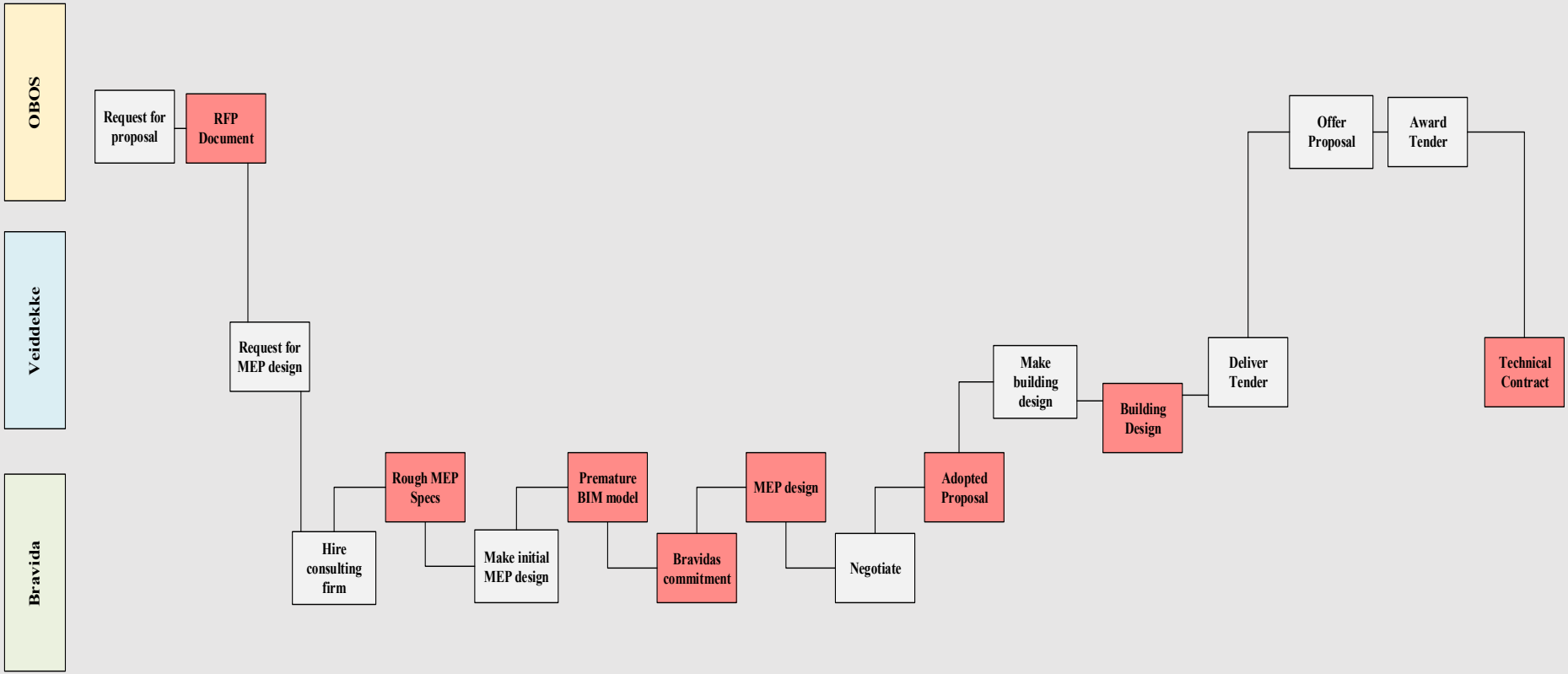
**Contractor –Veiddekke AS**

**Technical sub-contractor - Bravida AS**

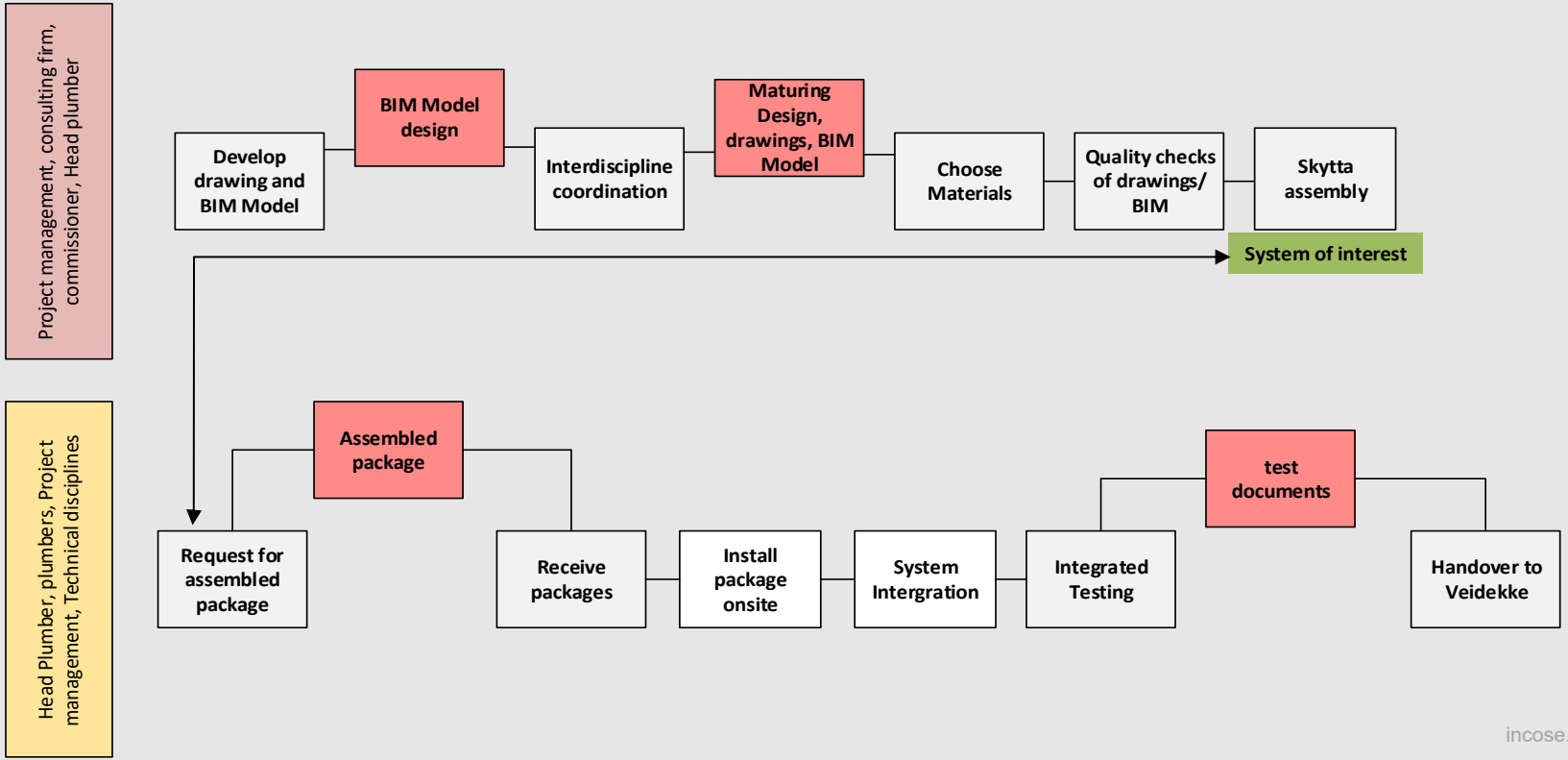
The office building under construction is at Ulvenveien 90 Oslo, and the offsite warehouse is at Industriveien, Skytta, Oslo.

The focus was on the Sprinkler system  on the 5th floor of the Building.

# As-Is CONOPS – Tendering



# As-Is CONOPS – Preparation at Bravida



# Research questions

How to develop a CONOPS model to help achieve an effective prefabrication process for plumbing systems in the construction projects?

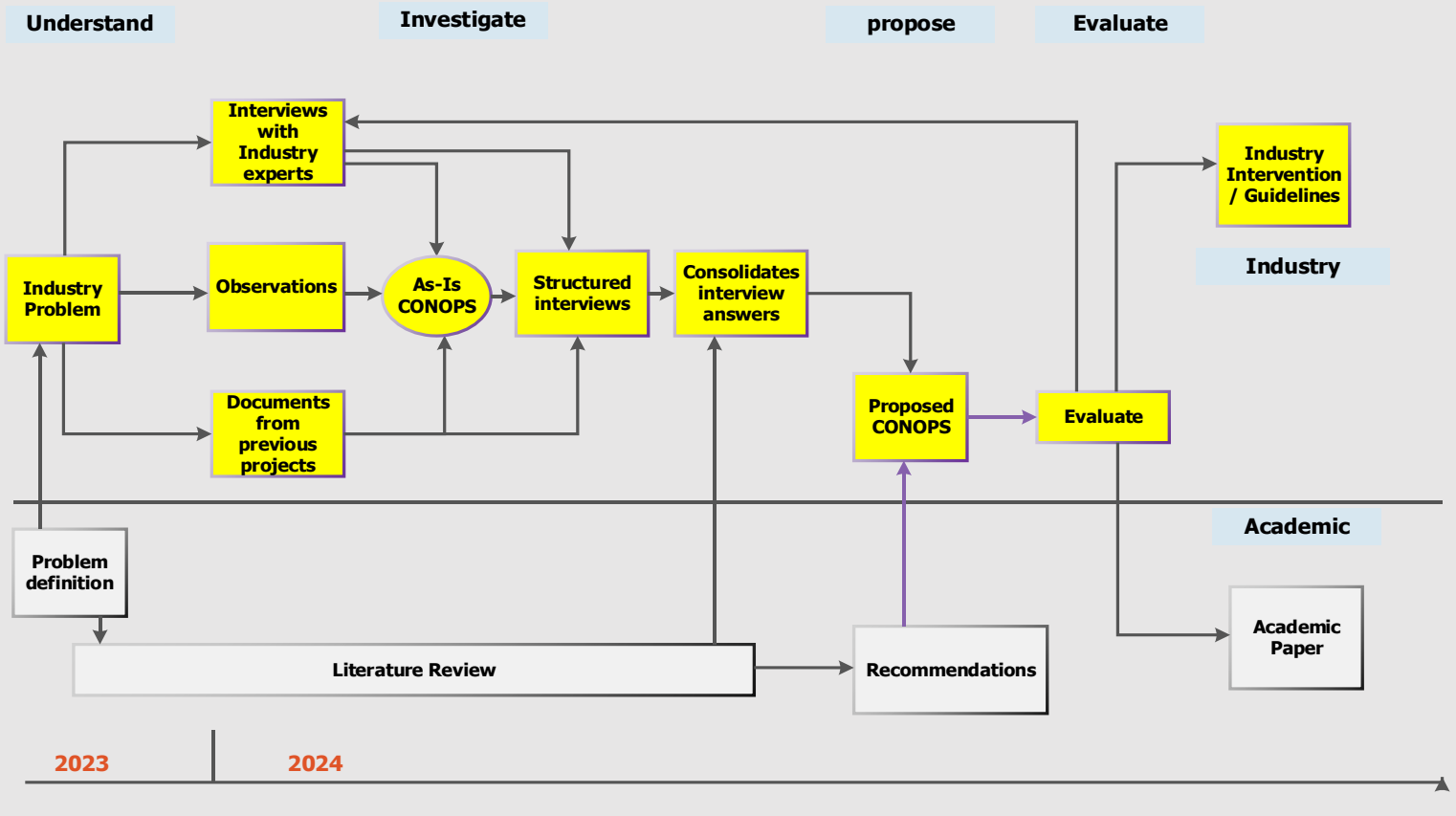
**Sub questions:**

**RQ1:** How to develop a CONOPS model to identify pain points in the As-Is state and propose a To-Be plumbing solution state?

**RQ2:** How can prefabrication help reduce project costs regarding physical waste, logistics, and labor costs?

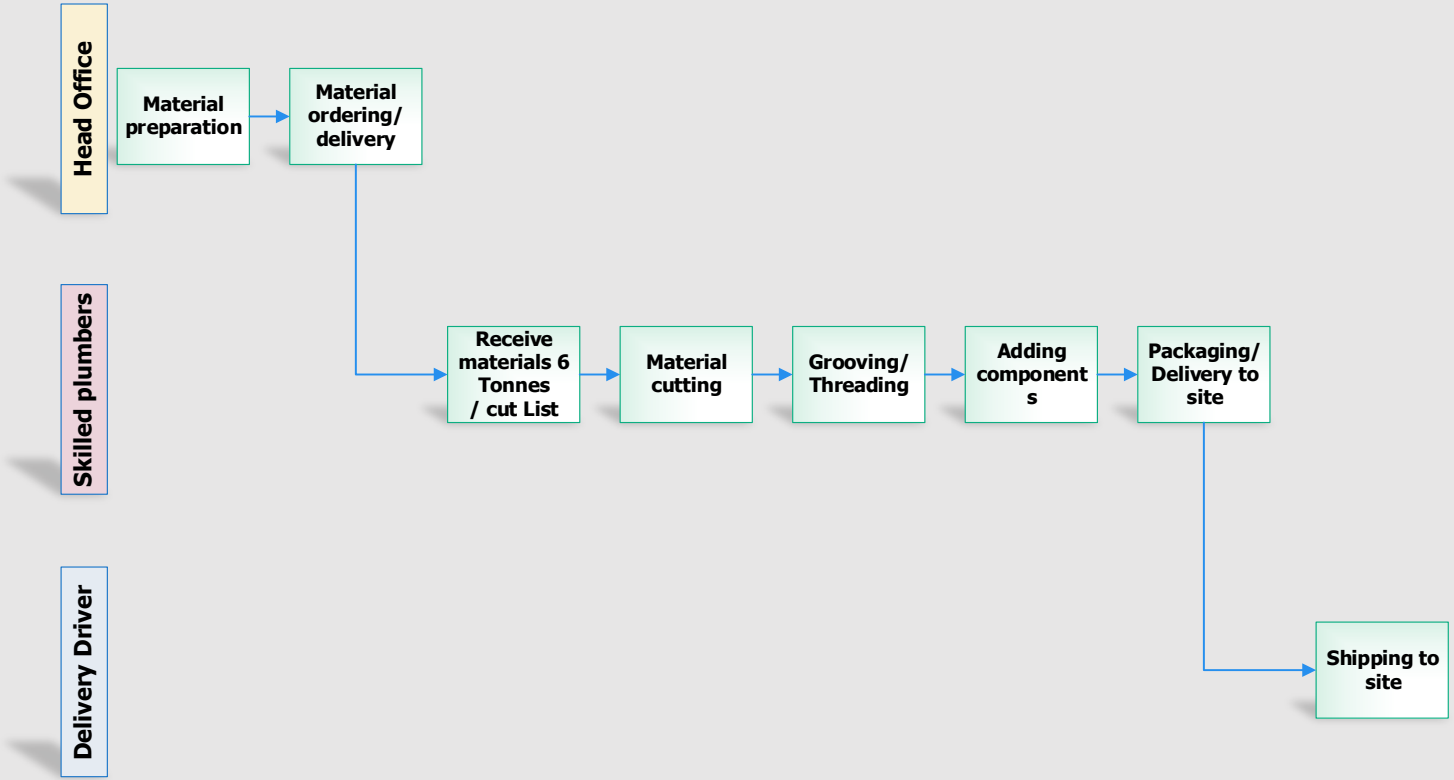
**RQ3:** How can prefabrication help reduce project delivery times at the construction site?

# Research Design



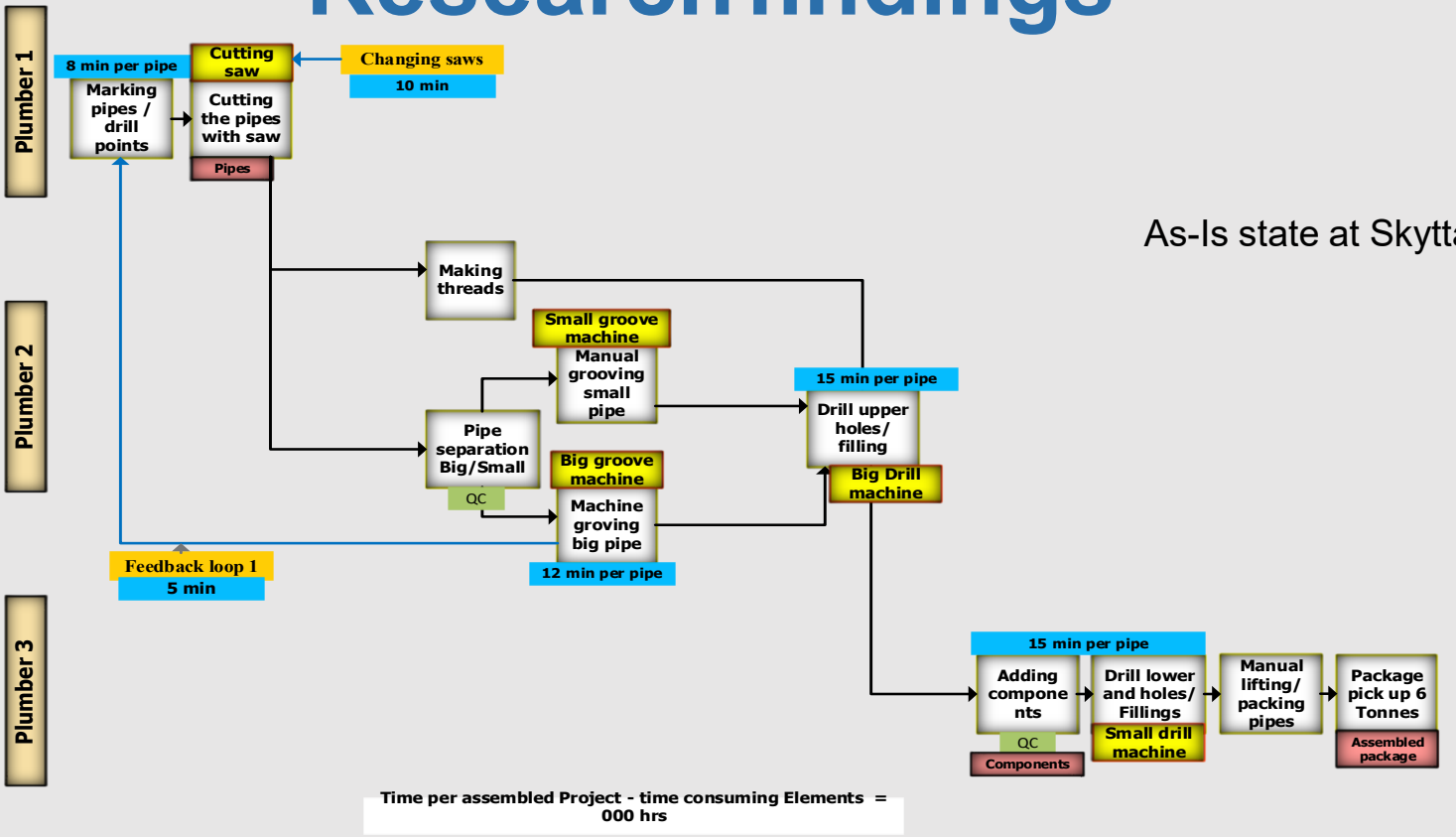

high-level research design in the research.

# Case site: Skytta Offsite Assembly Warehouse




Skytta Assembly site

# Research findings




As-Is state at Skytta site

Artifacts Stakeholders Pain points Quality Checks Equipment

# Research findings

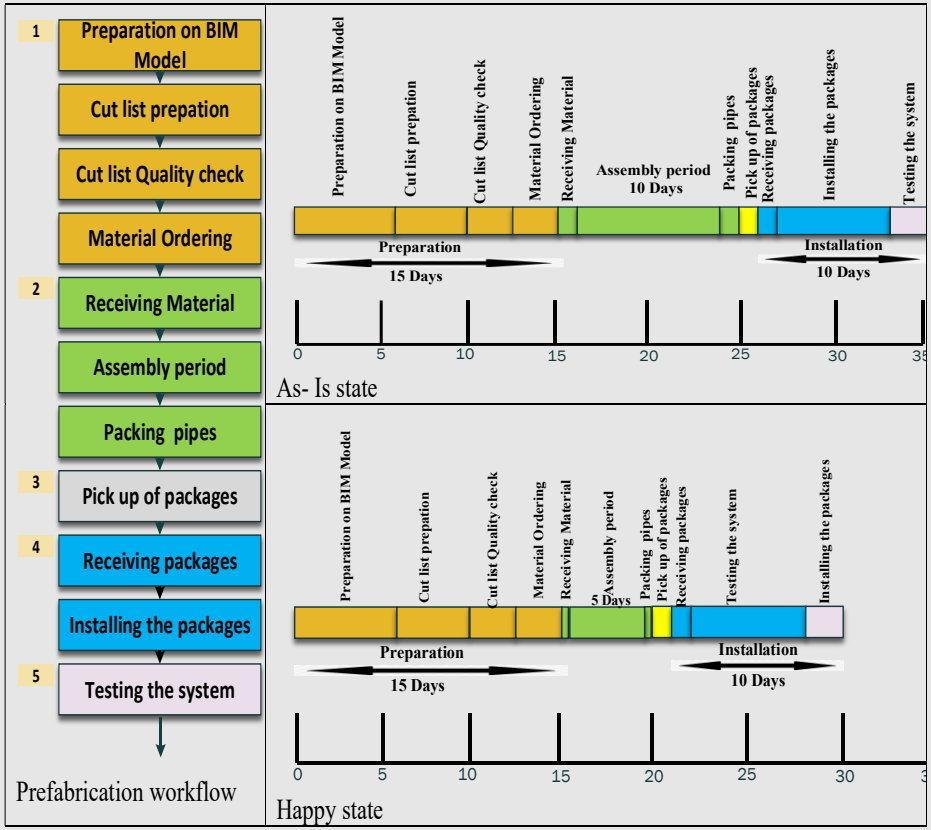

As-Is state at Skytta site

# Skytta As-Is mapping Challenges

- The process of marking and cutting pipes takes **8 to 10** minutes per pipe.
- Rectifying incorrect cut takes over **5** minutes, leading to rework at the Ulvenveien site
- Grooving takes **12-15** minutes per pipe.
- **Only 30%** of the rented workspace is utilized.
- Rework of wrong cut sizes is expensive

Installed Sprinkler system with Re-work

# Workflow and Labor calculation




The first step in the workflow requires **15 working days** to complete.
This extended period is due to the time it takes to translate the plumbing system measurements into a cut list and quality check.
The difference between the Happy and As-Is states is **93.75 hrs.**, which translates to a lost cost of **69.8 KNOK.**

| Woker cost per day | |
|---|---|
| Hours per day | 7.5 |
| Wokers per day | 2.5 |
| Cost per worker (NOK) | 300 |
| Total | **5625** |

| Happy State Assembly time 5th floor | |
|---|---|
| Hours per day | 7.5 |
| Workers per day | 2.5 |
| Assembly time (Days) | 5 |
| Total time per 6 tons | **93.75** |

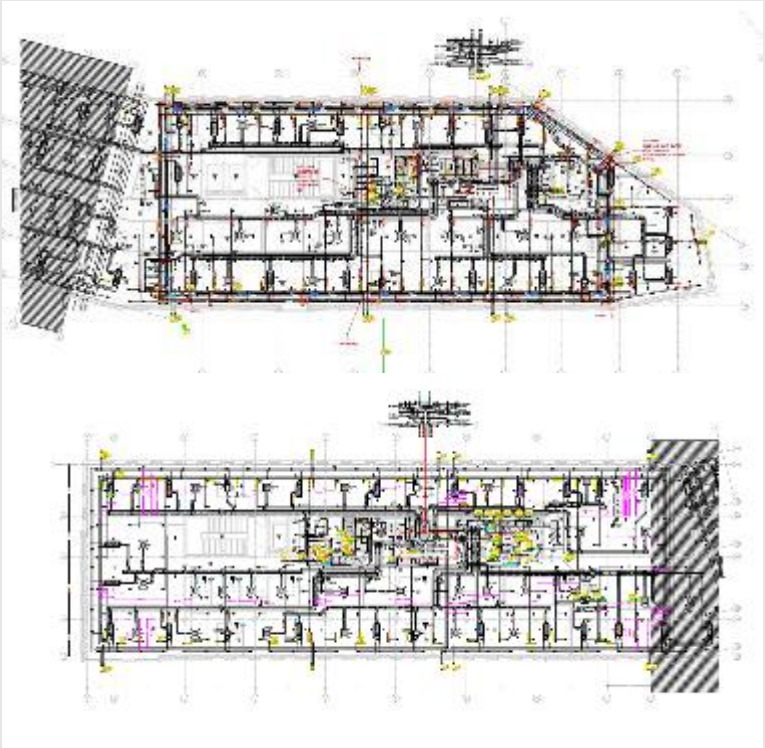
| As-IS Assembly time 5th floor | |
|---|---|
| Hours per day | 7.5 |
| Workers per day | 2.5 |
| Assembly time (Days) | 10 |
| Total time per 6 tons | **187.5** |

**As- Is time** = (187.5 /159) * 60 = 71 min per pipe
**Happy state** = (93.75/159*60) = 35 min per pipe
**Lost time** = 71-35 = 35
=(35*159/60) = 93 hrs
**Lost cost** = 93*300 = 69.8 KNOK

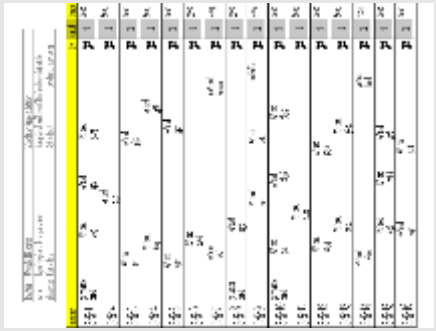
# Cut list created from the BIM model design for 5th floor

| | | | |
|---|---|---|---|
| Prosjekt | Ulven B1 HK kontor | Materialer: Kruse rilledoler | |
| navn | kappliste plan 5 del 2 320 varme | Rør: grålmalte rillerør stål fra heidenreich (avtale | |
| plassering | Plan 5 del 2 | Sist redigert | torsdag 14. mars 2024 |

| nummer | | | | | | | | DN | antall | lengde |
|---|---|---|---|---|---|---|---|---|---|---|
| 5-5-1 | 90°venstre bend | ½" ned 406 | ½" ned 2474 | ½" ned 5473 | | | | 32 | 1 | 6000 |
| 5-5-2 | | | ½" ned 3072 | | | | | 32 | 1 | 6000 |
| 5-5-3 | | ½" ned 671 | | ½" ned 3670 | | | | 32 | 1 | 6000 |
| 5-5-4 | | ½" ned 669 | | | ½" ned 5468 | | | 32 | 1 | 6000 |
| 5-5-5 | | ½" ned 2467 | | ½" ned 5473 | | | | 32 | 1 | 6000 |
| 5-5-6 | | ½" ned 2466 | | | | | | 32 | 1 | 5900 |
| 5-5-7 | | ½" opp 165 | | | | 90°bend venstre | | 32 | 1 | 2494 |
| 5-5-8 | 90°høyre bend | ½" ned 2492 | | | | | | 32 | 1 | 5900 |
| 5-5-9 | | | ½" ned 191 | ½" ned 3184 | | endelokk | | 32 | 1 | 3465 |
| 5-5-10 | 90°venstre bend | ½" ned 742 | ½" ned 2836 | ½" ned 5835 | | | | 32 | 1 | 6000 |
| 5-5-11 | | | ½" ned 3434 | | | | | 32 | 1 | 6000 |
| 5-5-12 | | ½" ned 1033 | | ½" ned 4032 | | | | 32 | 1 | 6000 |
| 5-5-13 | | | ½" ned 1031 | | ½" ned 5830 | | | 32 | 1 | 6000 |
| 5-5-14 | | ½" ned 2829 | | | | 90°opp bend | | 32 | 1 | 4734 |
| 5-5-15 | | | ½" ned 958 | ½" ned 3588 | ½" ned 3938 | | | 32 | 1 | 6000 |
| 5-5-16 | | | ½" ned 1992 | ½" ned 5481 | | | | 32 | 1 | 6000 |



# Artefacts and Materials



1. Cut list

2. Raw Materials pipes 6 tones

3. Components added to pipes

4. Arranging pipes in numbered order

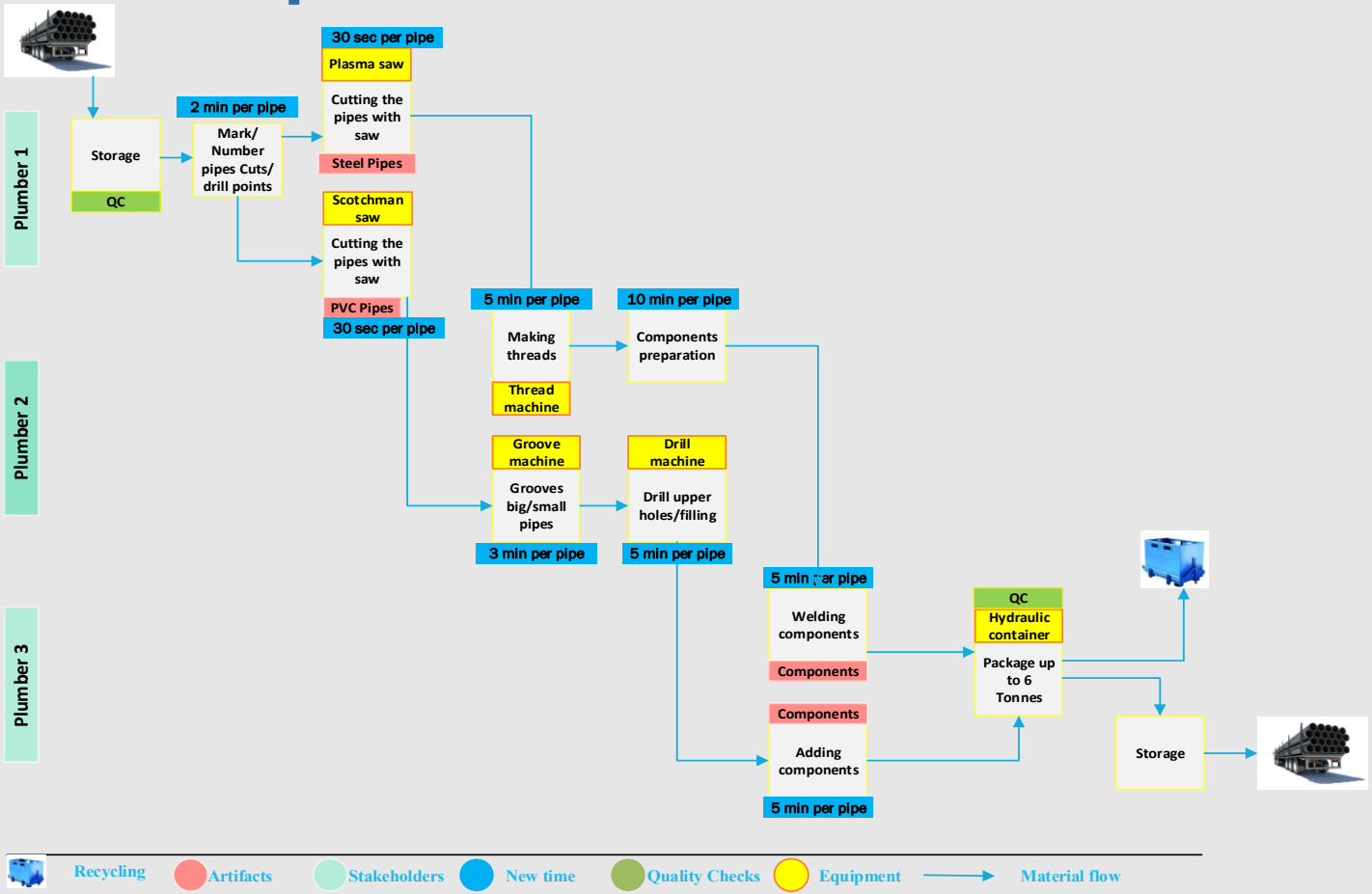
5. Packed and ready for delivery

6. Packages on building site

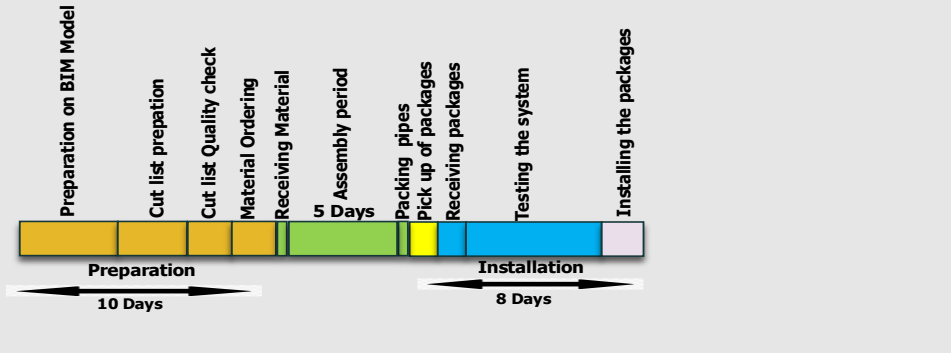
7. Fitting according to numbering

8. Installed pipes

# The Proposed To-Be CONOPS scenario



# Effort time lapsed at Skytta site




To- Be State

| To-Be Assembly time 5th floor | |
|---|---|
| min per pipe | 15.3 |
| 6 tons pipe | 159 |
| Total time per 6 tons | **2432.7** |

**To- Be time**= 2433/60 = 40.55
**Saved Time** = As- Is - To- Be
=187.5-40.55 = 146.95
**Cost saved** = 146.95 * 2.5* 300 =110 KNOK

| Item | Meters |
|---|---|
| **Heating** | 2430 |
| **Sprinklers** | 7610 |
| **Cooling** | 2694 |
| | 12734 |

| | |
|---|---|
| **6 tons in meters** | 159*6= 954 |
| | 12734 /954=13 |
| **To-Be** | 40.55*300 =12165 |
| | 12165*13=158145 |
| **Building savings** | 731250-158145 |
| | 573105 NOK |

**To-Be State**

1 pipe is assembled and prefabricated at Skytta at 15.3 minutes.

= 159 pipes * 15.3 minutes

= 2432 / 60

= 40. 55 to fabricate 159 pipes.

**Money savings**

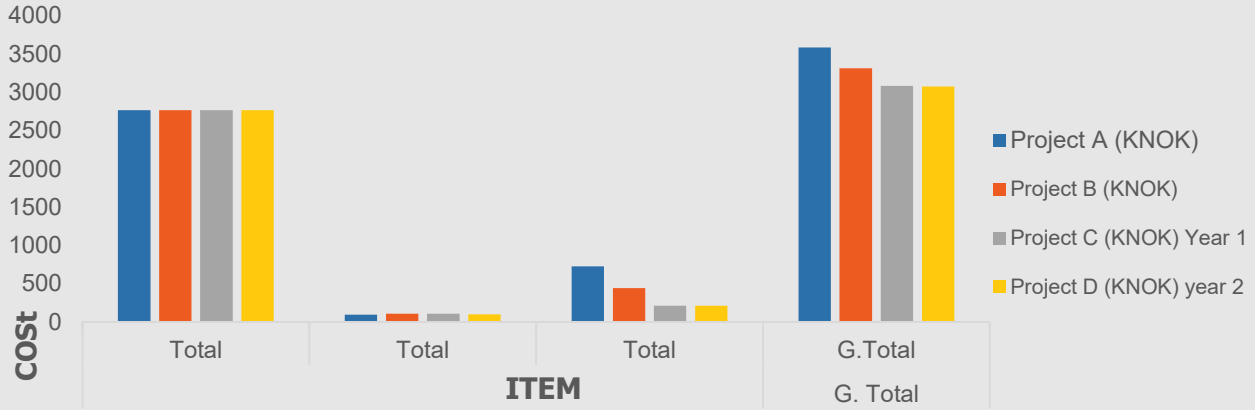
= 187.5 hours of As-Is – 40.55 hrs To-Be

= 146.95 hrs to be saved for 159 pipes

= 146.95 * 2.5*300

= **110 KNOK** to be saved

# Cost Model




| PHASES | | Project A (KNOK) | Project B (KNOK) | Project C (KNOK) | Project D (KNOK) |
|---|---|---|---|---|---|
| | | | | Year 1 | year 2 |
| | | As-Was Onsite | As-Is Skytta Offsite | To- Be Prefabrication | Prefabrication |
| Capex | Total | 108 | 0 | 225 | 0 |
| Opex | G.Total | 3585 | 3312 | 3081 | 3076 |

# Evaluation

| No | Question | - | = | + | Comments |
|---|---|---|---|---|---|
| 1 | Does the model address the pain points identified in the As- Is state at Skytta? | | | BM/PM | |
| 2 | Do you believe the To-Be model is useful for effective prefabrication in the plumbing segment at Bravida AS? | | | BM/PM | |
| 3 | Does the proposed model meet your expectations in addressing the vision for Bravida AS for prefabrication? | | | BM/PM | Provides a good point of departure and some good recommendations for rethinking the process and setting up a new more streamlined production-line in a new and better fit location |
| 4 | Does the proposed model demonstrate the potential in improving the project delivery times? | | | BM/PM | |
| 5 | Does the proposed model demonstrate the potential in reducing the project deliveries cost? | | | BM/PM | Provides a very good point of departure for us to develop a more detailed cost/investment proposal. Much easier for the plumbing department to start that process now, as you have analyzed it and pinpointed the pain points and cost savings. They will however need to go more in detail in their budget process. |
| 6 | Does the proposed model improve work to labor allocations? | | BM | PM | |
| 7 | Does the proposed model improve the logistics plan at Skytta? | | | BM/PM | |

# Discussion

**How to develop a CONOPS model to help achieve an effective prefabrication process for plumbing systems in the construction industry?**

Develop the CONOPS model by analyzing the current state, identifying pain points, designing an integrated To-Be model using prefabrication principles, and validating it with industry.

- **How to develop a CONOPS model to identify pain points in the As-Is state and propose a To-Be plumbing solution state?**

  We mapped stakeholder roles, workflows, materials, and challenges to define the As-Is state, then use these insights to design a streamlined To-Be prefabrication process.

- **How can prefabrication help reduce project costs regarding physical waste, logistics, and labor?**

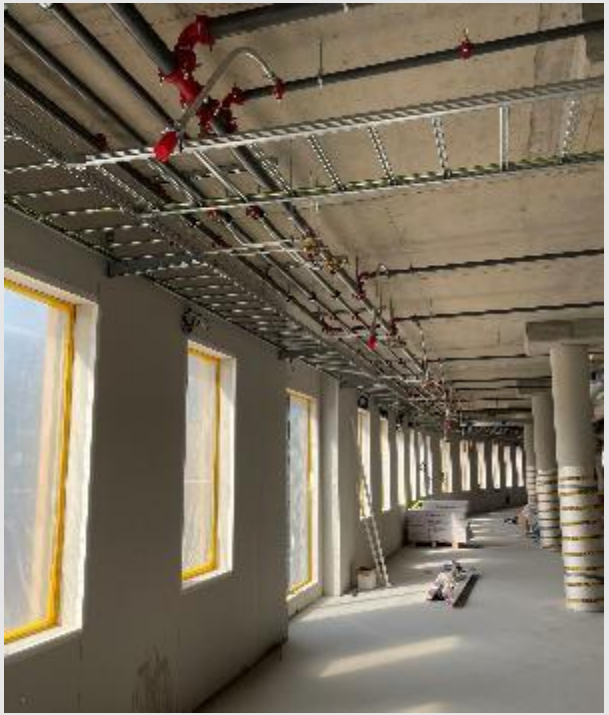
  Prefabrication reduces labor costs, cuts waste, improves logistics, and increases space utilization to 80%, resulting in savings of 573 KNOK

- **How can prefabrication help reduce project delivery times at the construction site?**

  Prefabrication with the CONOPS model cut project delivery time from 35 to 22 working days with saving of 1911 hrs.

# Conclusion

- We explored the goal based on the challenges of project cost and delivery times in the plumbing processes.
- We applied a CONOPS model to map the workflow process of the offsite assembly warehouse.
- The case study and the CONOPS to study Skytta assembly as the system of interest and identify the paint points.
- The construction process time reduced to **12 days** in the preparation, assembly installation, and testing phases
- The proposed streamlines workflow saving **1911 hrs**., translating **573kNoK.**
- We achieved this solution through proper work distribution, increased space utilization to **80%,** and eliminating manual work duplication



# Limitations

Previous documentation

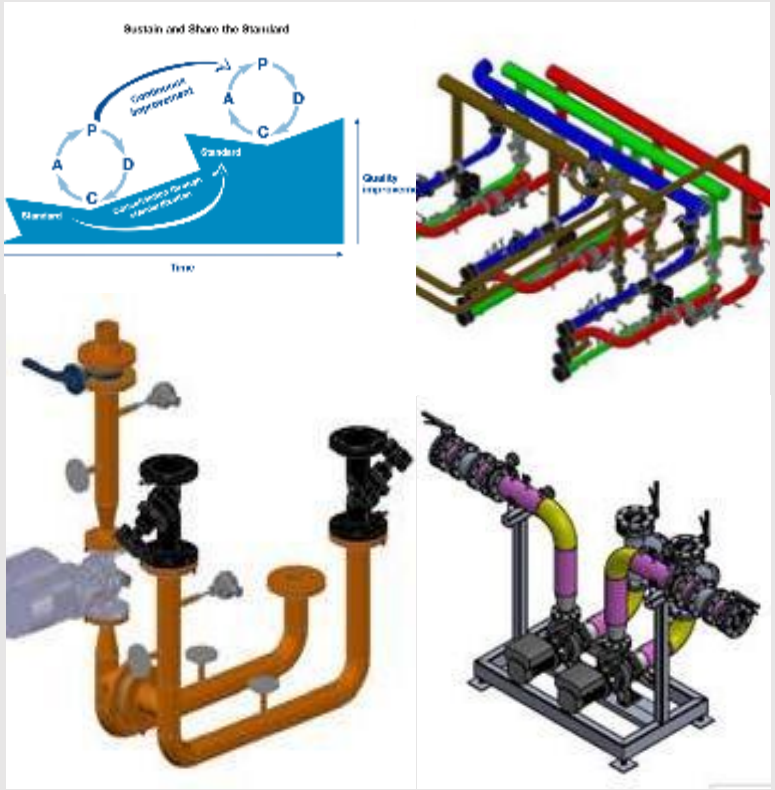
Support from internal stakeholders with data

Industry vs Academia balance

Language barrier

# Future work

- The graphical CONOPS needs to be used in actual test cases to determine its efficiency and effectiveness.
- Estimating the productivity levels during prefabrication is essential, as this metric will enable labor efficiency assessment.
- Integrating digital tools into the proposed To-Be CONOPS model is essential to enhance operational efficiency and minimize preparation time.
- For the technical contractor, we recommend building prefabrication capabilities while assessing the potential of the proposed CONOPS model.



# The 21st Annual System of Systems Engineering Conference

**Conference theme: World as Systems of Systems**

**28 June – 1 July 2026**
**University of South-Eastern Norway**
**Campus Kongsberg**

**1 – 4 July 2026**
**Kongsberg Jazz Festival**

https://sosengineering.org/2026/

**Conference General Chair:**
Satyanarayana Kokkula
University of South-Eastern Norway

**Conference Program Co-Chairs:**
Maarten Bonnema, University of Twente
Jakob Axelsson, Mälardalen University

**Deadline:**

**Paper Submission:**
March 5th 2026

**Notification of Accepted Paper:**
April 15th 2026

**Full Manuscript:**
May 10th 2026

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