



**University of
Nottingham**

UK | CHINA | MALAYSIA

Ontology-Based Construction Progress Monitoring: A Conceptual Framework

Asha Palihakkara, Carlos Osorio Sandoval, Walid Tizani and Zigeng Fang

Centre for Structural Engineering and Informatics (CSEI)

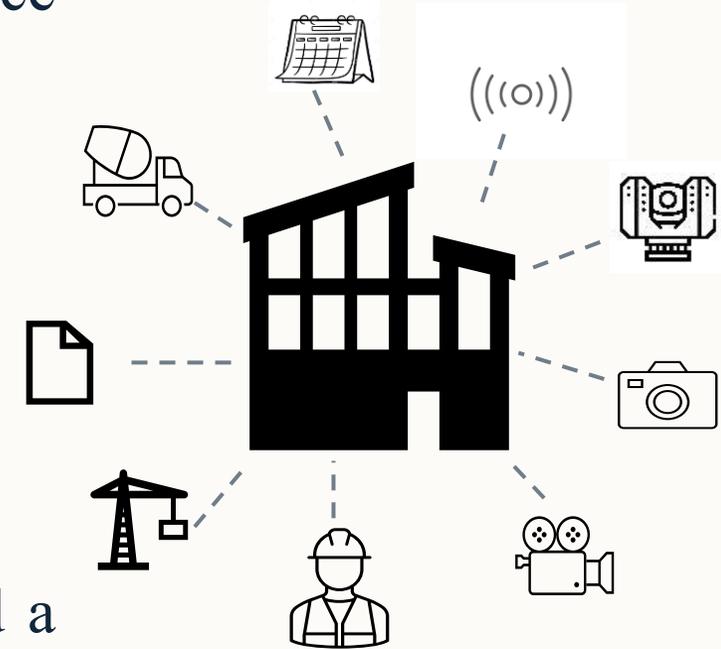
Faculty of Engineering

University of Nottingham



Introduction

- Progress monitoring is essential for ensuring schedule compliance and project objectives.
- The execution phase of a construction project comprises of;
 - A collaborative environment
 - Multiple streams of data
 - Wide array of digital tools
 - Heterogeneous data formats
- Automated monitoring is challenged by data heterogeneity and a lack of integration.
- A semantic, ontology-based approach offers a structured, unified representation across domains.





Research Problem and Gap

- Most automated approaches rely heavily on object detection techniques (appearance-based or occupancy-based).
- Visual techniques offer only binary progress updates (e.g., built/not built).
- Schedule and resource data are rarely integrated into monitoring systems.
- Visual-only methods neglect rich sources like labour utilisation, event logs, and resource flows.
- Data flows from different domains are incompatible, making cross-system reasoning difficult.
- Although many established ontologies exist in the construction industry, there's a lack of comprehensive, scalable, and semantically-driven frameworks to represent and reason about construction progress holistically.



Research Aim and Objectives

- The framework will:
 - Integrate multi-source data (planning, as-built, schedules, reports).
 - Semantically represent progress, using modular, domain-specific ontologies.
 - Enable rule-based reasoning and inference for deeper insights beyond binary status.
 - Facilitate the timely detection of progress discrepancies and support corrective actions.
- The use of Semantic Web technologies allows for:
 - Interoperability between systems.
 - Linking across domains (BIM, IoT, Planning).
 - Reasoning to support proactive project control.
- The framework builds upon widely accepted vocabularies (IFC, BOT, QUDT, etc.) to avoid redundancy and improve real-world adoption.



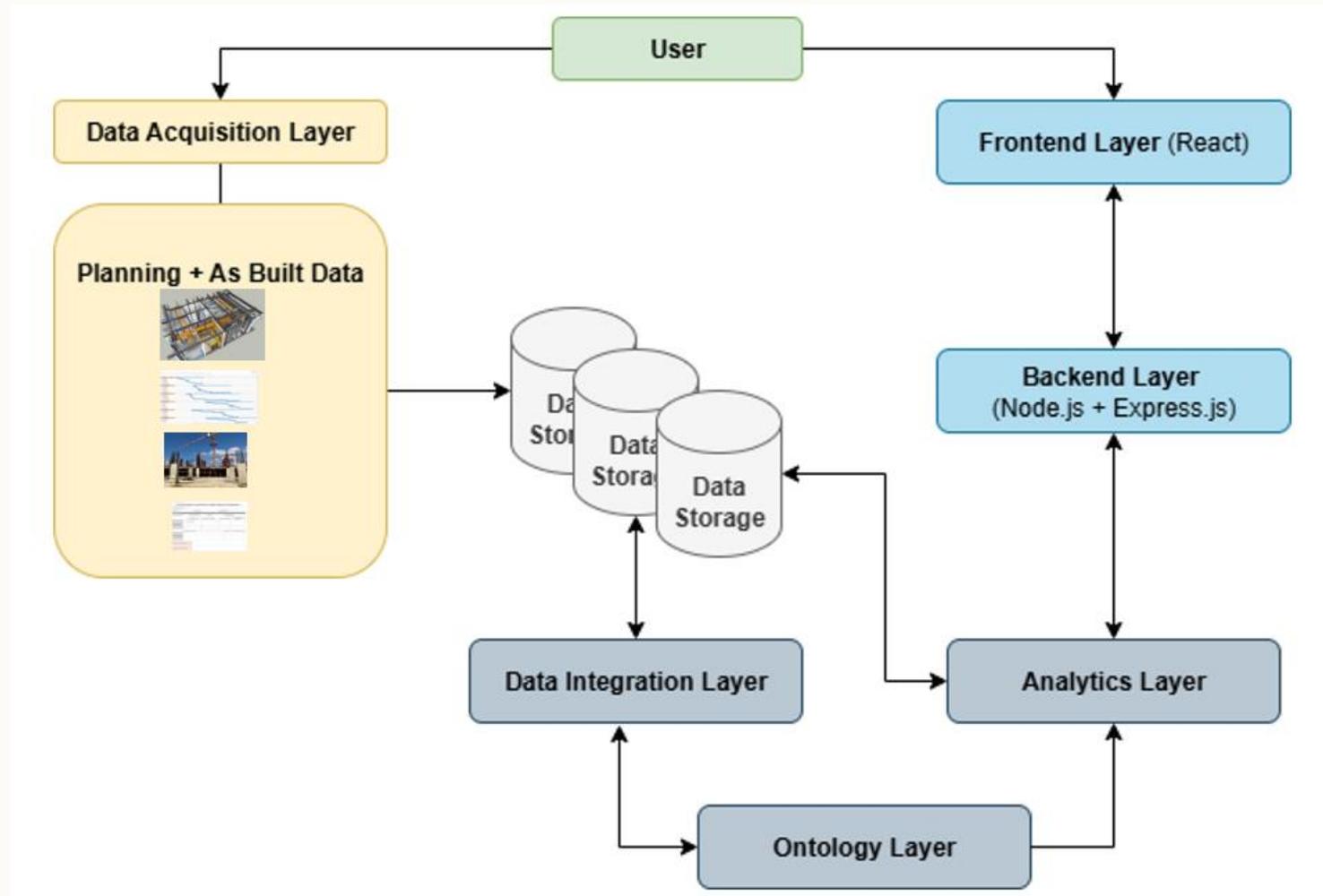
Construction Progress Monitoring System

- Key Considerations for System Design:
 - Physical Progress representation
 - Determining the schedule compliance
 - Inclusion of data on inspections and formalities
 - Progress analysis and report generation
- System Design Features
 - Near real-time tracking (weekly update frequencies)
 - Ability to be used collaboratively
 - Clear visual and analytical representation of the progress
 - Capability of tracking activities within the site
 - Capability of generating progress reports
 - Actual vs Planned dashboard representation



System Architecture

- The proposed ontology-based construction progress monitoring follows a six-layered system architecture focusing on data acquisition, integration, processing, storing, and visualisation.





Data Acquisition Layer

- Collection of planning and as-built data.
- Pre-processed data will be utilised.
- Input data types;
 - BIM model
 - As-Planned Schedule
 - Pre-processed visual captures
 - Event logs and reports
 - External data: weather (from an API)



Data Integration Layer

- Transformation of heterogeneous input data into semantically enriched data aligned with the ontology.
- Convert relevant data from their native formats to RDF.
- Map each data item with the ontology.
- Validate data using SHACL to ensure it conforms to the ontology schema.

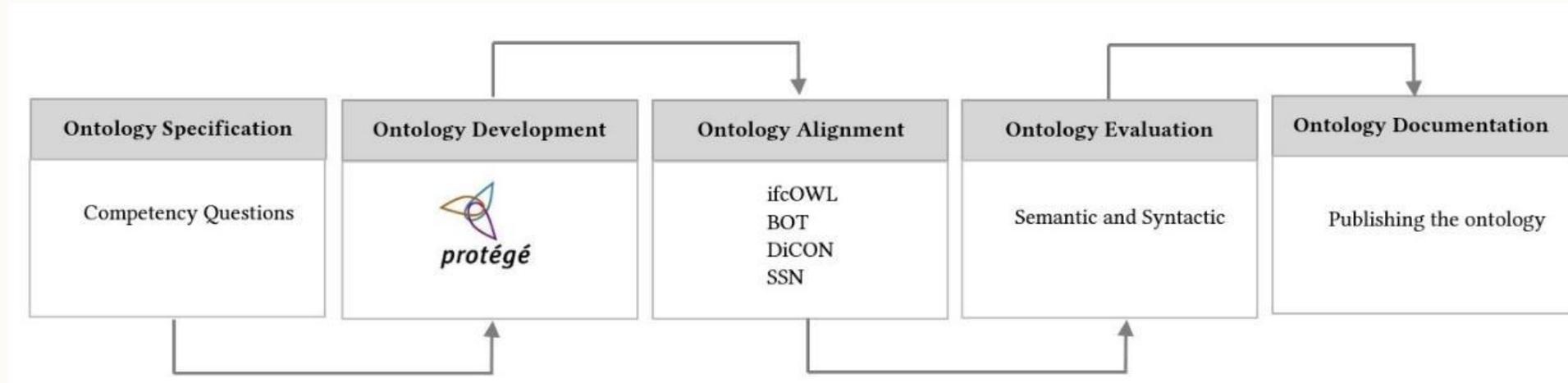


Ontology Layer

- Receives RDF triples from the Integration Layer, stores and connects them in a knowledge graph, and exposes them to the Analytics and Backend Layers.
- This layer is responsible for;
 - Defining classes and properties
 - Defining constraints
 - Defining and hosting logics and reasoning rules (SWRL)
 - Help create the knowledge graph



Ontology Layer CNTD..



- Purpose: Enable semantic integration of heterogeneous construction data for automated progress monitoring, milestone tracking, and schedule compliance.
- Scope: Data integration in a timely manner and construction activity representation, mapping tasks, dependencies and resource requirements.
- End users: This includes construction managers, site engineers, quantity surveyors etc.

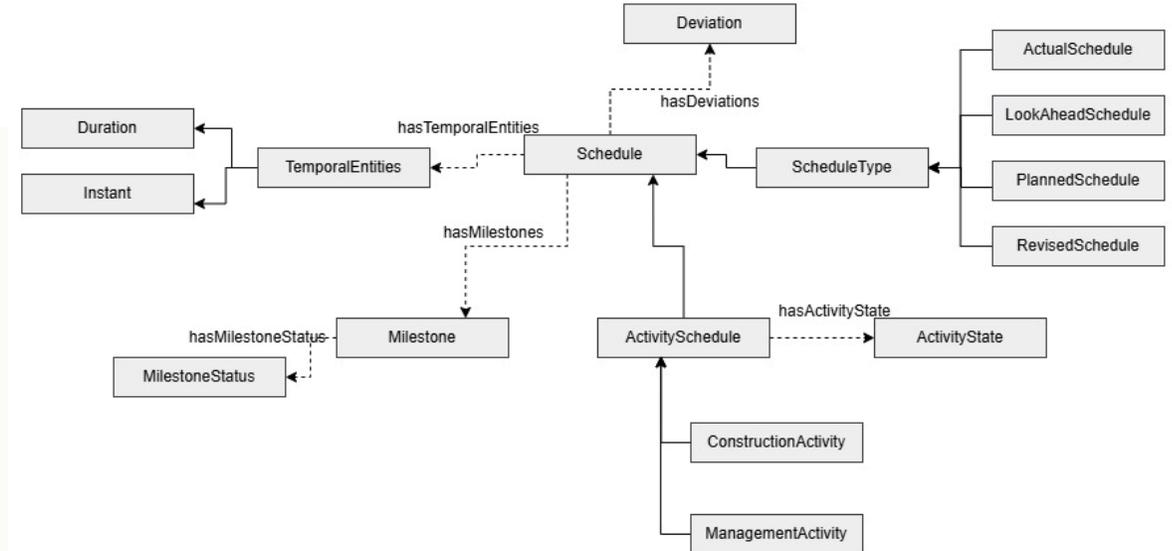
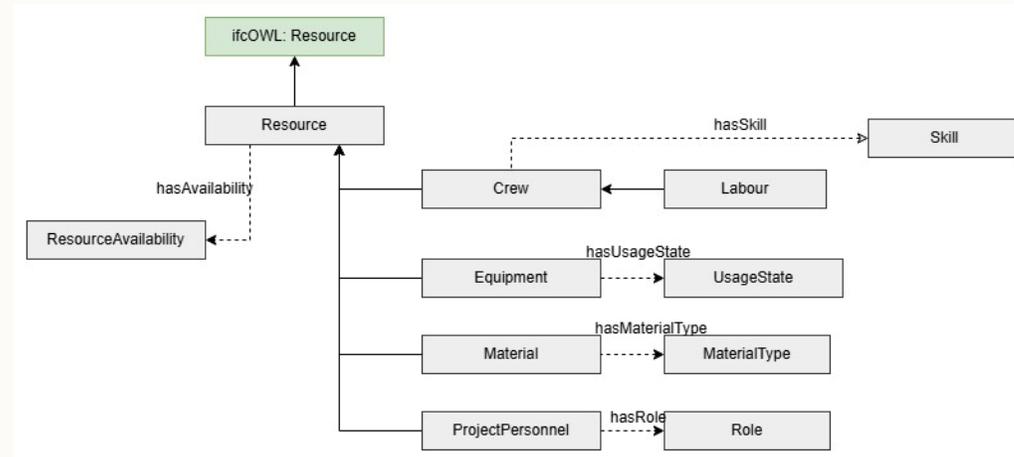
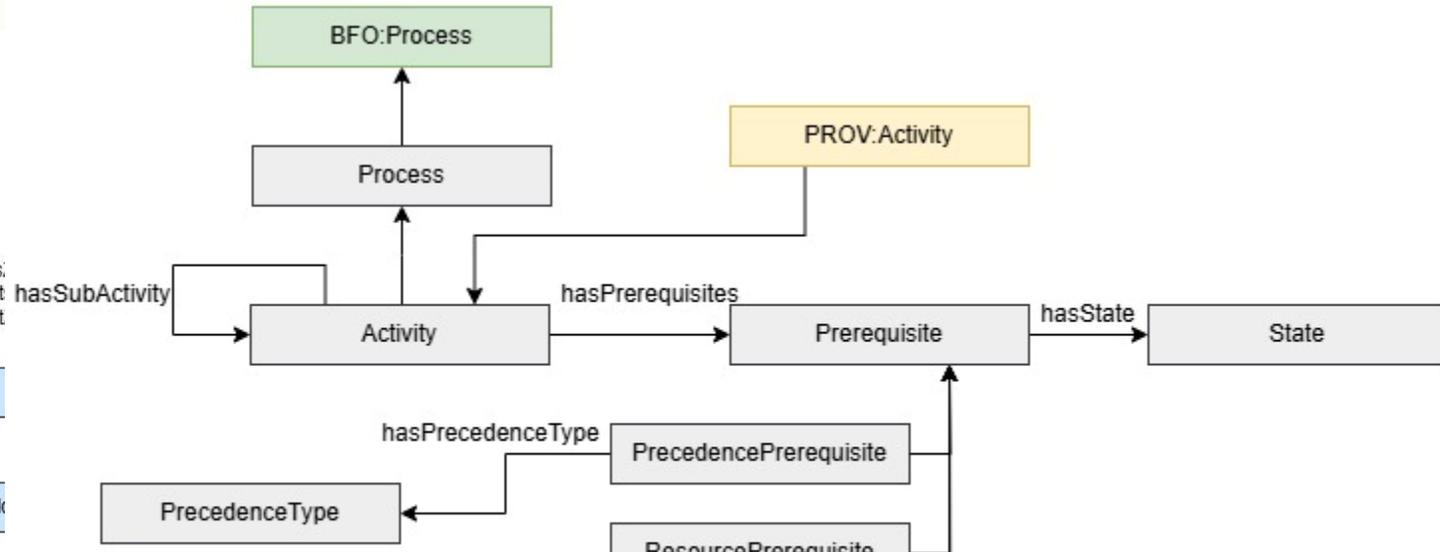
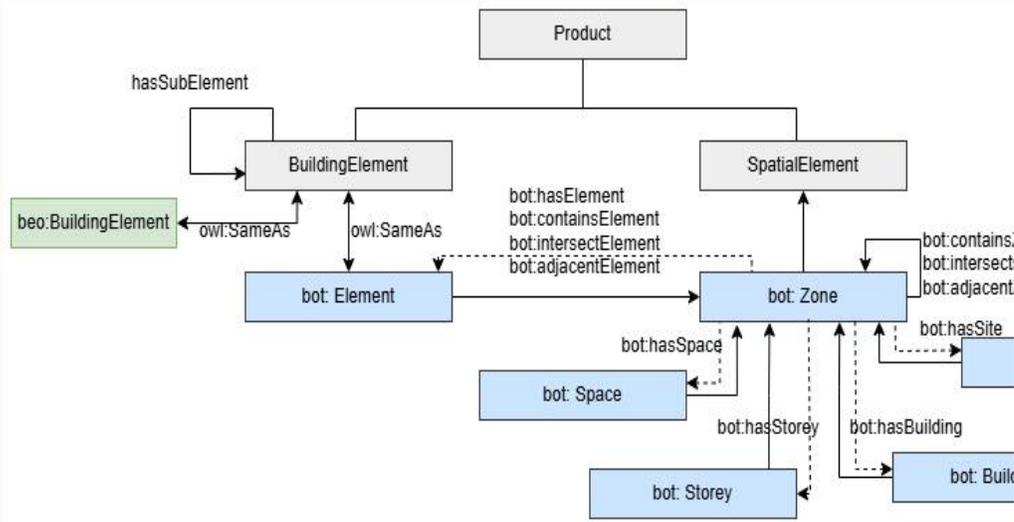


Ontology Development – Modular Approach

- The proposed ontology consists of five domain-specific modules and a core module that integrates them into a unified knowledge base.
 - **OntoProduct** (Product Module): Represents physical and spatial components in a construction project.
 - **OntoProcess** (Process Module): Defines construction workflows, task dependencies, and execution sequences.
 - **OntoResource** (Resource Module): Represents labour, equipment, and materials used in construction.
 - **OntoSchedule** (Schedule Module): Handles scheduling concepts, milestones, and timeline constraints.
 - **OntoData** (Data Module): Represent, describe, and manage the metadata of all incoming data streams used in the progress monitoring process
 - **OntoPMS** (Core Module): Integrates all other modules, providing logical axioms, reasoning rules, and cross-domain relationships for progress monitoring.



Modular Approach Cntd...





Analytics Layer

- To provide automated reasoning, KPI computation, and rule-based insights over the knowledge graph.
- Apply SWRL rules to infer knowledge.
- Run SPARQL queries to derive insights.
- Compute KPIs for the progress monitoring.



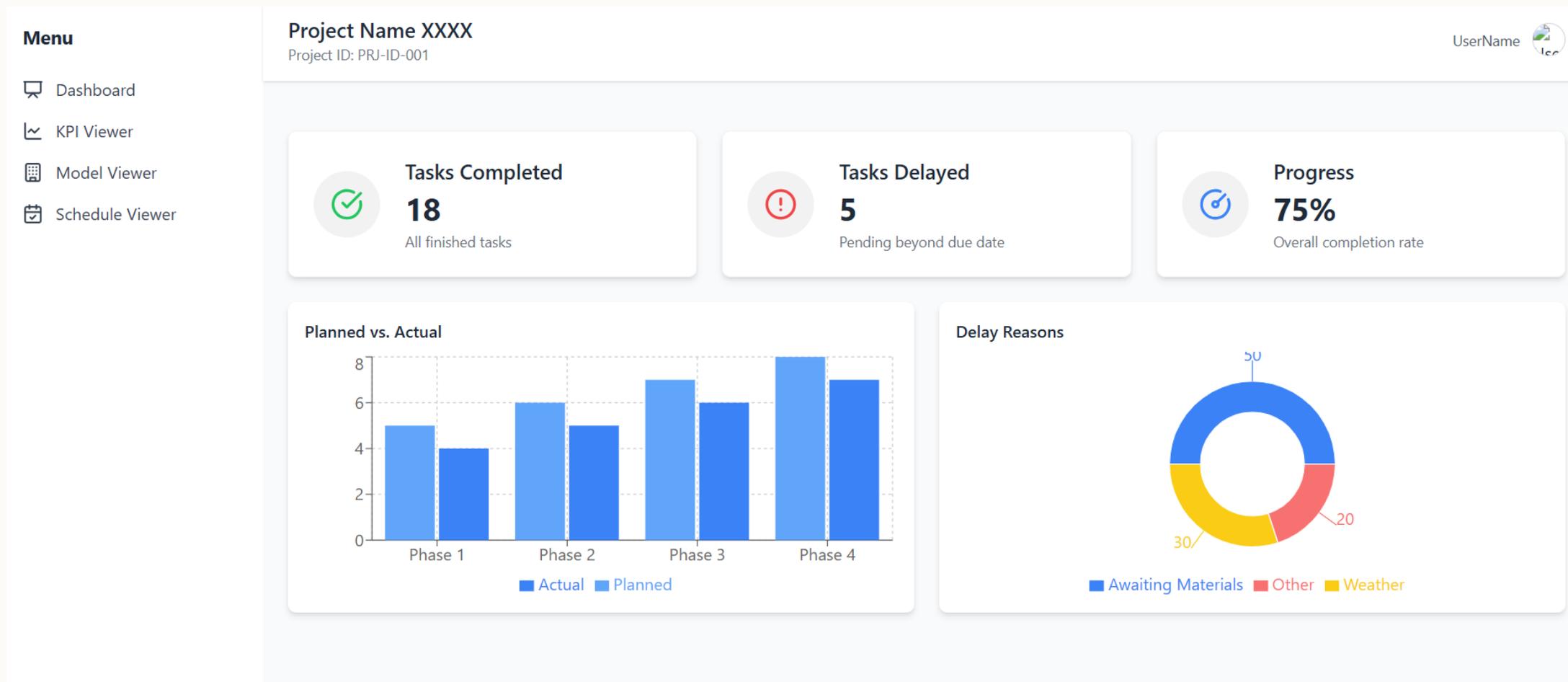
Backend Layer

- To manage data access, execute SPARQL queries, and handle communication between the frontend and the semantic system.
- Tools and Frameworks utilised;
 - Express.js + Node.js (REST API backend)
 - Apache Jena Fuseki (SPARQL endpoint)
 - SPARQLWrapper / AXIOS (HTTP-based queries)



Frontend Layer

- To provide a user interface and 3D visualisation.





Conclusions and Future Work

- This study introduced a conceptual framework for ontology-based construction progress monitoring.
- Focuses on tackling data fragmentation and interoperability through semantic web technologies.
- Framework integrates heterogeneous data (as-planned, as-built, visual, schedule, etc.) via a modular ontology.
- Enables automated reasoning, milestone verification, and schedule compliance checks.
- Future works:
 - Validate and test the framework through synthetic and real-world case studies.
 - Enhance scalability and accuracy for broader industry adoption.



University of
Nottingham
UK | CHINA | MALAYSIA

Thank you