# AGENT-BASED MODELING AND SIMULATION OF CONSTRUCTION CREW PERFORMANCE





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# Background

Delays in construction described as the time overrun beyond the specified completion date
(Assaf and Al-Hejji 2006)

56%

Projects suffer from uncertainties in both project objectives and means at the beginning of the project
(Howell et al. 1993)

Productivity has been declining for the past years
(Aziz and Hafez 2013)

Uncertainties in workflow and resource availability
(Ballard and Howell 1998)

Planning and control are at the core of construction management processes
(Alarcón and Calderón 2003)

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# Simulation

- Study, analyze, understand and improve systems and processes (lowering costs, optimizing schedules, …) (AbouRizk 2010)
- Cyclone, Stroboscope, Symphony, Anylogic

## DES

- Dynamic
- Stochastic
- Process-centric (chain of activities and resources linked together ) (Abou-Ibrahim et al. 2019)

## ABM

- Agents and their interactions
- High complex… interdepende…
- 3 aspects
  - Identify agents …
  - Agent relationsl…
  - Agent environm…

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# The Last Planner System

1. Master scheduling
2. Phase scheduling
3. Lookahead planning
4. Weekly work planning

(Tommelein and Ballard 1997)

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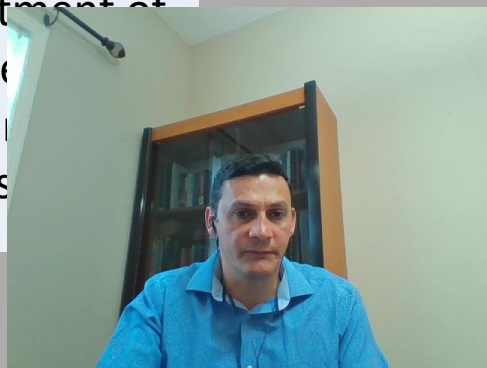
| Metrics | Ratio | Goal |
|---|---|---|
| Percent Plan Complete (PPC) | Activities completed to activities planned to be completed | Reliability of planning on the WWP level of the LPS |
| Percent Reliability Index (PRI) | Actual to planned progress | Reliability of planning at activity level (planning effectiveness) |
| Capacity to Load Ratio (CLR) | Activities done at the end of the WWP to all activities planned on the WWP | Ability of teams to efficiently use their resources and balance between their resources and load |
| Percent Improved Complete (PIC) | Improved activities during WWP to total number of activities that required improvement | Reliability and commitment of teams at the WWP le implement requi improvements |

(El Samad et al. 2017, Gonzalez et al. 2008, Rizk et al. 2017, Ezzeddine et al. 2019)



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# Methodology & Research Objectives

## RESEARCH METHOD : SIMULATION

OBJECTIVE : Use Simulation to Integrate Unforeseen Conditions and LPS Metrics into the Calculation of Crew Production Rates

**Inputs**

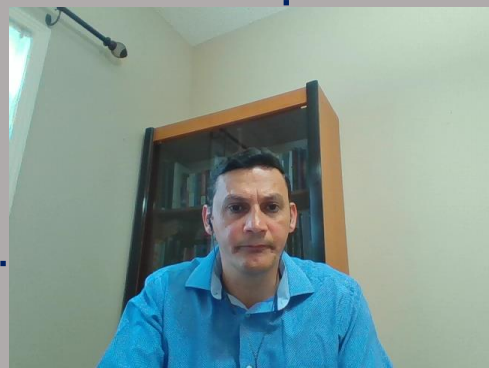
- Duration of Activity
- Minimum, mode and maximum values for PIC, PRI, PPC and CLR

**Input Analysis**

- DES
- ABM

**Output**

A more realistic production rate named Improved Production Rate (IPR)



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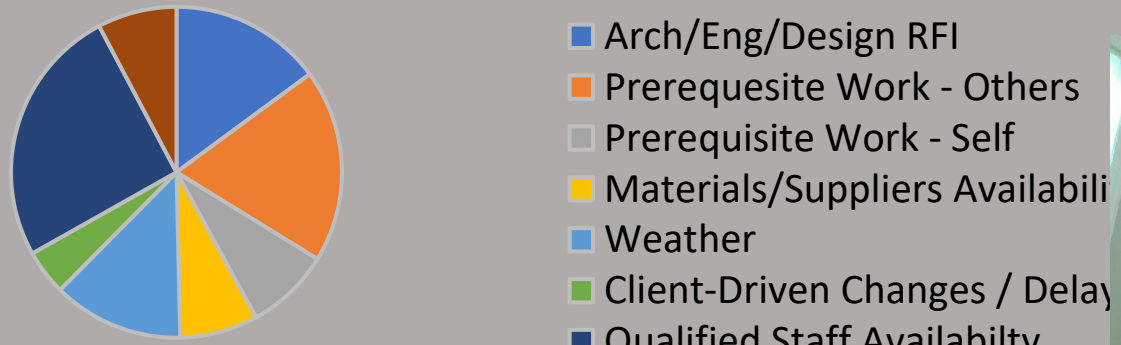
# Pharmaceutical Construction Project: Data acquired over a span of 94 weeks

## Data Sorting and Analysis

| Reason | Description | Frequency over 94 weeks |
|---|---|---|
| **Arch/Eng/Design RFI** | Information on design drawings from architects and engineers | 452 |
| **Prerequisite Work - Others** | Prerequisite work from other subcontractors is not ready | 573 |
| **Prerequisite Work - Self** | Prerequisite work from the main contractors is not ready | 250 |
| **Materials/Suppliers Availability** | Materials are not available from suppliers | 231 |
| **Weather** | Unforeseen weather conditions | 388 |
| **Client-Driven Changes / Delays** | Changes or delays from the client | 134 |
| **Qualified Staff Availability** | Unavailable human resources | 771 |
| **Safety non-conformance** | Inadequate safety measures and conditions | 235 |
| **Total** | | 3034 |

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# Modelling using

anylogic®

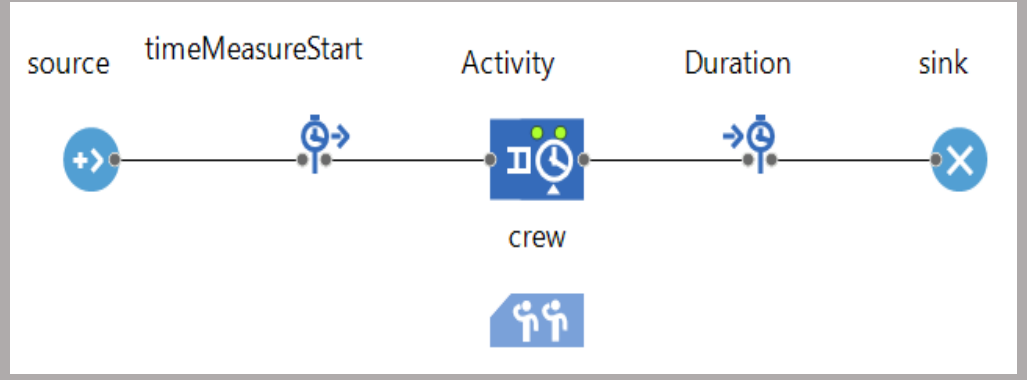


Figure 1 – Discrete-Event Process

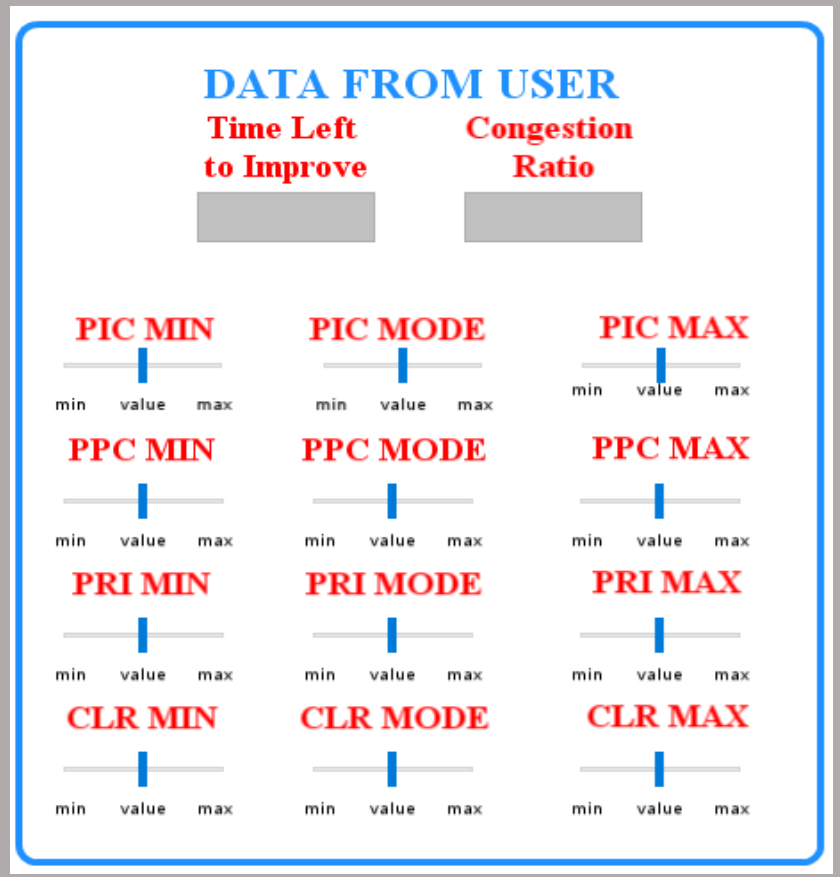


Figure 2 - User Dashboard

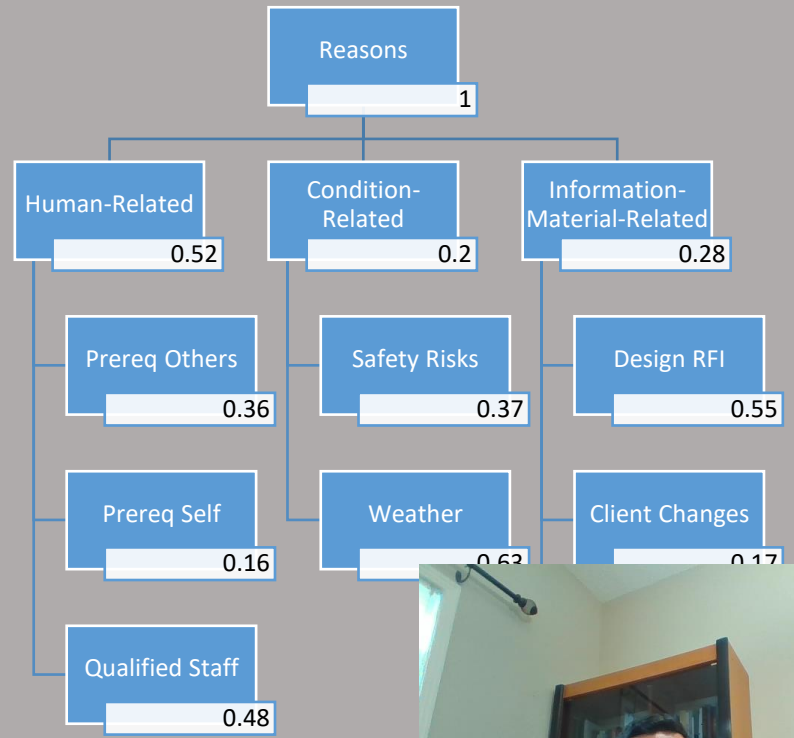


Figure 3 – Reasc

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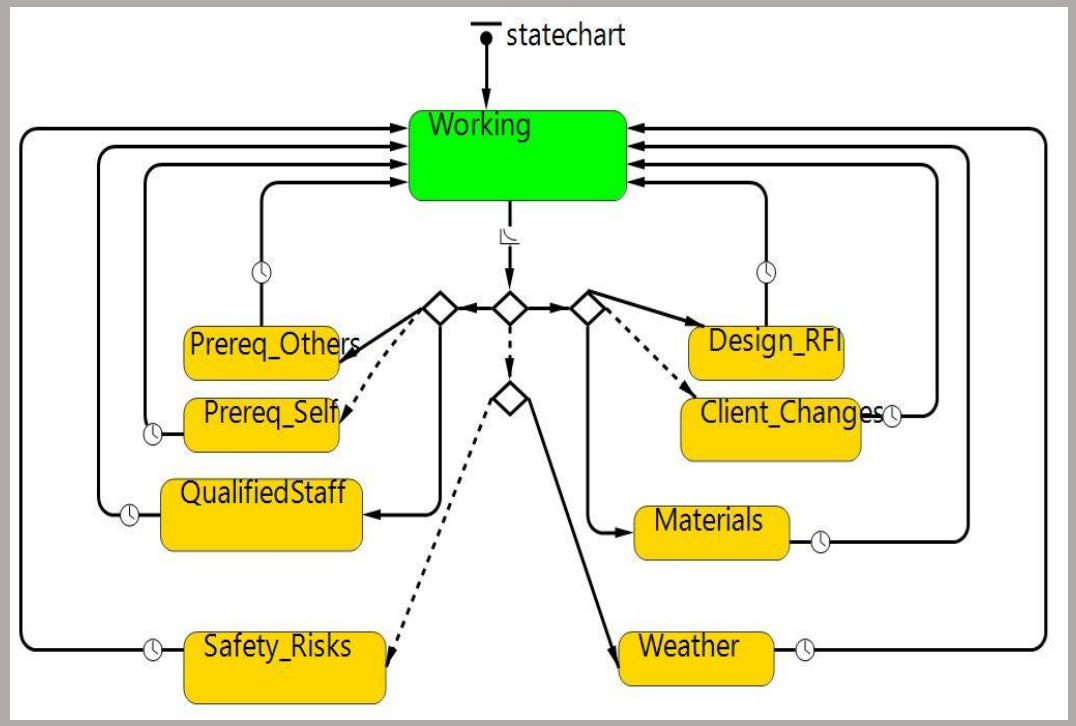
# Flowchart & Steps




Run the model

Realistic approximation of the rate that the crew will most probably work
work required, by taking into account unforeseen conditions and LPS metr

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# Three different scenarios of crew performances are simulated

| Experiment | Min. Metrics | Mode Metrics | Max. Metrics | Congestion | Mean Duration | Most Likely IPR |
|---|---|---|---|---|---|---|
| **Good performance** | 0.7 | 0.9 | 1 | 0.2 | 1.7 | 6.7 |
| **Average performance** | 0.4 | 0.6 | 0.8 | 0.5 | 3.91 | 3.74 |
| **Bad performance** | 0.1 | 0.4 | 0.5 | 0.9 | 28.05 | 1.1 |

Table 1 - Table Showing Simulation Results of Mean Durations and Most Likely IPR Values among Different Crew Perfor

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# Conclusions

The proposed tool showed its strength and potential in project monitoring and control

1

## Model Input

1. Duration or Time left to improve during the WWP
2. Crew performance metrics
3. Level of congestion during task execution

2

## ABM

ABM was used to take into account unforeseen delays in execution such as workers waiting on materials, information, or rework

3

## Model Output

Most Likely Production Rate which the Crews will work on

# Future Work

- Getting more accurate coefficient values for PIC, CLR, PPC, PRI, congestion, and idleness due to rework, lack of information, and lack of materials
- Testing this tool on several case study projects and comparing values of improved production rates from the simulation model
- Automating this framework to develop a practical u