

Planning and scheduling infrastructure projects for success

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- Scheduling Techniques
- Objectives and Schedule Influences
- Practical Constraints Affecting Schedules
- Uncertainties Associated with Construction



- Construction industry has considerable contribution to countries economy
- Over 80% of infrastructure projects completed behind schedule
- Top causes of delays in Infrastructure projects are:
 - Major change in design during construction;
 - Ineffective planning and scheduling;
 - Changes in the scope of the project; and
 - Slow decision-making.

Emam et al. (forthcoming)





Criteria Contributing to Schedules Quality of Programme. Emam *et al.* (2014)

Scheduling Variables

- Scheduling technique / representation;
- Objective-driven Scheduling;
- Constraints; and
- Uncertainties.

Scheduling Techniques



Classification of scheduling techniques (Kenley and Seppänen, 2009)

Scheduling Techniques – Activity-based

University of **Bolton**

							Critical Remaining Work
ID	Activity Name	Original Duration	Early Start	Early Finish	Actual Total Cost	At Completion J Total Cost	
GR impro	ovements Rye, Port Chester	539.00d	1-Jul-09	21-Dec-10	\$164,328.00	\$9,452,300.00	
A1010	Notice to Proceed	0.00d			\$0.00	\$0.00	Notice to Proceed
A6540	Mobilize on Site	5.00d	1-Jul-09	6-Jul-09	\$108,000.0C	\$360,000.00	Mobilize on Site
ALLOWA	NCES	465.88d	6-Jul-09	15-Oct-10	\$0.00	\$1,037,320.00	· · · · · · · · · · · · · · · · · · ·
A7120	Compensation for Track Outages-Allowance	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$100,000.00	
A7130	Historic Restoration-Allowance	300.00d	6-Jul-09	16-Sep-10	\$0.00	\$150,000.00	His
A7140	Artwork Installation-Allowance	300.00d	6-Jul-09	16-Sep-10	\$0.00	\$50,000.00	Art
A7430	Steel Repairs-Allowance	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$20,000.00	
A7640	Rock Removal-Allowance	100.00d	6-Jul-09	30-Nov-09	\$0.00	\$13,500.00	Rock Removal-Allowance
A7650	Haul and Dispose Non-Haz Material-Allowa	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$10,000.00	
A7660	Haul and Dispose Hazardous Material-Allo	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$22,500.00	
A7670	Relocate Haz Material on site-Allowance	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$1,750.00	
A7810	Crack Repair - 1350lf-Allowance	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$98,550.00	
A7820	Spall Repair - 640 sf-Allowance	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$165,120.00	
A7830	Elastometric Bearing 99@\$4,100 ea-Allowa	320.00d	6-Jul-09	15-Oct-10	\$0.00	\$405,900.00	
GENERA	L REQUIREMENTS	436.88d	6-Jul-09	16-Sep-10	\$31,785.00	\$180,000.00	▼ 13-Jul-10
A7240	General Requirements to be billed at % co	300.00d	6-Jul-09	16-Sep-10	\$31,785.00	\$180,000.00	General R
SUBMITT	AL, REVIEW AND PROCURE	195.00d	1-Jul-09	11-Jan-10	\$0.00	\$0.00	11-Jan-10, SUBMITTAL, RE
SUBMIT	TALS	143.00d	1-Jul-09	20-Nov-09	\$0.00	\$0.00	20-Nov-09, SUBMITTALS
A2860	Lighting Package-Submittal	30.00d	1-Jul-09	12-Aug-09	\$0.00	\$0.00	Lighting Package Submittal
A2960	Panelboards-Submittal	30.00d	1-Jul-09	12-Aug-09	\$0.00	\$0.00	Panelpoards-Submittal
A6180	General Conditions and Requirement-Sub	20.00d	1-Jul-09	29-Jul-09	\$0.00	\$0.00	General Conditions and Requirement-Submi
A6190	Concrete, Cast in Place-Submittal	30.00d	1-Jul-09	12-Aug-09	\$0.00	\$0.00	Goncrete, Cast in Place-Submittal
A6210	Structural Steel-Submittal	30.00d	1-Jul-09	12-Aug-09	\$0.00	\$0.00	Structural Steel-Supmittal
A6680	Cap and Bearing Steel-Submittal	25.00d	1-Jul-09	5-Aug-09	\$0.00	\$0.00	Cap and Bearing See-Submittal
A6780	Work Platform-Submittal	35.00d	15-Jul-09	1-Sep-09	\$0.00	\$0.00	Work Platform-Submittal
A6690	Guard Rail Steel Shop Dwgs-Submittal	25.00d	29-Jul-09	1-Sep-09	\$0.00	\$0.00	Guard Rail Stee Shop Dwgs-Submittal
A6280	Paint-Submittal	15.00d	12-Aug-09	1-Sep-09	\$0.00	\$0.00	Paint-Submittal
A6300	Communications Node-Submittal	15.00d	12-Aug-09	1-Sep-09	\$0.00	\$0.00	Communications Node-Submittal
A6550	PreCast Conc Steps and Ramps-Submittal	15.00d	12-Aug-09	1-Sep-09	\$0.00	\$0.00	PreCast Conc Sleps and Ramps-Submitt
A6700	E. Overpass Steel Stairs-Submittal	25.00d	12-Aug-09	16-Sep-09	\$0.00	\$0.00	E Overbass Steet Stairs-Submittal
A6200	Masonry-Submittal	15.00d	26-Aug-09	16-Sep-09	\$0.00	\$0.00	Masonry-Submitta
A6220	Metal Rails-Submittal	15.00d	24-Sep-09	15-Oct-09	\$0.00	\$0.00	Metal Rails Submittal

Activity-based planning

Scheduling Techniques – Activity Cyclic Planning



Analytical Design and Planning Technique (ADePT)

Scheduling Techniques – Activity Cyclic Planning

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Discrete Event Simulation

Scheduling Techniques – Location-based



Location-based planning

Scheduling Techniques

Type of Project	Scheduling method
Linear and continuous projects	LSM
Multiunit repetitive projects	LOB
High-rise buildings	LOB, VPM
Refineries and complex projects	PERT/CPM
Simple projects	Bar/Gantt charts

Selection of Scheduling Techniques (Yemin and Harmlink, 2002)

Schedules Objectives

Main objectives:

- Maximise Safe Work Conditions;
- Minimise Environmental Impact;
- Minimise Time;
- Minimise Cost;
- Maximise Quality; and
- Scope Coverage.

These objectives are conflicting in nature and require trade-offs. Project stakeholders will have different objectives priority



Schedule Constraints

The schedules normally are constrained due to several reasons thus:

- Precedence relationships;
- Space limitation;
- Resource availability;
- Resource continuity;
- Others

Schedule Models Philosophy

"Philosophy [nature] is written in that great book which ever is before our eyes -- I mean the universe -- but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. The book is written in mathematical language, and the symbols are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth."



Galileo Galilei

Schedule Model: A Deterministic Formulation

The following model captures a mathematical formulation for scheduling model that can be solved using linear optimisation technique.

- The model explicitly states the objective to minimise cost
- Subject to the following constraints
 - Precedence constraints i.e. relationships
 - Second constraint is to ensure the availability of resources is not exceeded

$$\begin{array}{ll} Min & C_n \\ s.t. & C_1 = 0 \\ & C_j - t_j \geq C_i \quad \forall (i, j) \in E \\ & \displaystyle \sum_{j \in \mathcal{A}(t)} r_{jk} \leq a_k \quad t = 1, 2, 3 \dots C_n; \, k = 1, 2, 3 \dots K \end{array}$$

Construction scheduling problems solved!

The straight answer is **NO**

The presented formulation has several shortfalls as follow:

- Uncertainties are not considered in the model
- It is static model which is not suitable to construction projects

Sources of Uncertainties

There are known knowns; there are things we know that we know.

There are known unknowns; that is to say, there are things that we now know we don't know.

But there are also unknown unknowns – there are things we do not know we don't know.

-Donald Rumsfeld



Sources of Uncertainties



(Loch, DeMeyer, Pich 2006)

Planning for Uncertainties



(Loch, DeMeyer, Pich 2006)

Risk Management Process



Risk Management – Current Practice

University of **Bolton**



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Risk Register



Quantitative analysis probability distribution

Risk Management – Integrated Framework



Integrating Uncertainty and Optimisation to maximise utilisation

Dynamic Planning for Changing Environment



Dynamic Planning

Dynamic scheduling is defined as

"the process of absorbing the effect of real-time events, analysing the current status of schedule, and automatically modifying the schedule with optimised measures in order to mitigate disruptions."

There are three main categories of Dynamic scheduling:

- Reactive scheduling
- Predictive-Reactive scheduling
- Robust scheduling

Dynamic Planning – Analytics



The Analytics Stages

Dynamic Planning – Reactive Scheduling



Successor Resources

Dynamic Planning – Robust Scheduling



Dynamic Planning – Predictive Reactive Scheduling



Scheduling Techniques – BIM Integrated



3. Operations simulation vv(Stroboscope)

Integrated BIM planning Framework Wang et al. (2014)

Conclusion

- Select appropriate scheduling technique that best models project characteristics;
- Set-up reporting system that allows for Big Data Analytics to reduce uncertainties;
- Communicate schedules efficiently and effectively with project stakeholders;
- Understand the dynamic nature of construction industry and be proactive and responsive to change;
- The Industry should move towards relational contracts;
- Provide technical training to planning and scheduling team to enable them to facilitate using advanced techniques.
- Blending available knowledge (Analytics, Simulation, Optimisation, BIM, etc.) to achieve best results.



Thank You

Questions & Answers

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