Planning and scheduling infrastructure projects for success

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Agenda

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

Introduction

- 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*)

Introduction

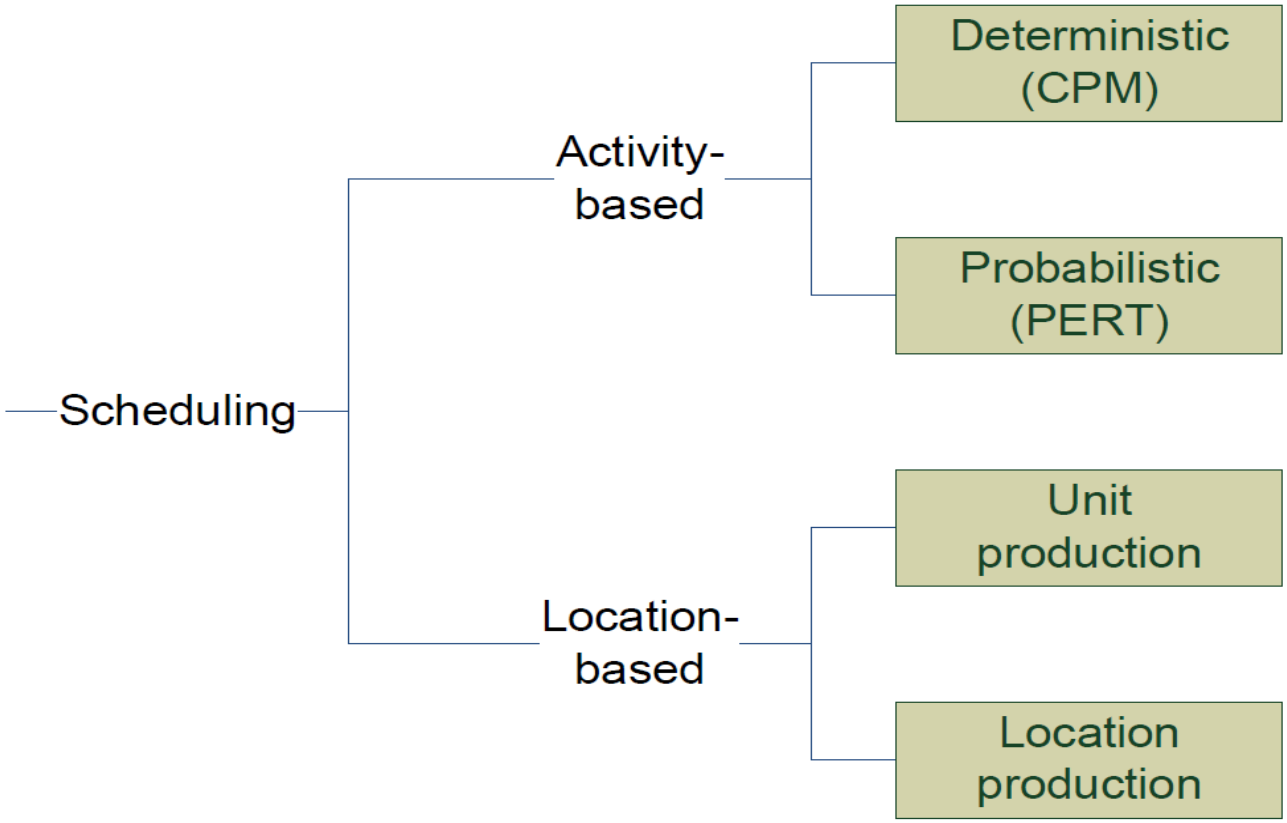
Rank	Description	Relative Importance
1	Contractual Related	0.88
2	Duration Estimation	0.80
3	Scheduling Parameters	0.79
4	Resources	0.76
5	Logic	0.70
6	Constraints	0.67

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

Date	Revision	Checked	Appr...
6-Nov-09	October update, Data Date Nov 6, 2009		

Actual Work
Remaining Work
Critical Remaining Work

Activity ID	Activity Name	Original Duration	Early Start	Early Finish	Actual Total Cost	At Completion Total Cost
SGR improvements 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
A6540	Mobilize on Site	5.00d	1-Jul-09	6-Jul-09	$108,000.00	$360,000.00
ALLOWANCES		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
A7140	Artwork Installation-Allowance	300.00d	6-Jul-09	16-Sep-10	$0.00	$50,000.00
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
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
GENERAL REQUIREMENTS		436.88d	6-Jul-09	16-Sep-10	$31,785.00	$180,000.00
A7240	General Requirements to be billed at % co...	300.00d	6-Jul-09	16-Sep-10	$31,785.00	$180,000.00
SUBMITTAL, REVIEW AND PROCURE...		195.00d	1-Jul-09	11-Jan-10	$0.00	$0.00
SUBMITTALS		143.00d	1-Jul-09	20-Nov-09	$0.00	$0.00
A2860	Lighting Package-Submittal	30.00d	1-Jul-09	12-Aug-09	$0.00	$0.00
A2960	Panelboards-Submittal	30.00d	1-Jul-09	12-Aug-09	$0.00	$0.00
A6180	General Conditions and Requirement-Sub...	20.00d	1-Jul-09	29-Jul-09	$0.00	$0.00
A6190	Concrete, Cast in Place-Submittal	30.00d	1-Jul-09	12-Aug-09	$0.00	$0.00
A6210	Structural Steel-Submittal	30.00d	1-Jul-09	12-Aug-09	$0.00	$0.00
A6680	Cap and Bearing Steel-Submittal	25.00d	1-Jul-09	5-Aug-09	$0.00	$0.00
A6780	Work Platform-Submittal	35.00d	15-Jul-09	1-Sep-09	$0.00	$0.00
A6690	Guard Rail Steel Shop Dwgs-Submittal	25.00d	29-Jul-09	1-Sep-09	$0.00	$0.00
A6280	Paint-Submittal	15.00d	12-Aug-09	1-Sep-09	$0.00	$0.00
A6300	Communications Node-Submittal	15.00d	12-Aug-09	1-Sep-09	$0.00	$0.00
A6550	PreCast Conc Steps and Ramps-Submittal	15.00d	12-Aug-09	1-Sep-09	$0.00	$0.00
A6700	E. Overpass Steel Stairs-Submittal	25.00d	12-Aug-09	16-Sep-09	$0.00	$0.00
A6200	Masonry-Submittal	15.00d	26-Aug-09	16-Sep-09	$0.00	$0.00
A6220	Metal Rails-Submittal	15.00d	24-Sep-09	15-Oct-09	$0.00	$0.00

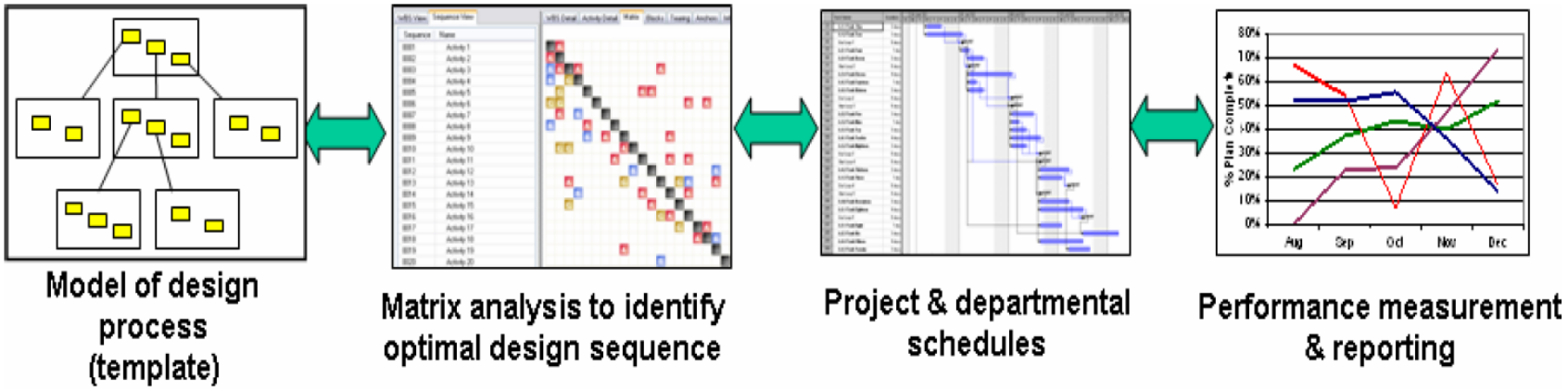
J A S O N D J F M A M J J A S O N D

Notice to Proceed
Mobilize on Site
13-Jul-10, GEN
11-Jan-10, SUBMITTAL, REVIEV
20-Nov-09, SUBMITTALS
Lighting Package-Submittal
Panelboards-Submittal
General Conditions and Requirement-Submittal
Concrete, Cast in Place-Submittal
Structural Steel-Submittal
Cap and Bearing Steel-Submittal
Work Platform-Submittal
Guard Rail Steel Shop Dwgs-Submittal
Paint-Submittal
Communications Node-Submittal
PreCast Conc Steps and Ramps-Submittal
E. Overpass Steel Stairs-Submittal
Masonry-Submittal
Metal Rails-Submittal

1 3-Dec-09 Rye Port Chester

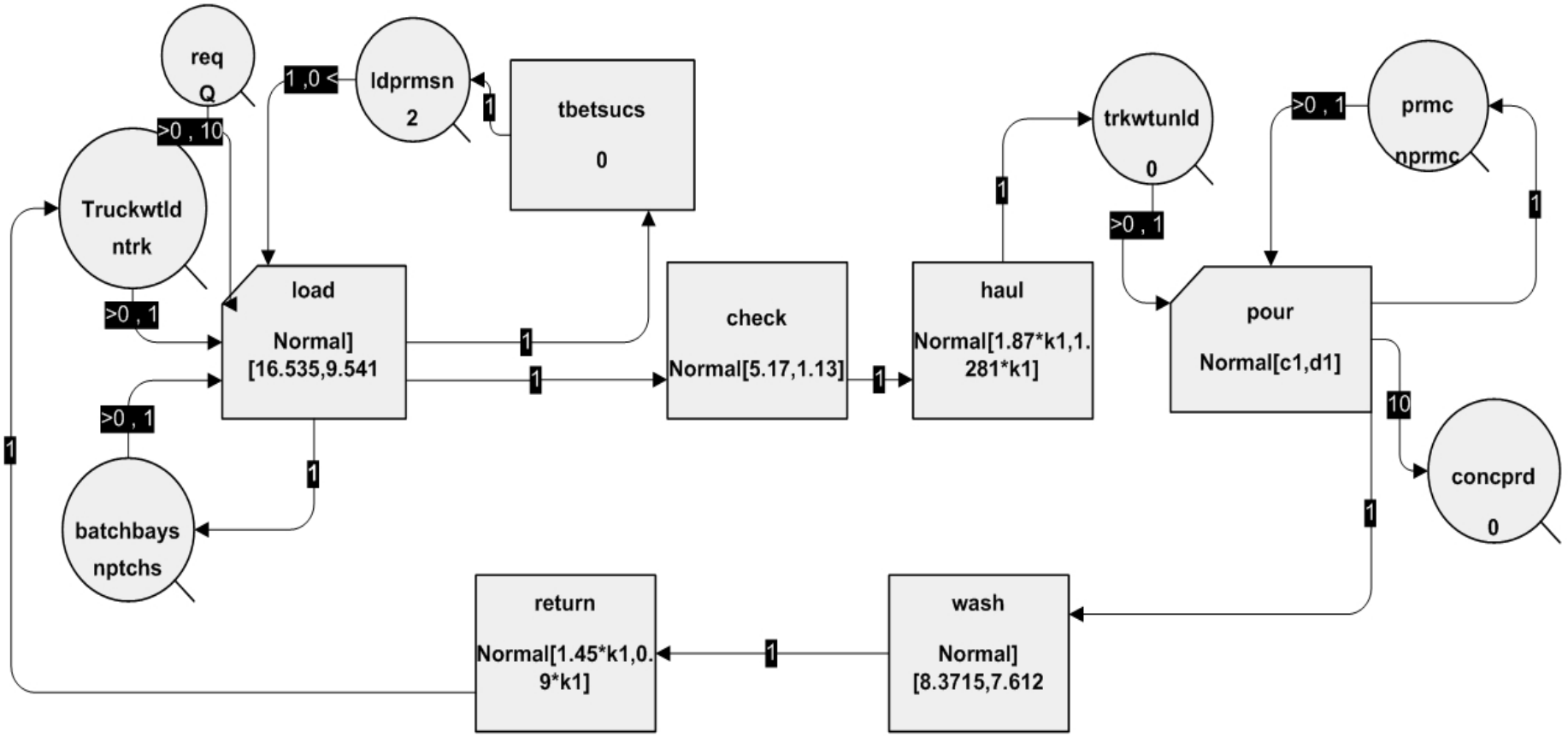
Activity-based planning

Scheduling Techniques – Activity Cyclic Planning

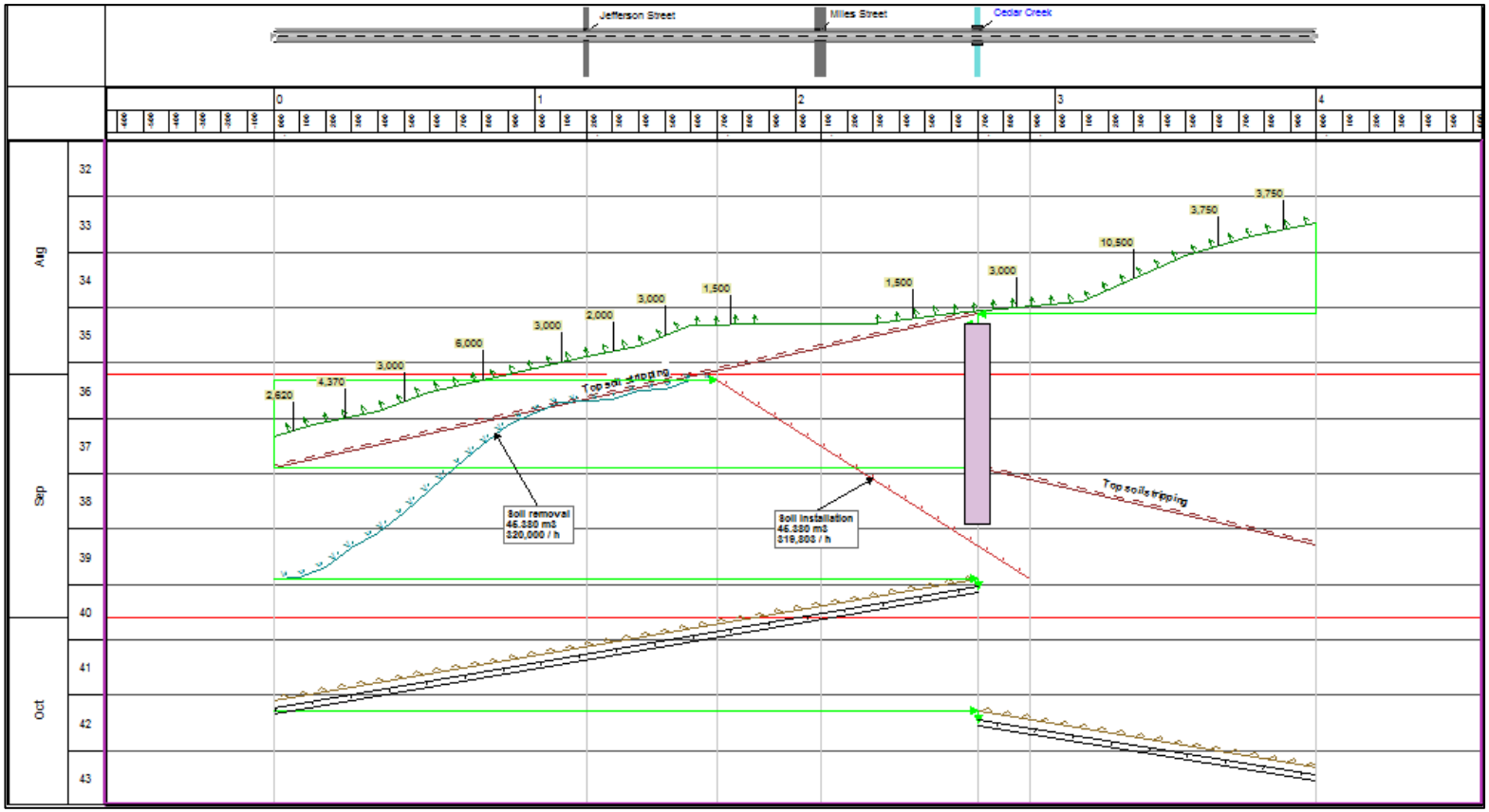


Analytical Design and Planning Technique (ADePT)

Scheduling Techniques – Activity Cyclic Planning



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

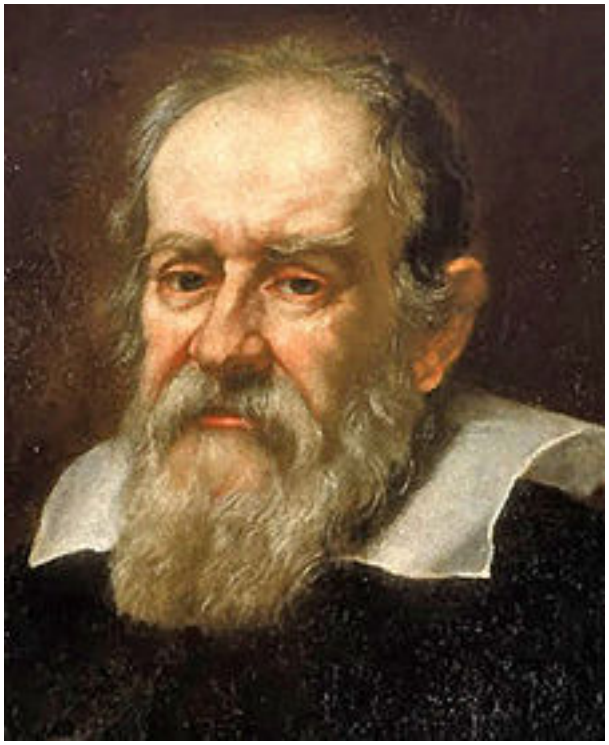
Schedule Constraints

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

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

Note: this is a sample formulations there are many other variations

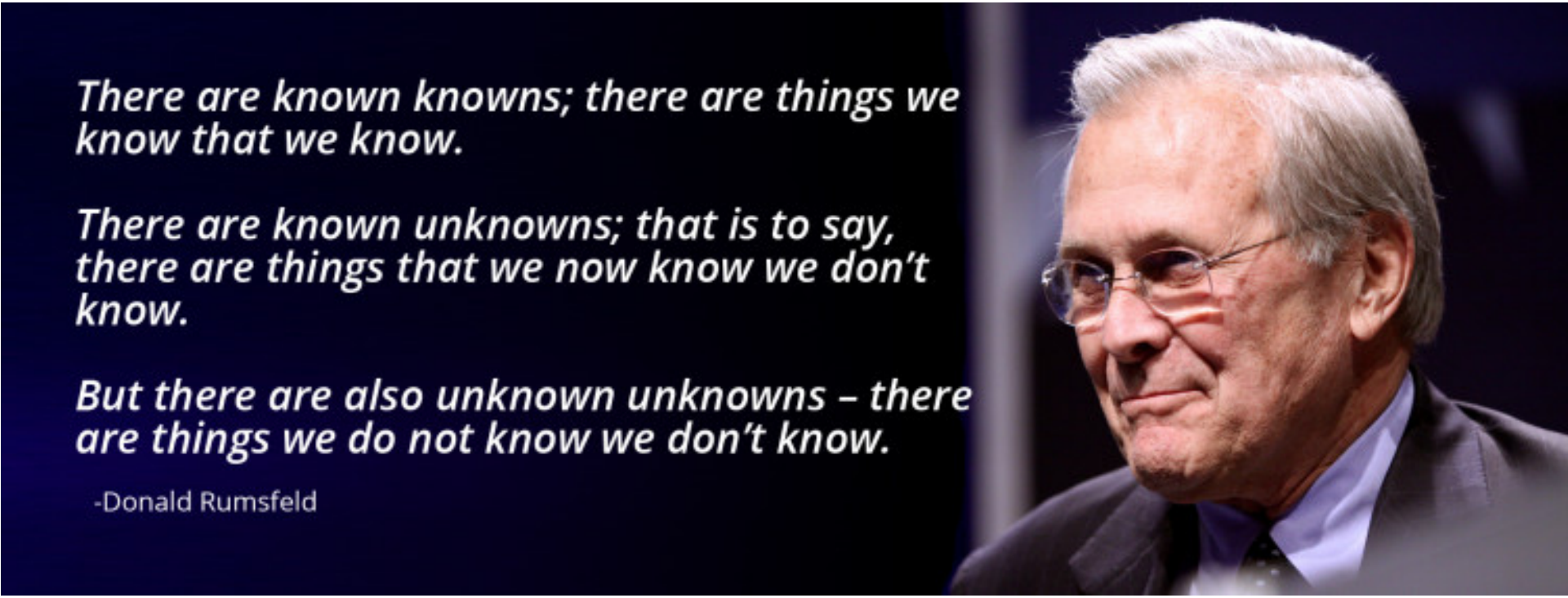
Construction scheduling problems solved!

The straight answer is **NO**

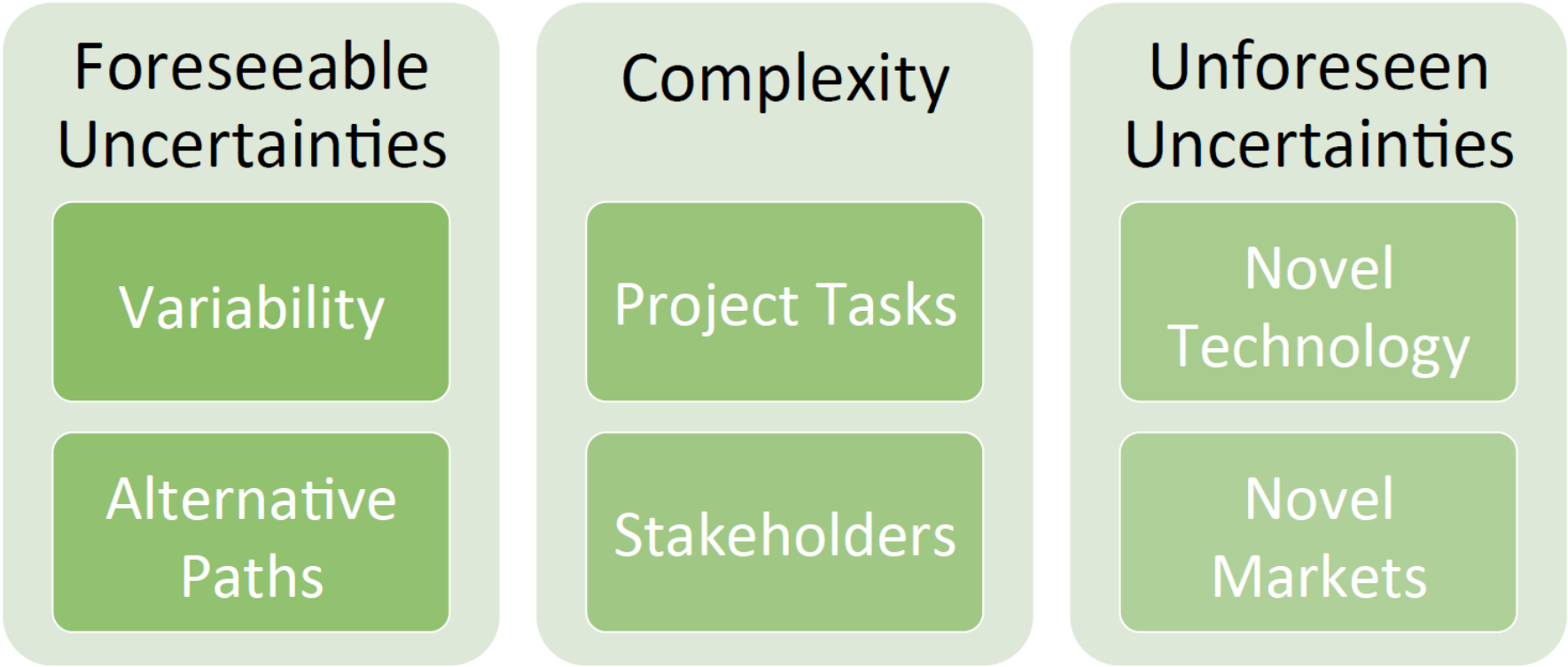
The presented formulation has several shortfalls as follow:

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

Sources of Uncertainties

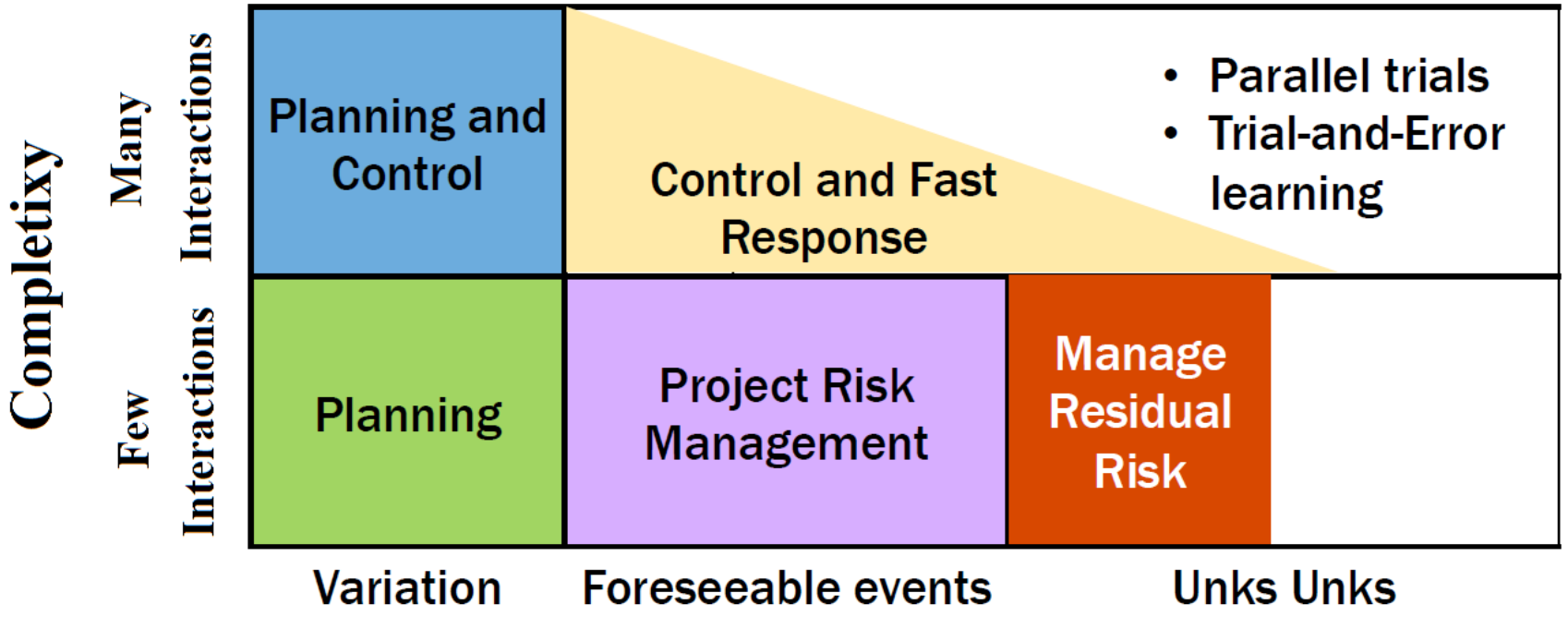


Sources of Uncertainties



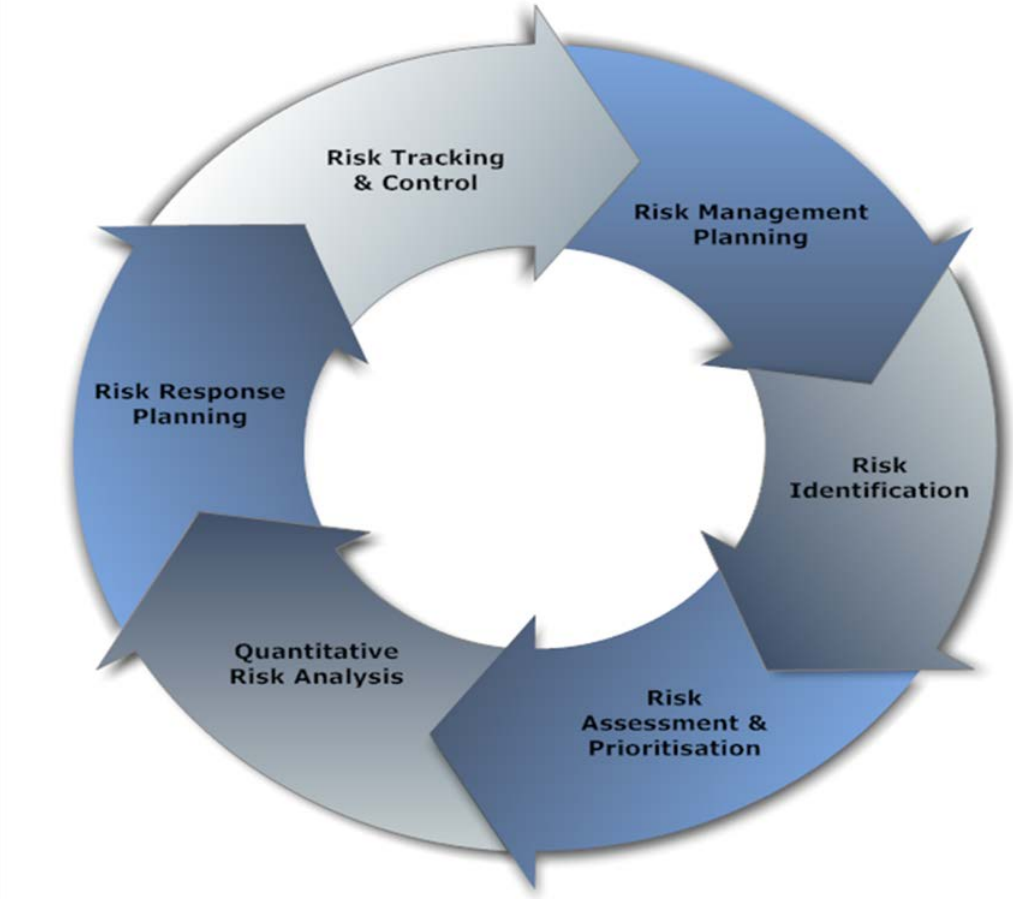
(Loch, DeMeyer, Pich 2006)

Planning for Uncertainties

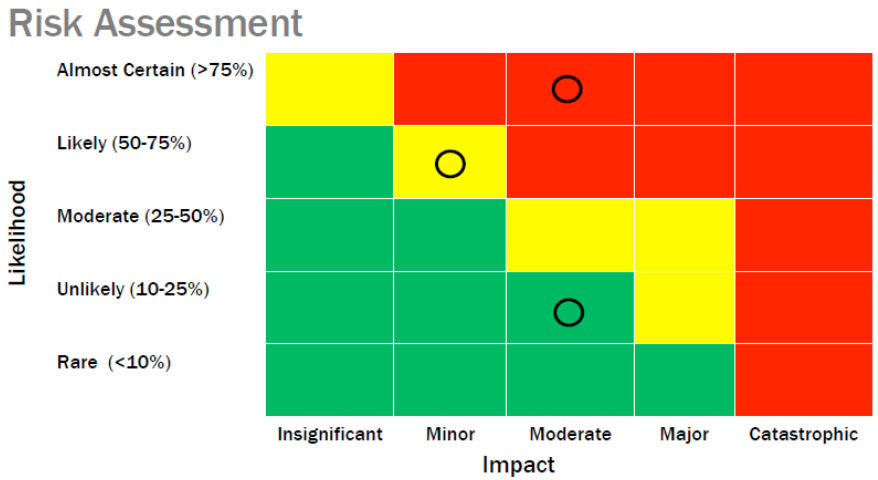


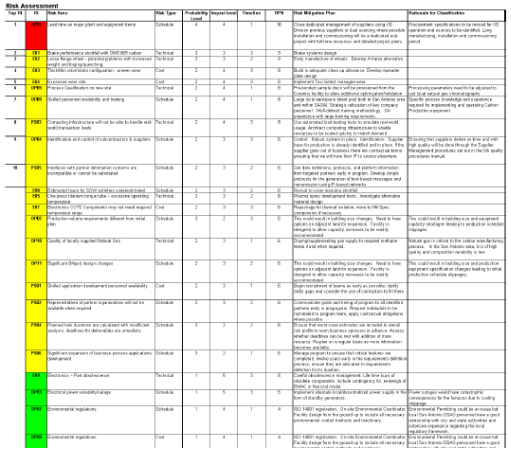
(Loch, DeMeyer, Pich 2006)

Risk Management Process

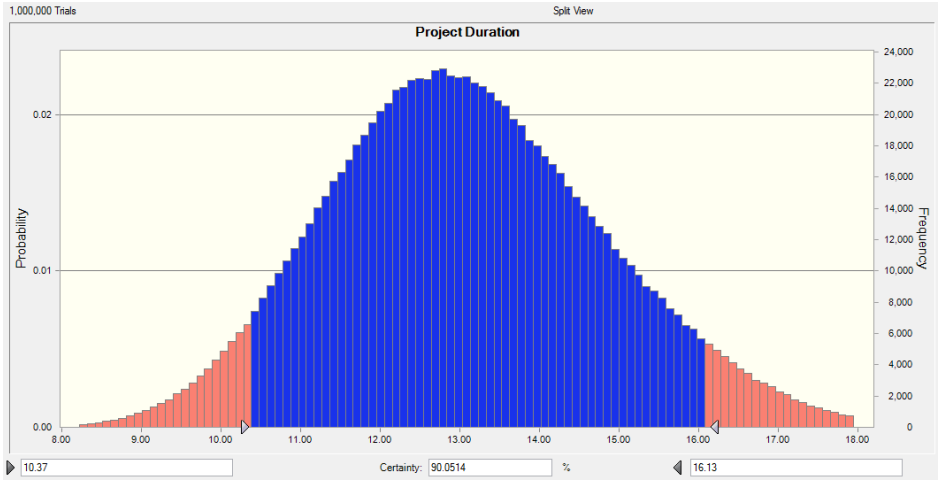


Risk Management – Current Practice



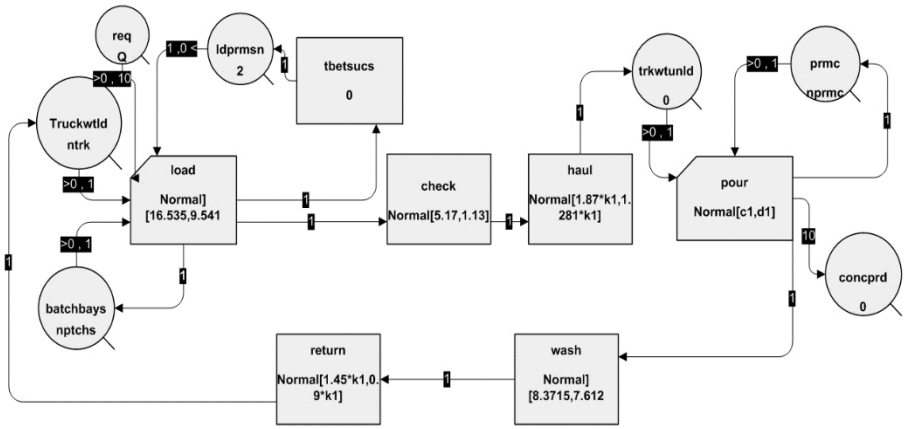


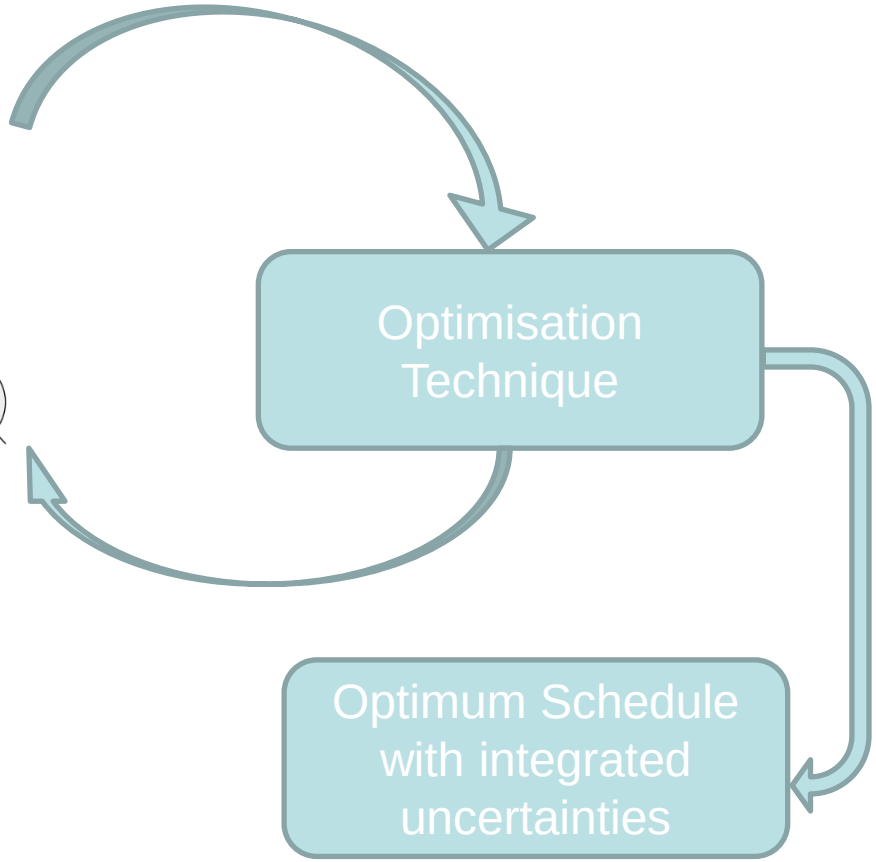
Risk Register



Quantitative analysis probability distribution

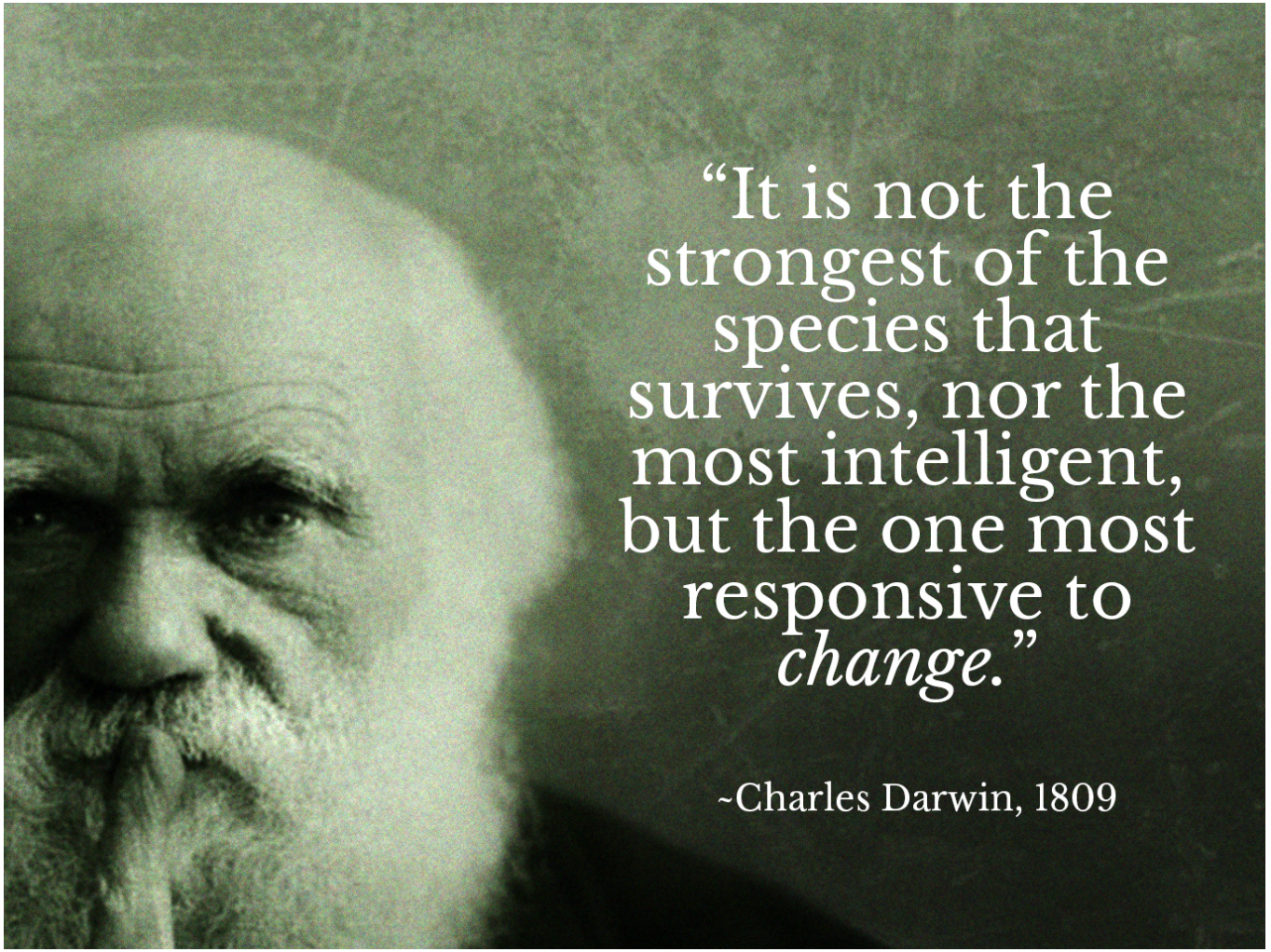
Risk Management – Integrated Framework





Integrating Uncertainty and Optimisation to maximise utilisation

Dynamic Planning for Changing Environment



Dynamic Planning

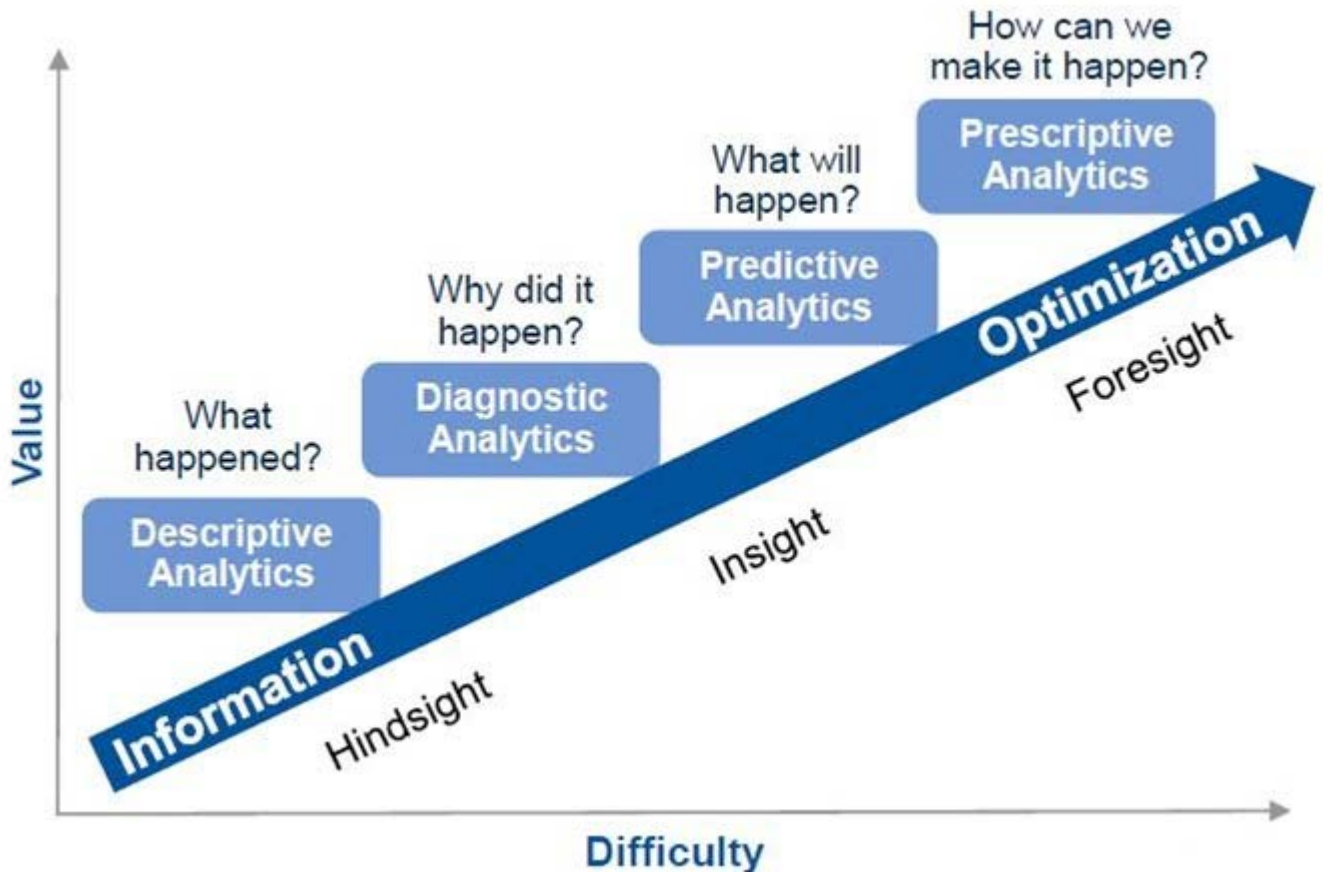
Dynamic scheduling is defined as

"*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:

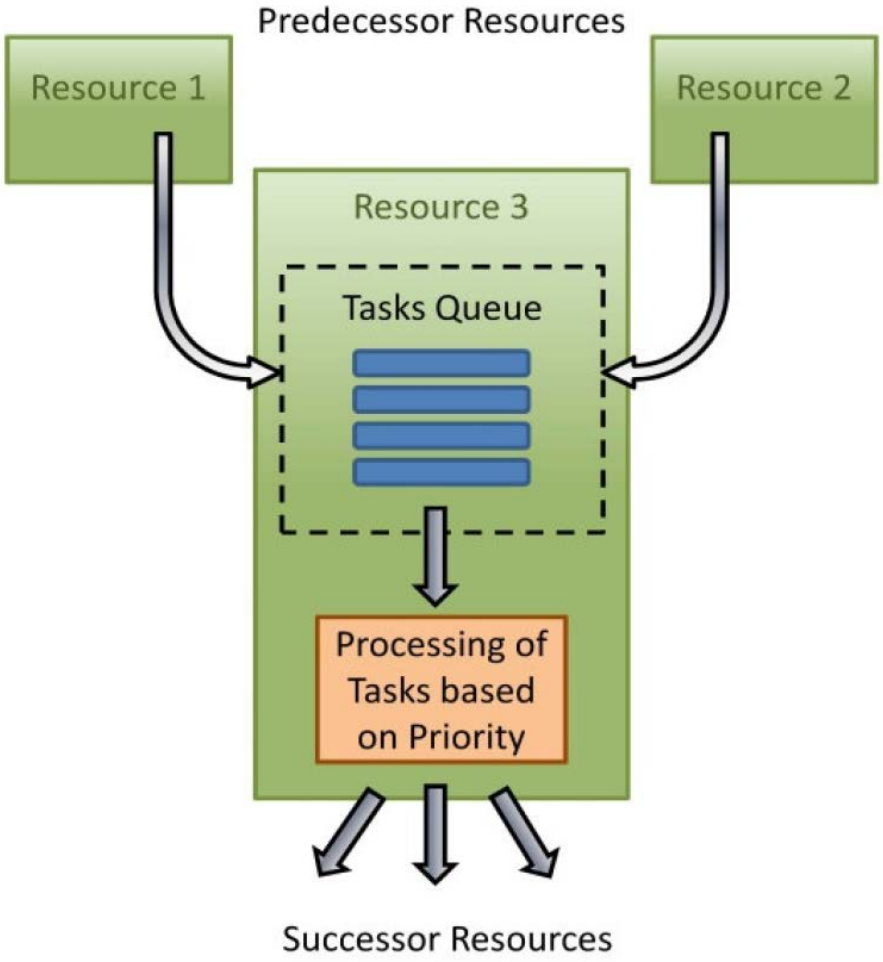
- Reactive scheduling
- Predictive-Reactive scheduling
- Robust scheduling

Dynamic Planning – Analytics

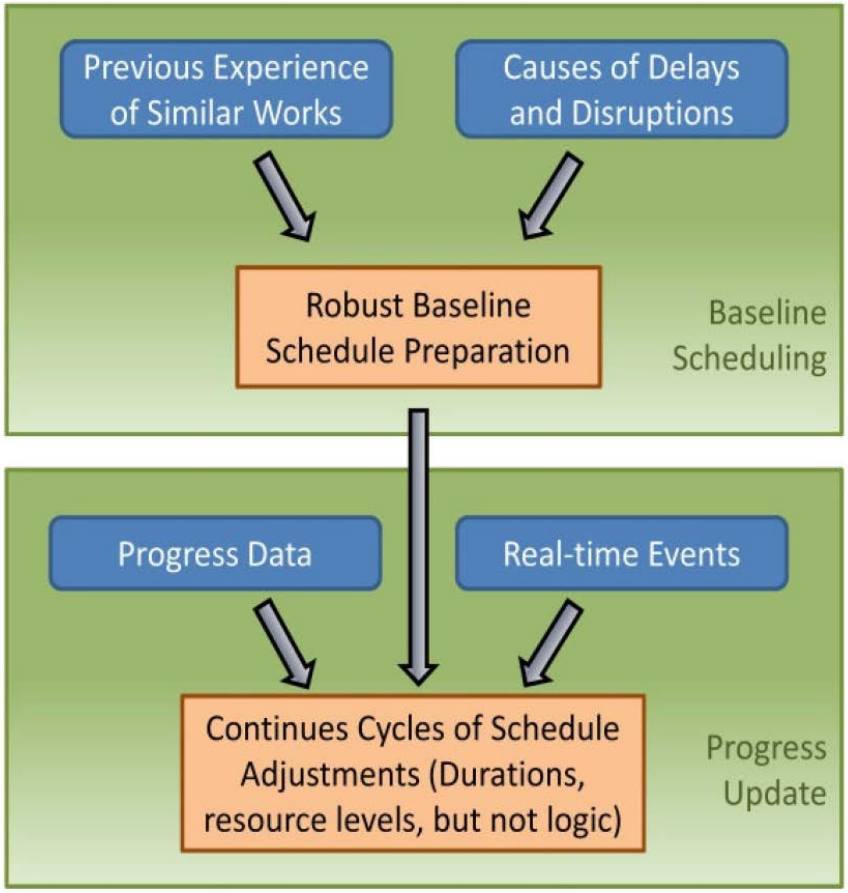


The Analytics Stages

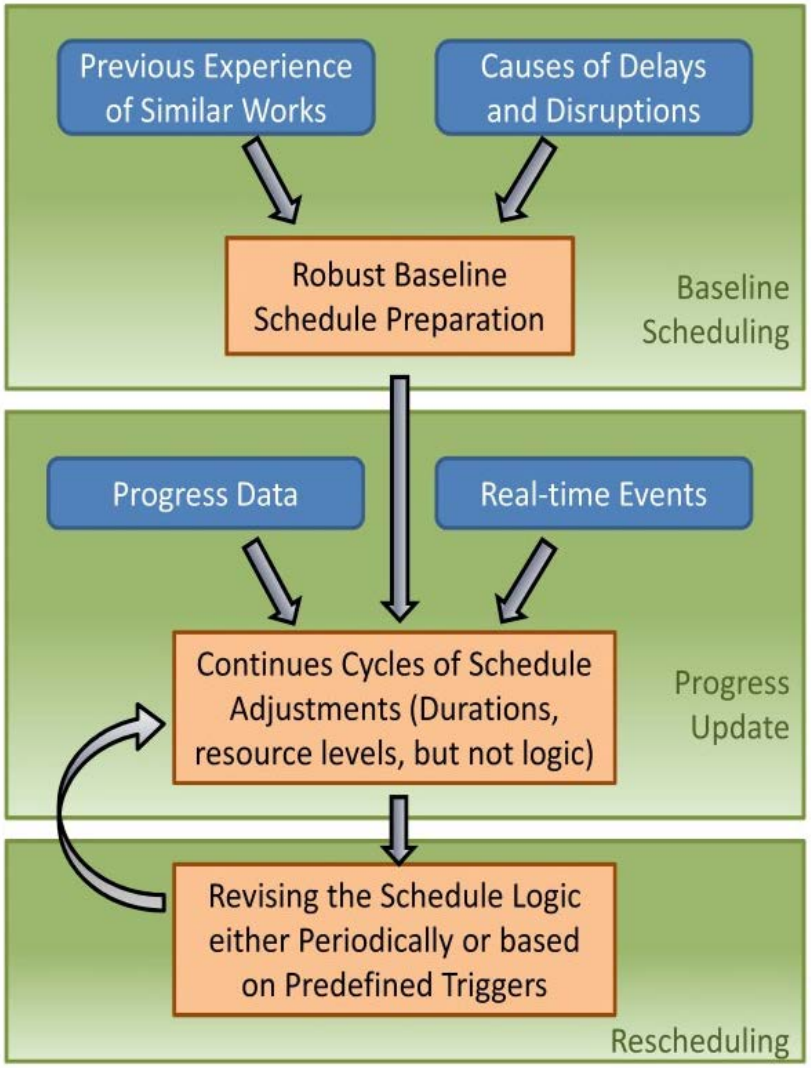
Dynamic Planning – Reactive Scheduling



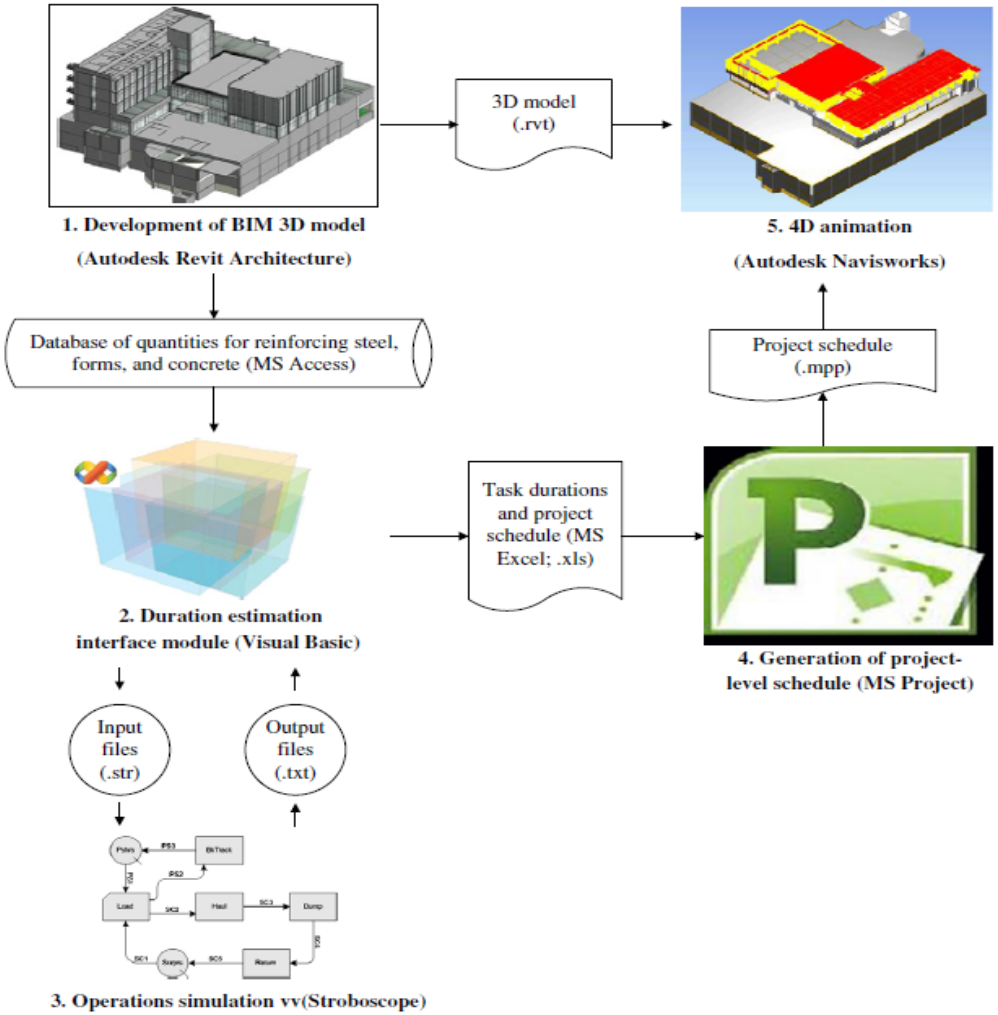
Dynamic Planning – Robust Scheduling



Dynamic Planning – Predictive Reactive Scheduling



Scheduling Techniques – BIM Integrated



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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