Design and Construction of Riyadh Metro Project – a Case Study

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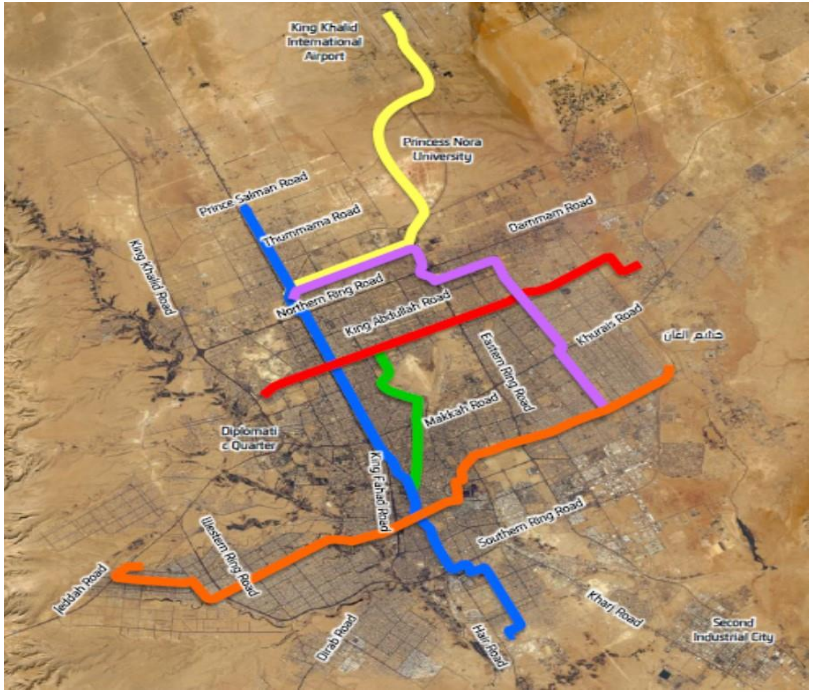
Contents

- Overview of Riyadh Metro Mega Project
- Challenges of Project Delivery
- Application of Concurrent Engineering to Design Phase
- Systems Engineering Practices
- Best practices and Take-Aways to other Greenfield Projects

Overview

- Largest Metro Project under construction in the world (USD 22bn)
- Total 6 lines, 175 km length, 85 stations
- Total 202 trains, 260 passengers/train
- 4 iconic stations, 5 transfer stations, 25 Park & Ride locations
- 7 depots and 12 power grid stations



Technology

- Fully automated driverless CBTC GoA4 based UTO operation
- Advanced Operation Control Centers (OCC)
- Integration of all OCC with Transportation Control Center (TCC)
- Modern Rolling Stock with unified design of trains

Project Delivery Organization

Line	Package	Design & Build Contractor	Engineer	Client
Line 1 Line 2	1	BACS	RMTC P1	Riyadh Development Authority (RDA)
Line 3	2	ANM	RMTC P2	
Line 4 Line 5 Line 6	3	FAST	RAMPED	

- Bechtel, Almabani, CCC and Siemens - BACS
- Salini Impregilo, Larsen & Toubro, Nesma, Ansaldo STS (now Hitachi), Bombardier, Idom and Worley Parsons - ANM;
- FCC, Samsung C&T, Alstom, Strukton, Freyssinet, Atkins, Typsa and Setec - FAST

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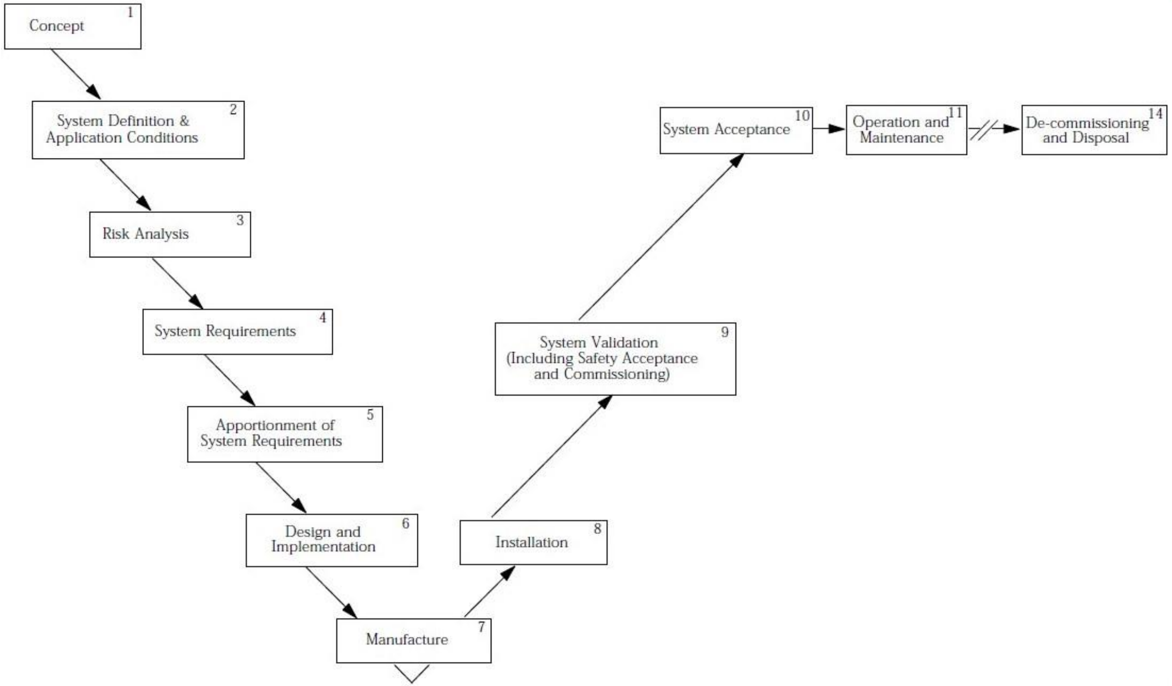
Delivery Schedule

- Mega infrastructure project to be delivered over a short period of time
- Delivery challenge to complete all 6 lines within an old and historic city
    - Interface issues with third parties (e.g. Wet and dry utilities, roads etc.,)

Sequential Development Cycle

- To deliver the Project as per Systems Engineering 'V' cycle as per EN 50126
- Strictly speaking construction only starts once design is finalized
- Schedule and cost impact



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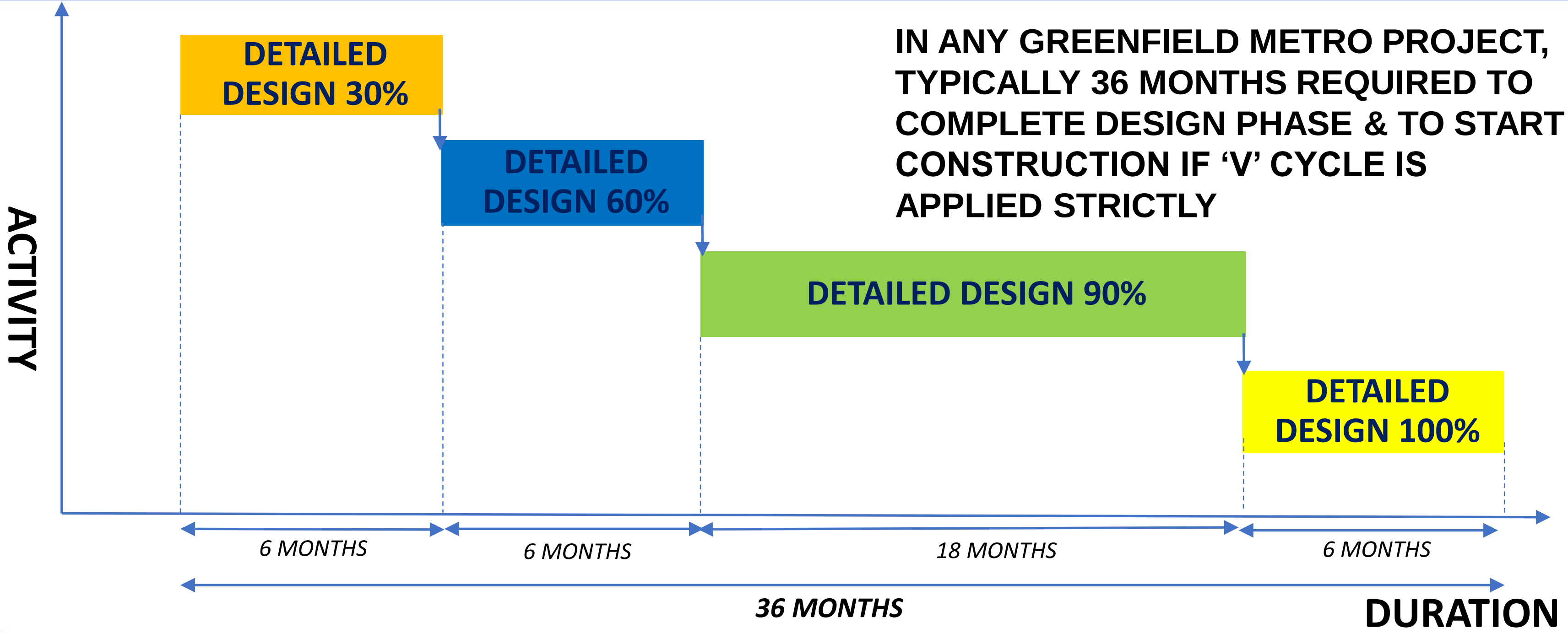
Railway Systems Engineering

- Railway is a complex distributed engineering systems
- Split between civil and system design
- Design development tends to be globally distributed
- Sequential design development, as implied by the V life cycle, consist of 4 fundamental consecutive steps:
  - Requirements and Specifications;
  - Design;
  - Implementation; and
  - Testing.

Typical Sequential logic – Design Phase

IN ANY GREENFIELD METRO PROJECT, TYPICALLY 36 MONTHS REQUIRED TO COMPLETE DESIGN PHASE & TO START CONSTRUCTION IF 'V' CYCLE IS APPLIED STRICTLY



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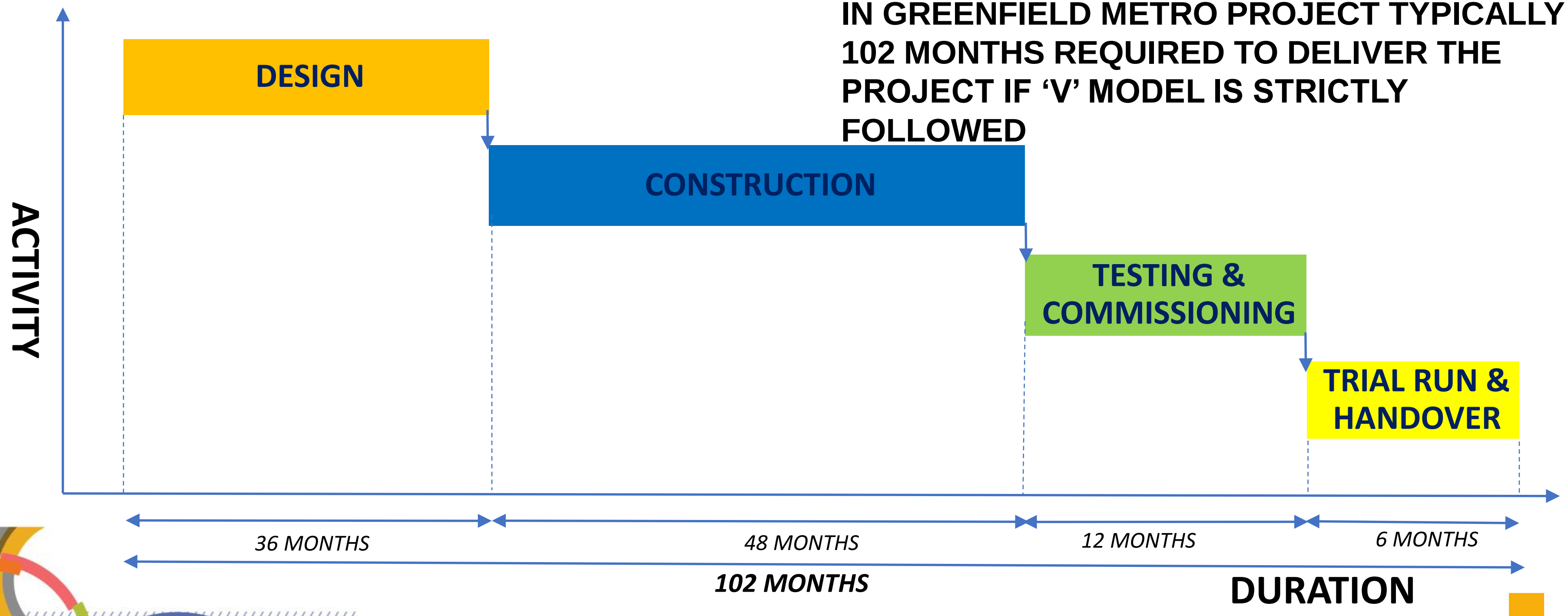
Sequential logic – Project completion

IN GREENFIELD METRO PROJECT TYPICALLY 102 MONTHS REQUIRED TO DELIVER THE PROJECT IF 'V' MODEL IS STRICTLY FOLLOWED



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Application of Concurrent Engineering

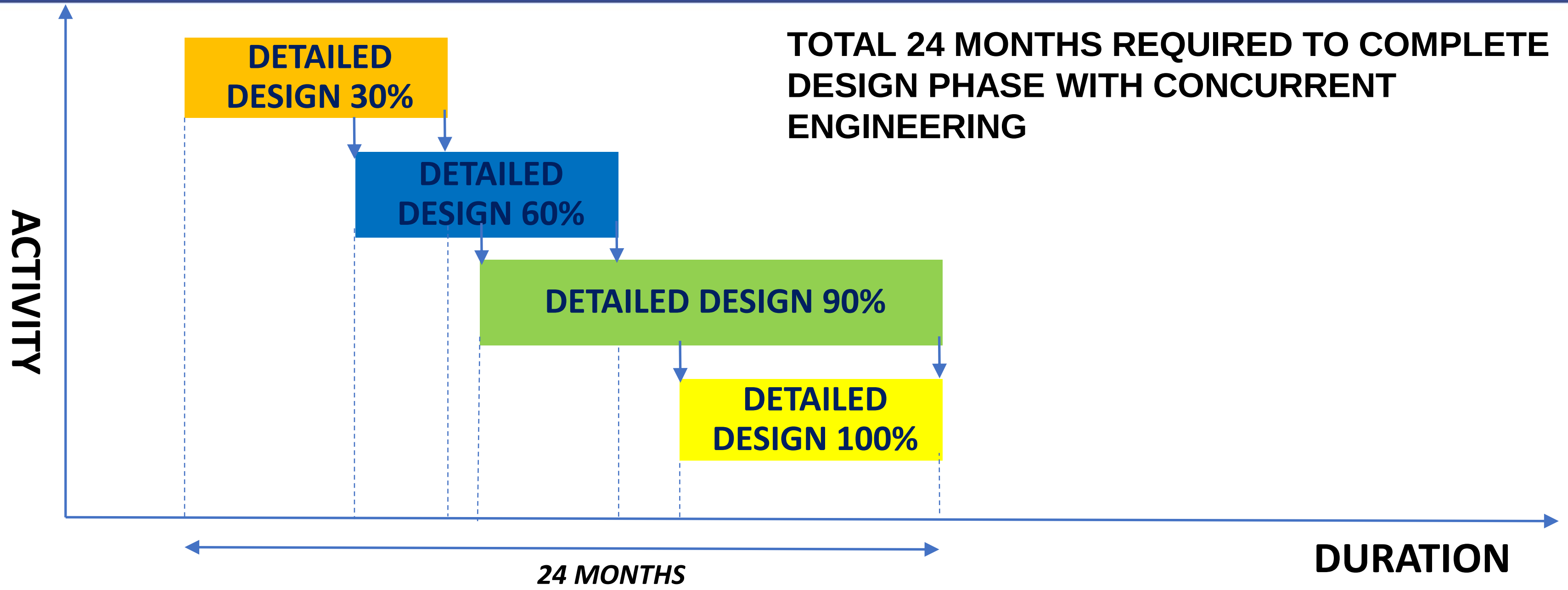
- Concurrent Engineering (CE) – the parallelization of design activities with a view to commence construction activities early
- Implementation within a Systems Engineering (SE) framework
  - Intent of SE is to encourage co-operative work among the various design specialist concurrently
    - At civil design level
    - At systems design level
    - At civil and systems design level
- CE defines a network of activities rather than a sequence of events
  - Each activity on network exists simultaneously with other activities

Concurrent Engineering - benefits

- Concurrent Engineering:
  - involves mobilization of construction experts during design phase
  - Provides designs that meets all functional and performance requirements
  - Facilitates early commencement of downstream activities
  - Enables early procurement of long lead items
  - Reduces the risk of rework – if implemented properly
  - Considers life cycle components, influences from the onset of project
  - Reduces ‘waste’ in design life cycle
  - Achieves continuous improvement in the design flow and output

Concurrent logic – Design Phase

TOTAL 24 MONTHS REQUIRED TO COMPLETE DESIGN PHASE WITH CONCURRENT ENGINEERING



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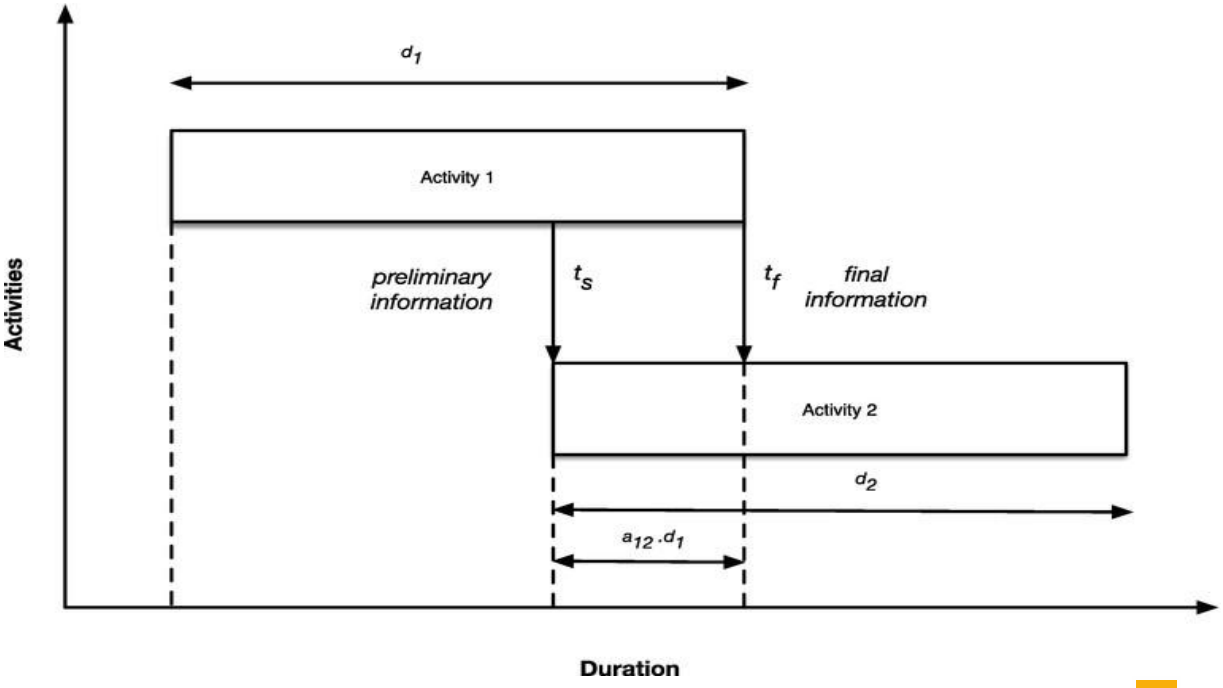
Concurrent Design logic

- Each independent design elements progressed concurrently
- Dependent design elements progressed with an overlap
- Continuous V&V undertaken

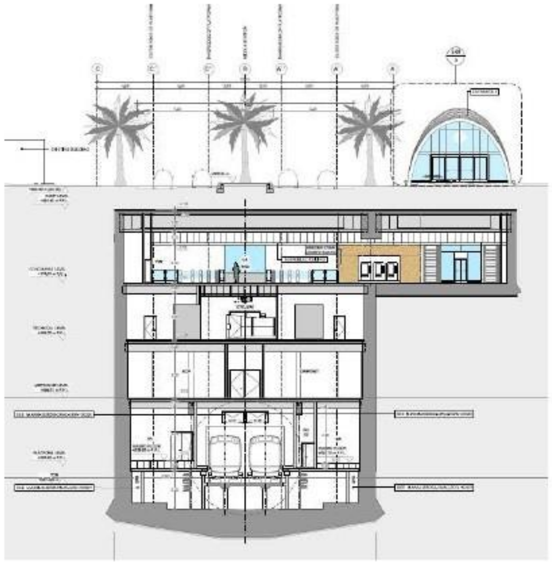


Application of Systems Engineering

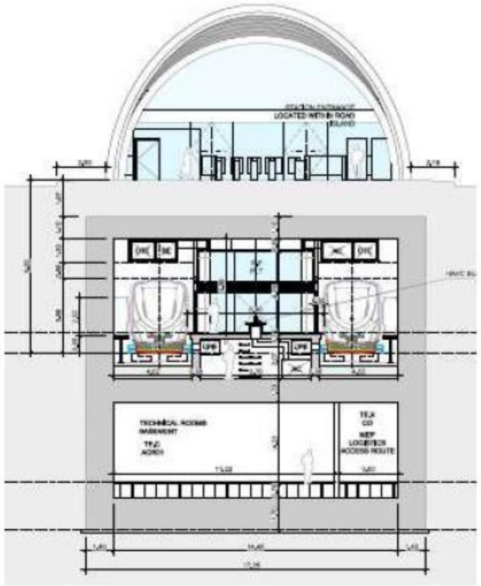
- Integrated design team established
  - At PMC level and at Contractor level
- Three station archetypes subjected to an integrated design approach
  - One Elevated
  - One At Grade
  - One Underground

Types of Stations

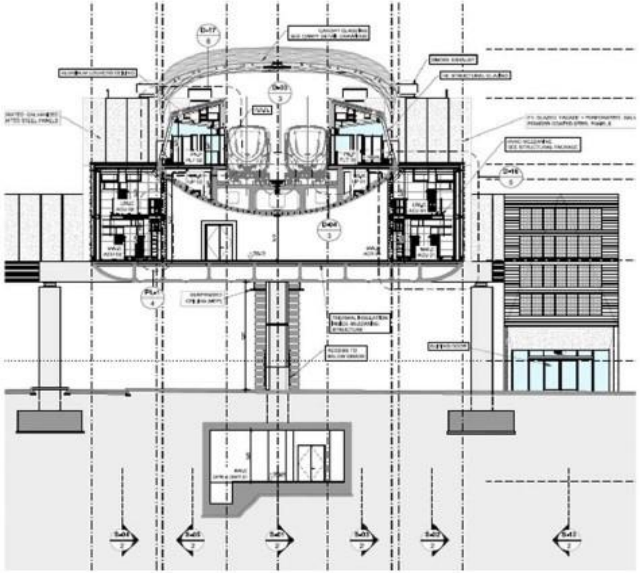
Deep Stations



Shallow Underground Stations



Elevated Stations



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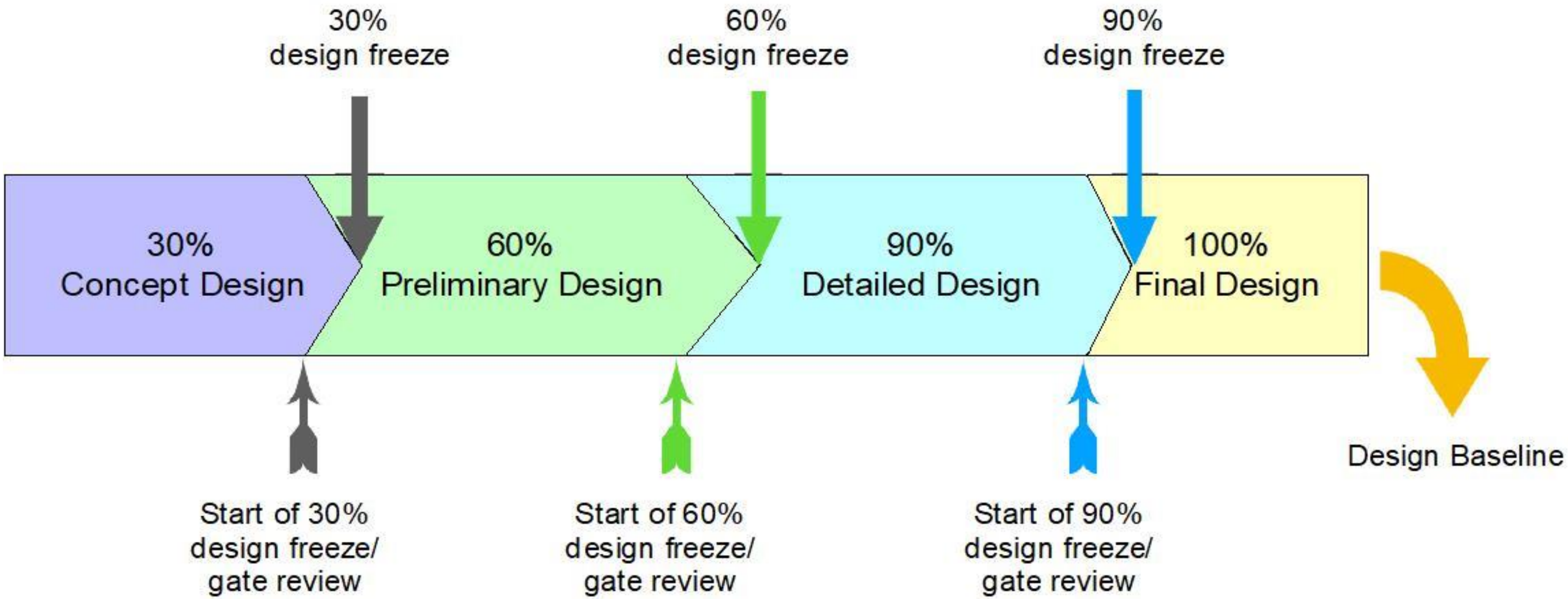
Design Gate Reviews

- Confirming traceability of customer requirements at each design phase
- Ascertain the status of each subsystem design of metro
- Identify main issues with the design and drive the current design progress
- Ensure requirements traceability in DOORS is as mature as the design
- Identify the gaps, review DCRs/RFIs/HLs and summarizing results
- Issue of design closure certificate to the contractor & informing the results to customer

Design Gate Reviews



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Best Practices and Take-Aways

- Minimize ‘waste’ in design phase by implementing CE principles
- Engage subject matter experts in the project as early as possible
- Conduct Design Gate Reviews at different design phases
- Conduct Safety Review for all key safety critical milestones
- Establish a ‘collaborative’ work place and ‘One Team’ approach
- Creating a ‘can-do’ attitude at every level of the Organization

Best Practices and Take-Aways

- Strong leadership to decision making and motivate the work force
- Seeing the big picture while keeping eye on the important details
- Being firm and flexible as per the need with the contractor to get job done
- Robust Systems Engineering and Integration processes
- Safe, timely, de-risked and cost-effective delivery with high quality
- Progressive assurance, early and regular involvement of O&M
- Testing integration between Rolling Stock and Signaling well in advance on a Test Track facility

THANK YOU

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