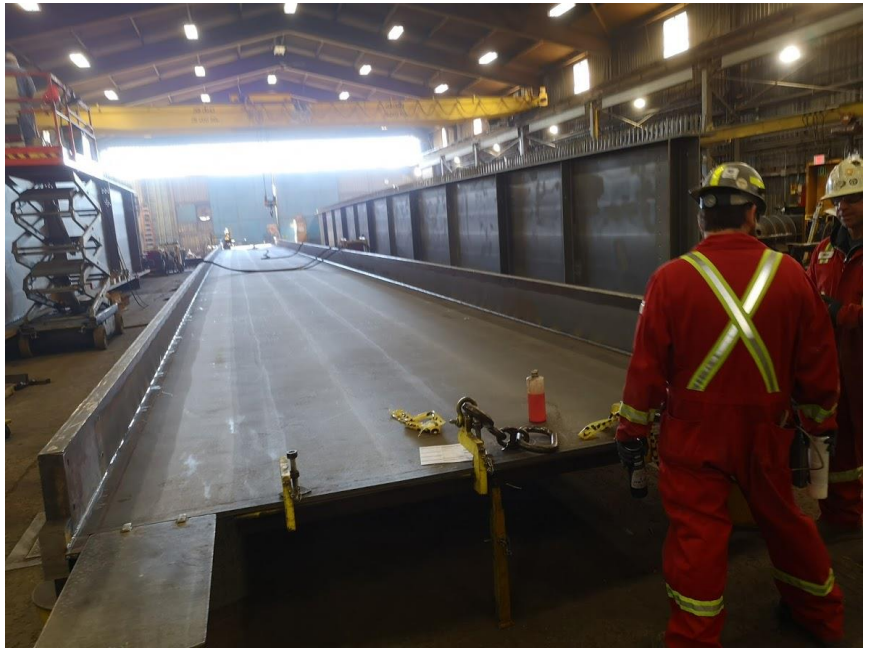
LEAN CONSTRUCTION PLANNING SUBJECT TO VARIATIONS IN DETAILED FEATURES OF FABRICATED BRIDGE GIRDERS

Badhon Das Shuvo

Ming Lu



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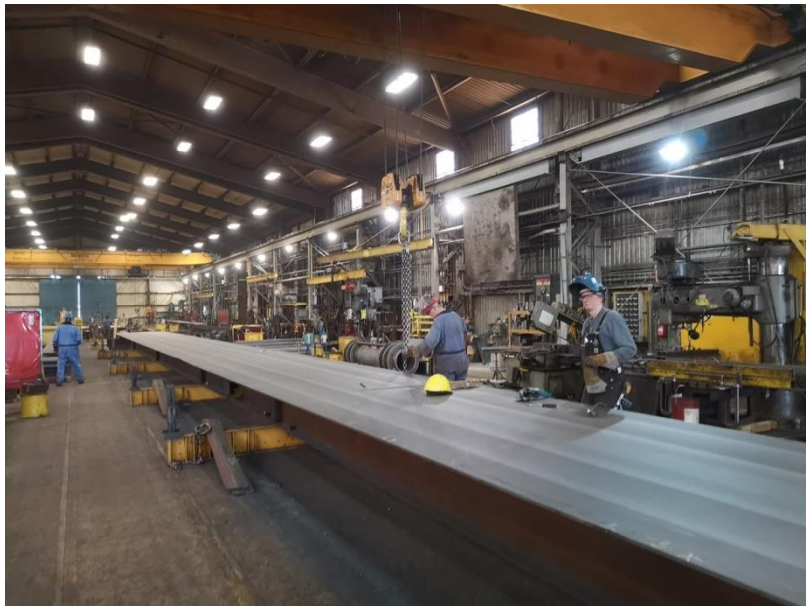
BRIDGE GIRDER FABRICATION

Challenges:

- bulky and heavy products
- alike in appearance, but unique structural component with special features
- multi-project simultaneous execution
- limited available skilled trades

complexity and uncertainty



PROBLEM STATEMENT

- Scheduling is done by a PMP certified P6 user (Spencer) and production planning by a shop manager (Chris)
- Spencer and Chris are both overwhelmingly busy; seldom have chances to communicate
- Now, Spencer needs to get inputs from the shop operations about production capacity (crew size, shop layout, productivity), sequence, girder lead time in shop, girder-to-girder loading time lag

BUT

PROBLEM STATEMENT (contd.)

Many inputs are uncertain variables, they keep changing

Chris has his gut feelings, but

It is difficult for him to give crisp clear answers to Spencer

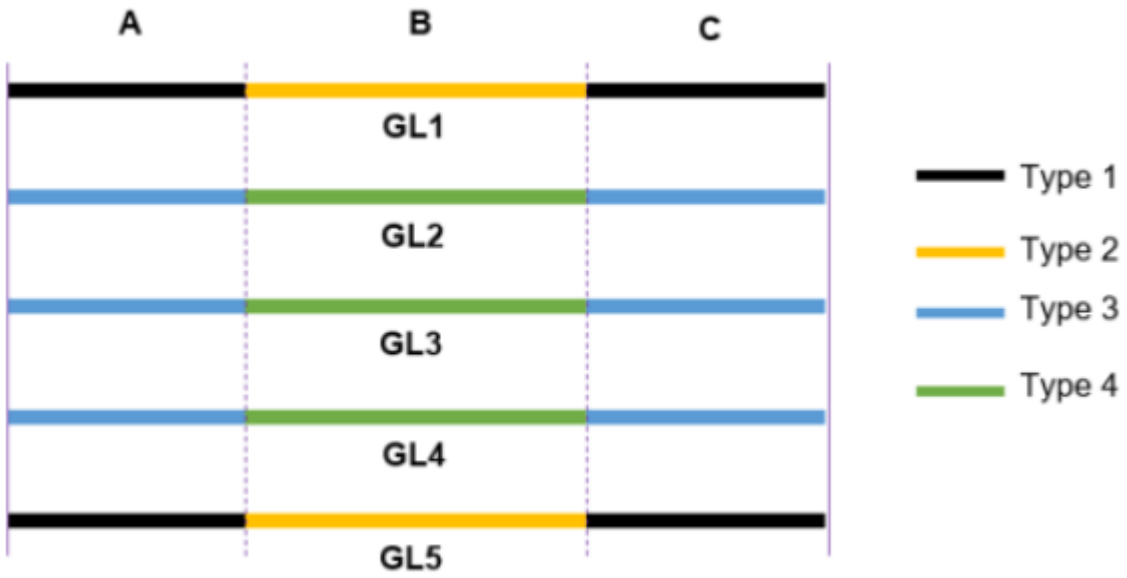
RESEARCH'S GOAL

To develop a valid virtual plant (i.e. simulation model)

which will be

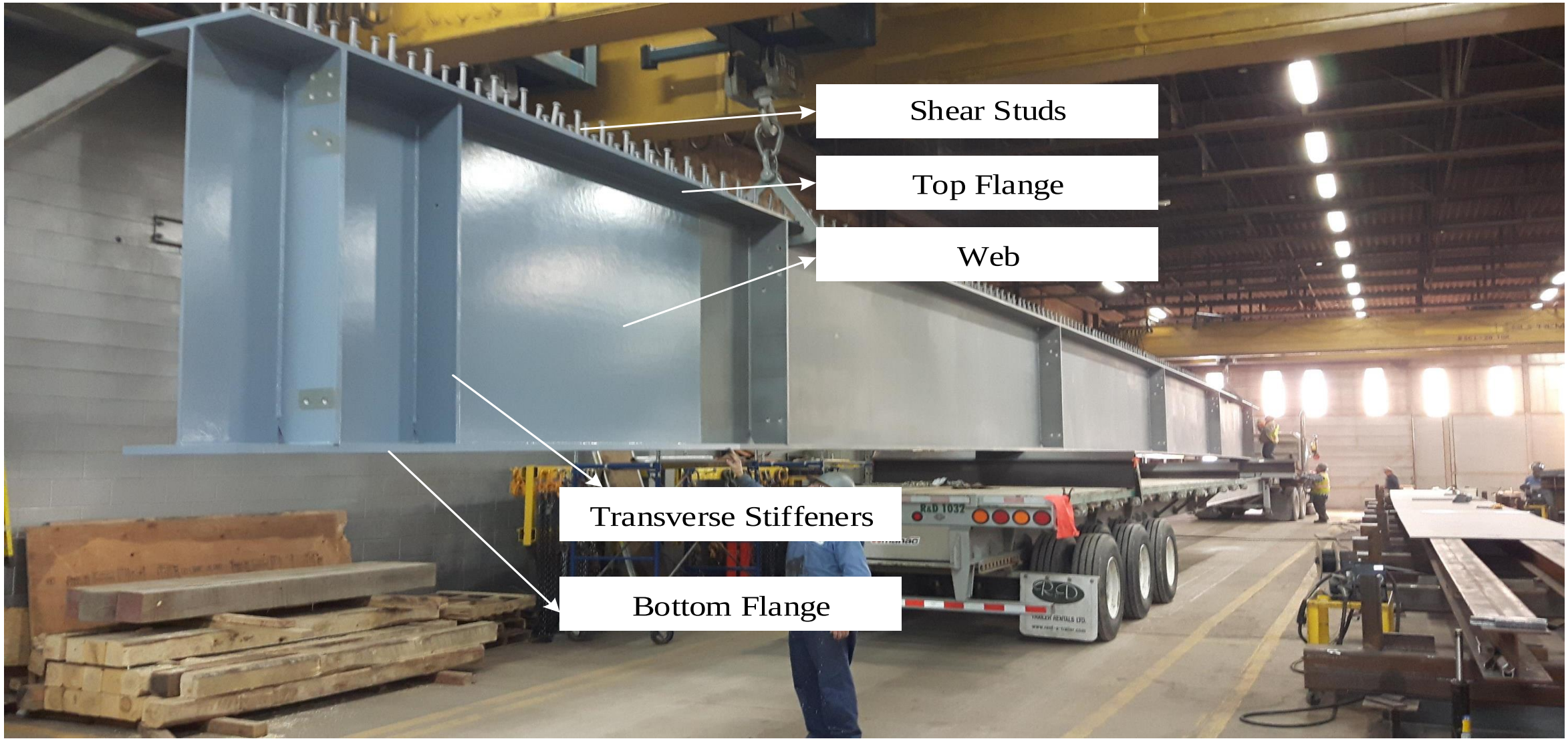
- at the figure tips of Spencer and Chris
- accounting for sufficient details and fully validated
- adaptive, flexible to the rapid changing situations
- user friendly to both

CASE STUDY



CLASSIFICATION OF GIRDERS

Type of Girder	Type 1	Type 2	Type 3	Type 4
Girders	GL1A, GL1C, GL5A, GL5C	GL1B, GL5B	GL2A, GL2C, GL3A, GL3C, GL4A, GL4C	GL2B, GL3B, GL4B
Symbol				


Shear Studs
Top Flange
Web
Transverse Stiffeners
Bottom Flange

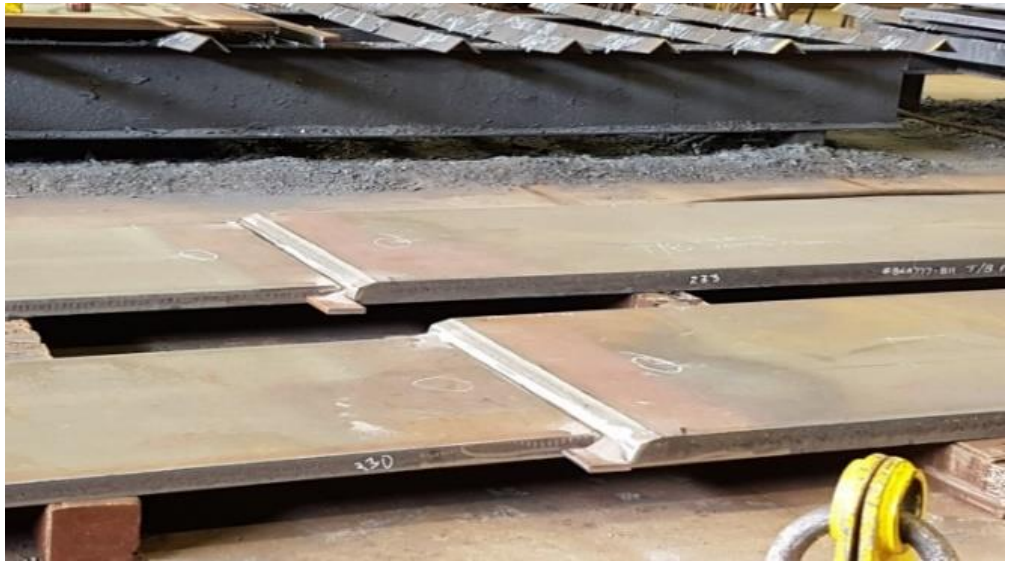
DESIGN VARIATIONS

- Length of the girder
- Number of field splice
- Stiffener Complexity
- Girder Shape Complexity

GIRDER

DESIGN VARIATIONS

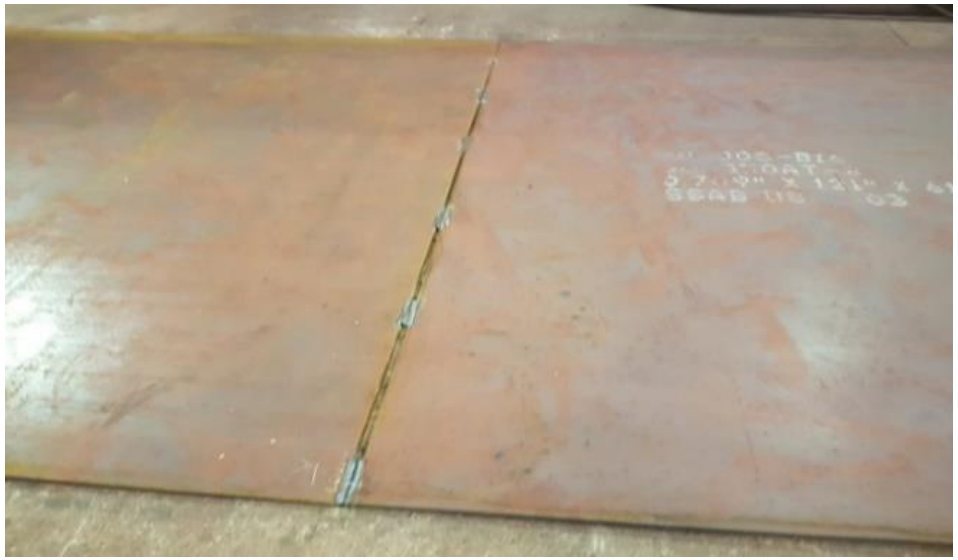
- Length of the flanges
- Width of the flanges
- Thickness of the flanges
- Number of drills in one end
- Number of flange splices



FLANGE

DESIGN VARIATIONS

- Length of the web plate
- Number of the web plates
- Width of the web plates
- Thickness of the web plates



WEB

FABRICATION OPERATION

(1) Receiving plates
(2) Flanges preparation
(3) Web preparation
(4) Stiffener preparation
(5) Assembling girder by fitting & welding flanges to web
(6) Stiffener fitting & welding
(7) Studding
(8) Field splicing
(9) Sandblasting & Finishing

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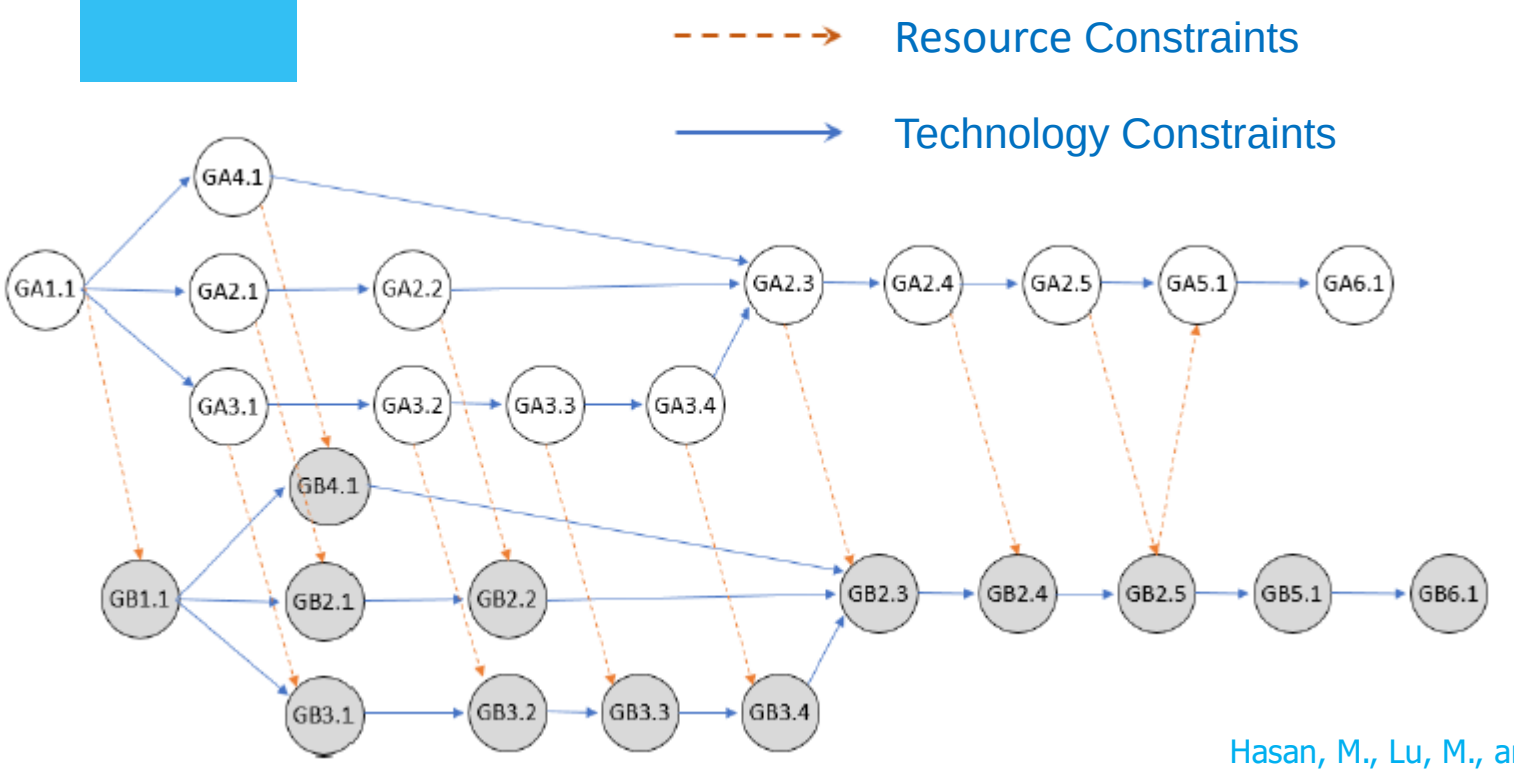
AON



⚠ MESSY

⚠ EXPLODES IN SIZE AND COMPLEXITY (due to repetitive units)

⚠ NOT ADAPTIVE TO CONSTANT CHANGES

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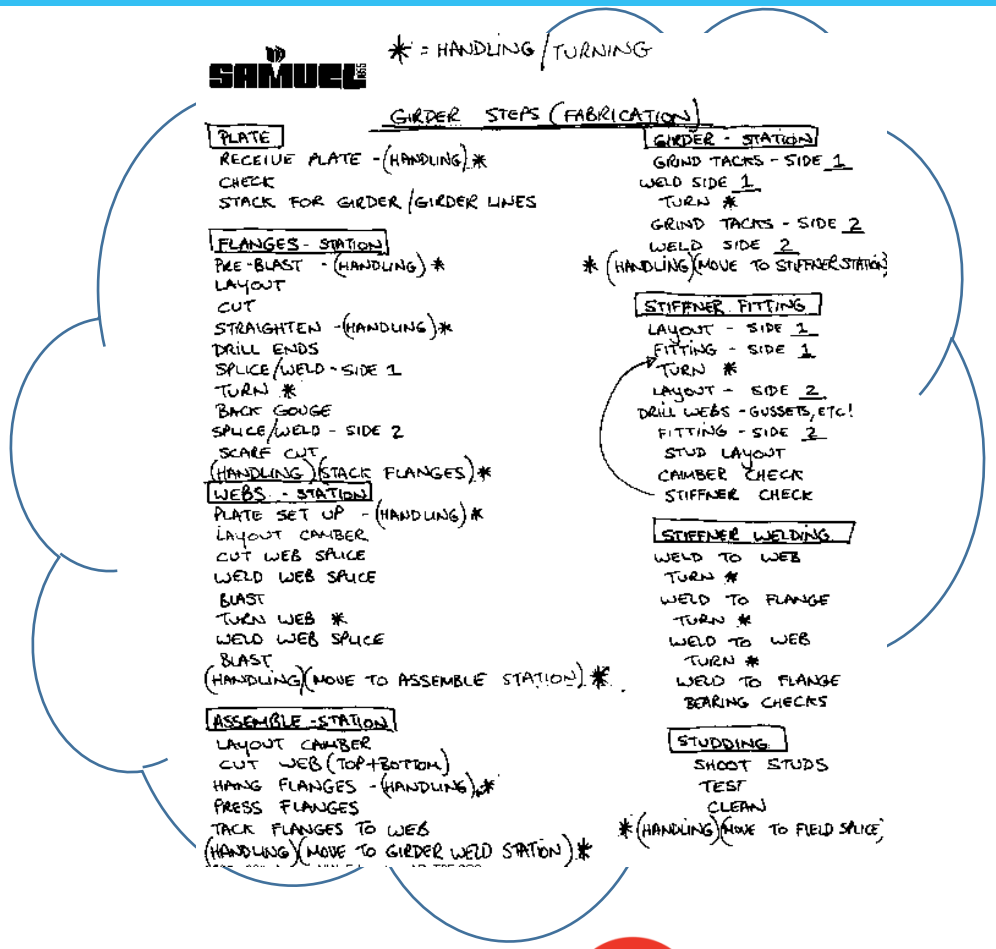
Eliciting knowhow on production processes



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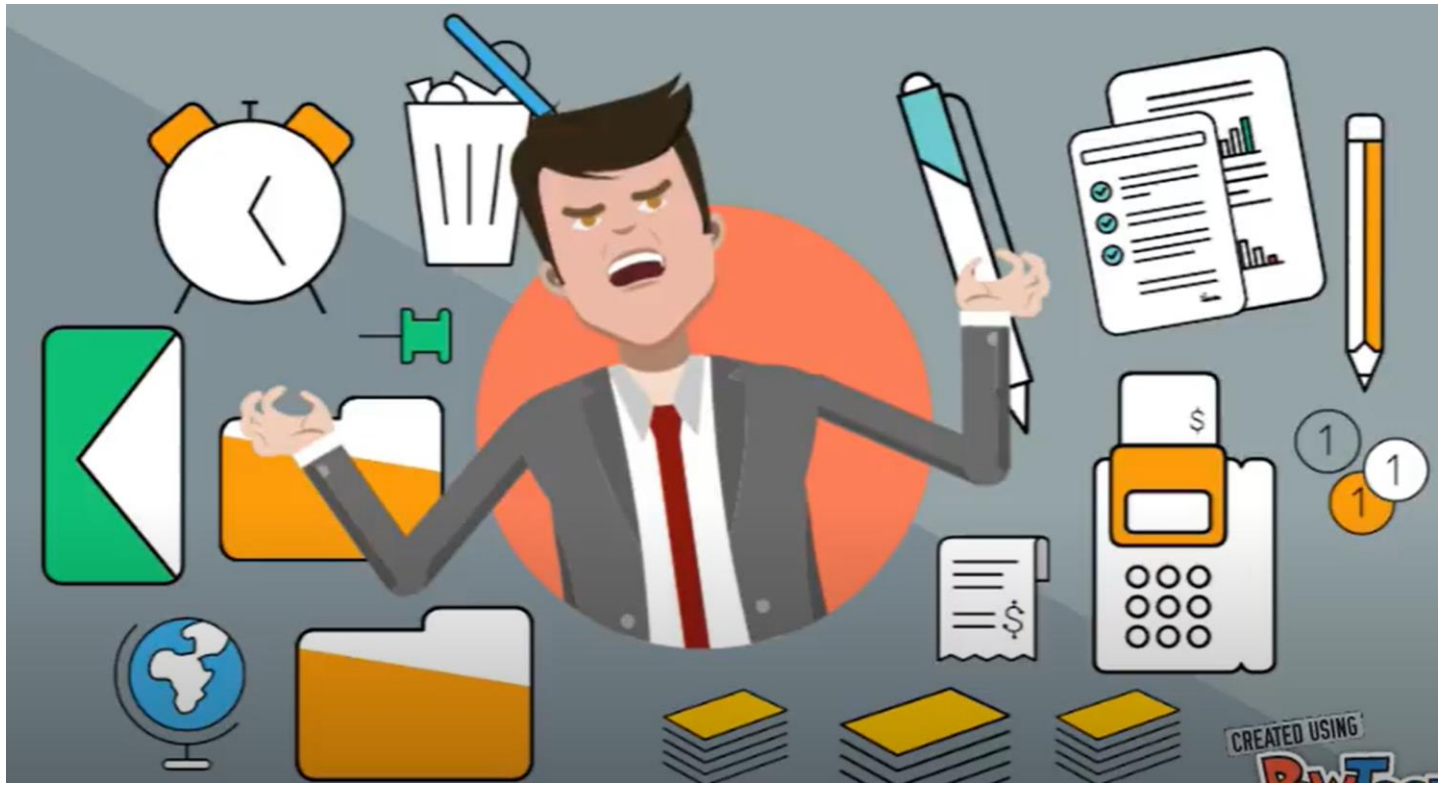
UNCERTAINTY

BUDGET OVERRUNS

SCHEDULE OVERRUNS

REWORK



PRODUCTIVITY LOSS

COMPLEXITY

MUDA (WASTE)

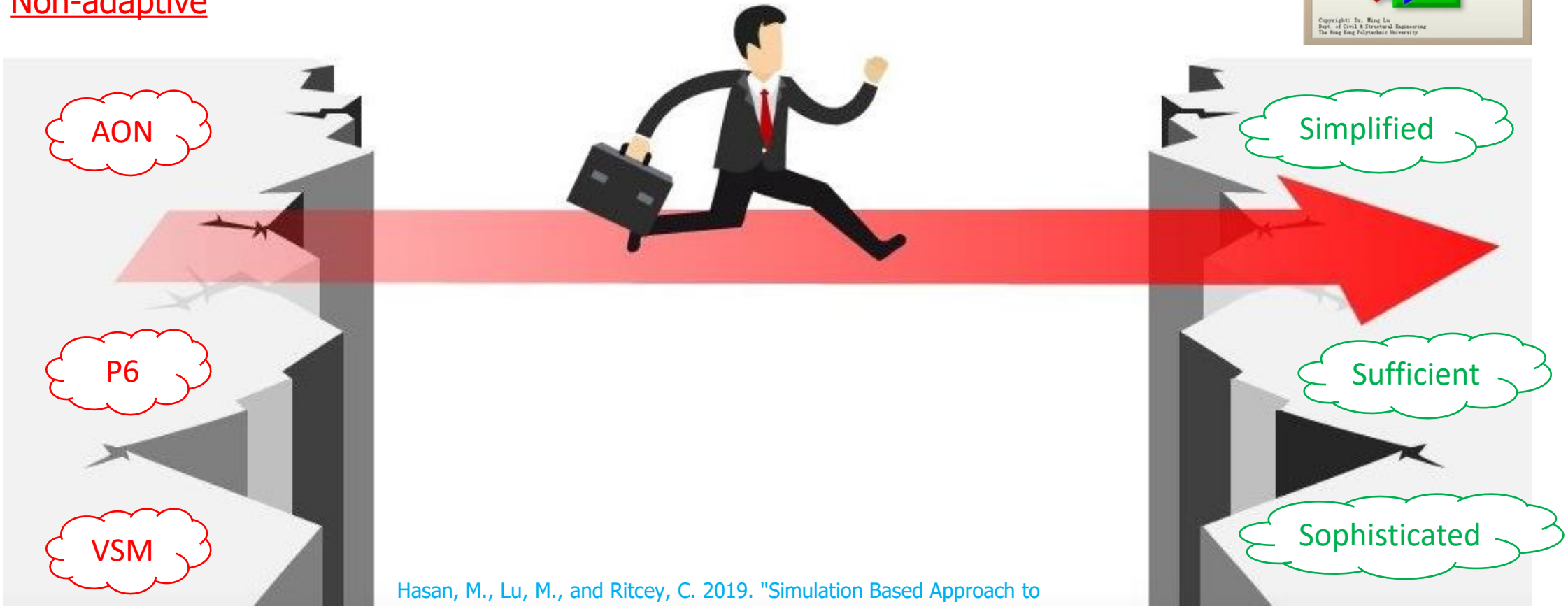
lack of consistency

discontinuity

invalid

Non-adaptive

SOLUTION!!!



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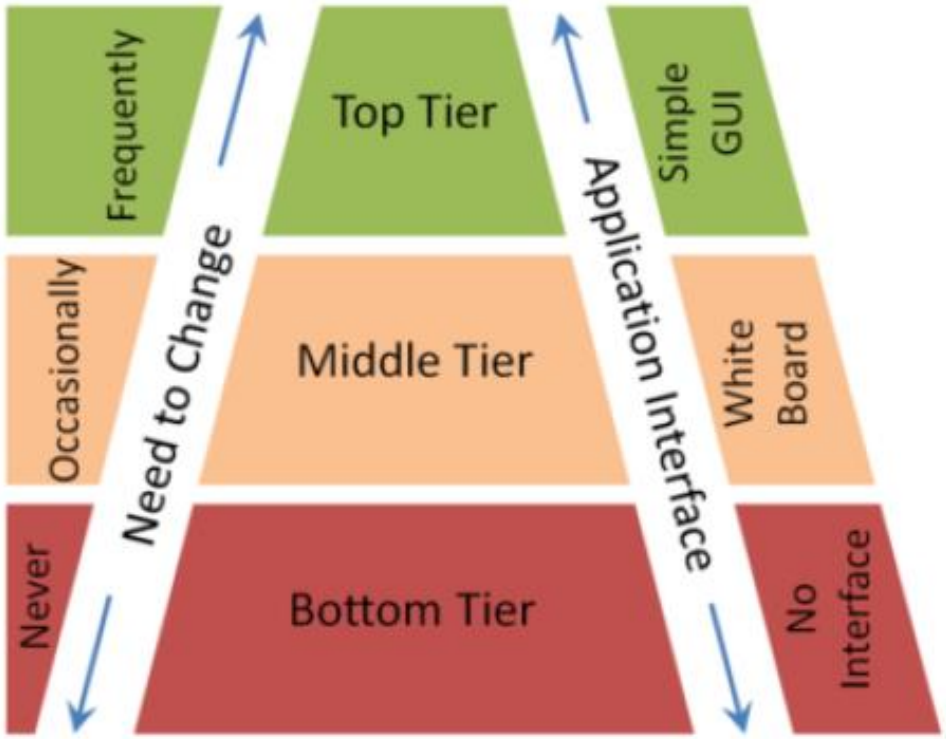
THREE-TIER SIMULATION FRAMEWORK (SDESA)



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BOTTOM TIER

- Schedules time events as per the logic and constraints defined in the middle tier and the top tier.
- Provides the analytical power of simulation analysis.
- Brings each piece, each step, each resource, and each time-dependent logical constraint into order along the timeline of simulation.

NEVER NEED TO CHANGE

MIDDLE TIER

- Plots flowchart-based network models which sufficiently represent resource flows and work flows.
- Adaptable to the changes in processing logic, time and resource requirements based on girder features.
- Changes entail when shop updates technology and layout.

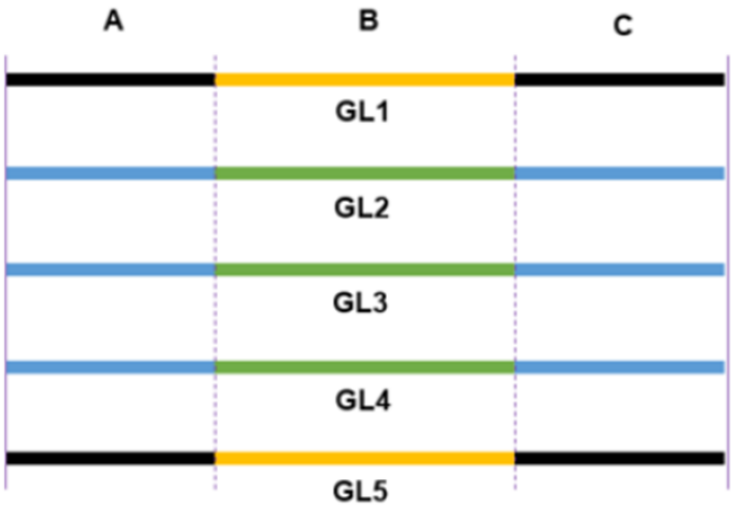
NEED TO CHANGE OCCASIONALLY

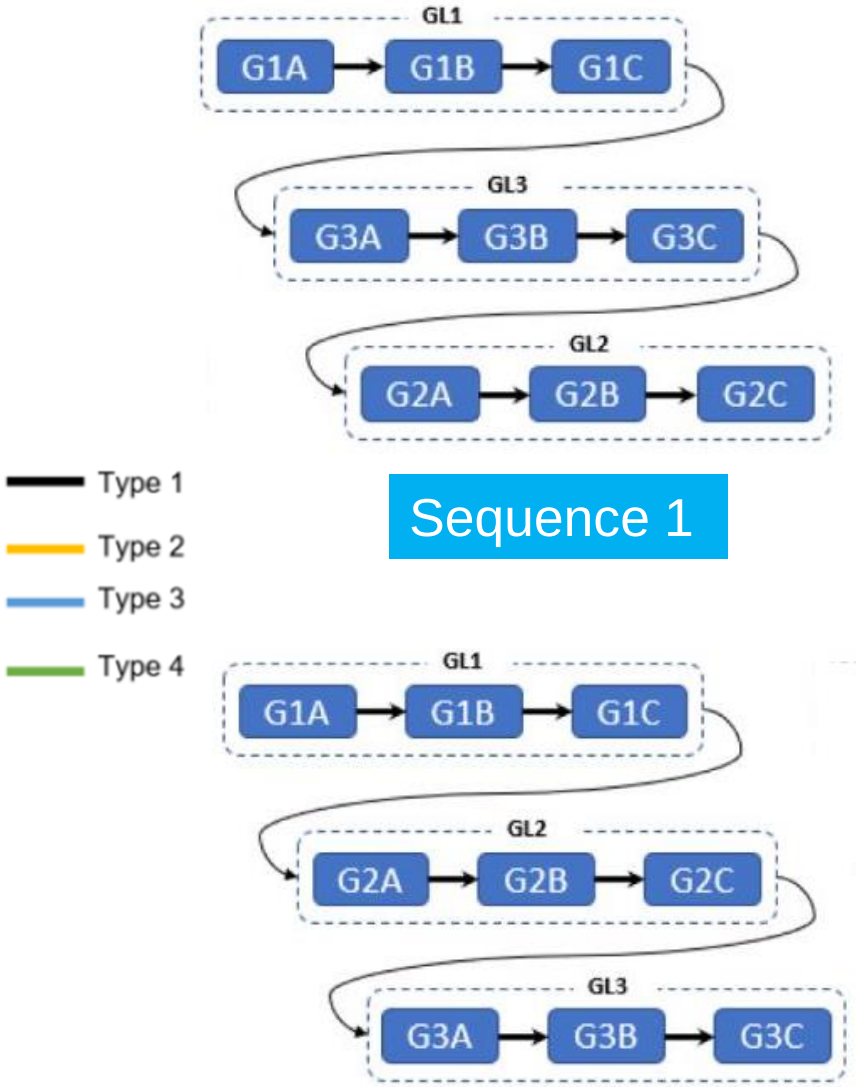
TOP TIER

- Simple interfaces with shop manager who defines raw material specifications, engineering design attributes and sequences of processing, resources available.

- No prior knowledge in simulation modeling is required except basic knowhow and limited experience in planning girder fabrication.

NEED TO CHANGE FREQUENTLY





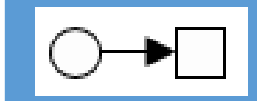
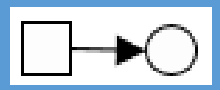
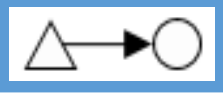
EASY TO CHANGE THE FABRICATION SEQUENCE

Shop Fabrication Plan (Girder by Girder)

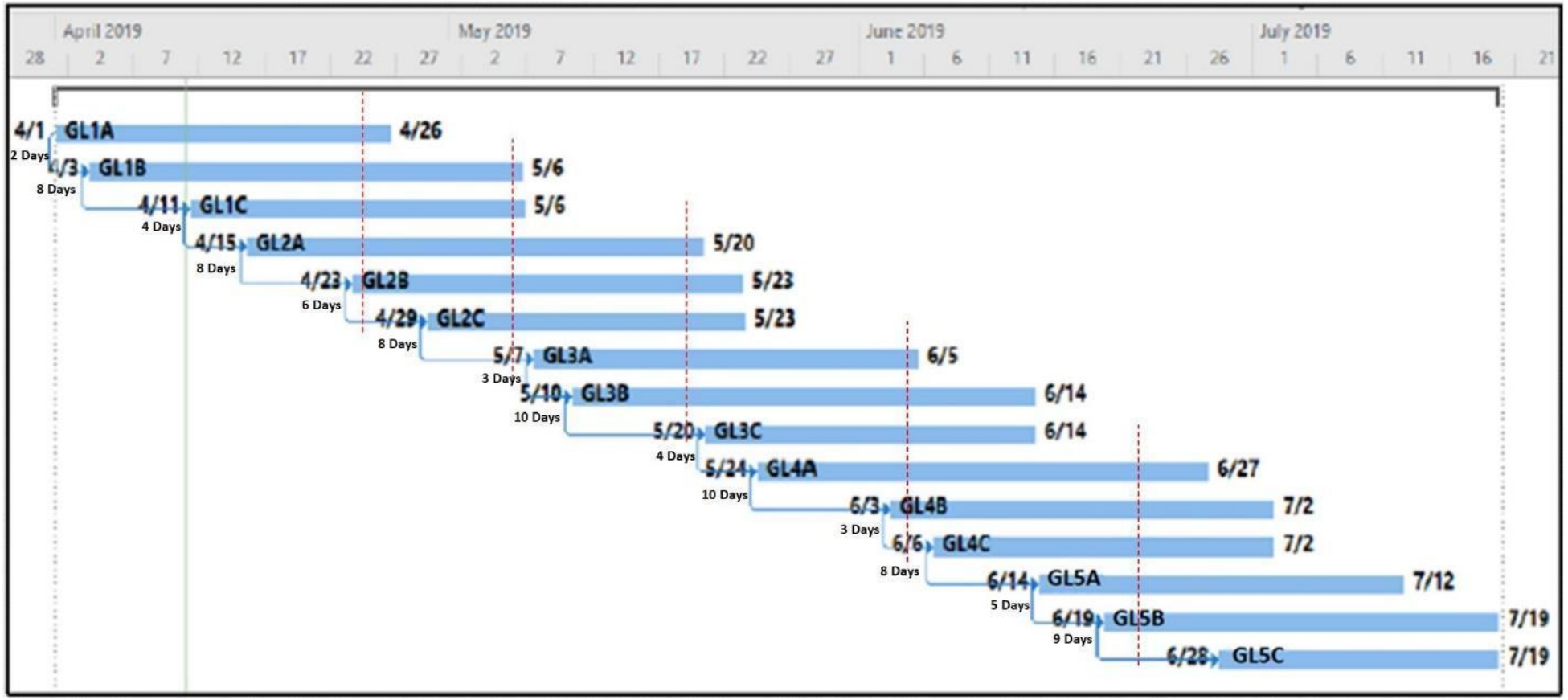
Girder Type	Girder ID	Start (D-M)	Finish (D-M)	Duration (Days)
○	1A	01-Apr	26-Apr	25
	1C	11-Apr	06-May	25
	5A	14-Jun	12-Jul	28
	5C	28-Jun	19-Jul	21
□	1B	03-Apr	06-May	33
	5B	19-Jun	19-Jul	30
△	2A	15-Apr	20-May	35
	2C	29-Apr	23-May	24
	3A	07-May	05-Jun	29
	3C	20-May	14-Jun	25
	4A	24-May	27-Jun	34
	4C	06-Jun	02-Jul	26
▽	2B	23-Apr	23-May	30
	3B	10-May	14-Jun	35
	4B	03-Jun	02-Jul	29

Start and finish fabrication time of each girder

SS lag times (days) between two different types of girders

Girder Type Combination	Remarks	Instances	Lag Time (Days)
	Type 1 girder precedes Type 2 girder with SS lag time	1A-1B	2
		5A-5B	5
	Type 2 girder precedes Type 1 girder with SS lag time	2B-2C	8
		5B-5C	9
	Type 1 girder precedes Type 3 girder with SS lag time	1C-2A	4
	Type 3 girder precedes Type 4 girder with SS lag time	2A-2B	8
		3A-3B	3
		4A-4B	10
	Type 3 girder precedes another Type 3 girder with SS lag time	2C-3A	8
		3C-4A	4
	Type 4 girder precedes Type 3 girder with SS lag time	2B-2C	6
		3B-3C	10
		4B-4C	3
	Type 3 girder precedes Type 1 girder with SS lag time	4C-5A	8

DECISION SUPPORT FOR PROJECT MANAGEMENT



Multiple girders (maximum 5 girders) can be processed concurrently at any given moment

CONCLUSION

- ✓**Presented a simulation case of planning bridge girder fabrication** to illuminate on *mura* inherent in girder fabrication;
- ✓**Elaborated the variations in girder fabrication time and inter-girder lag** in the context of applying lean concepts for planning in practice;
- ✓**Explored a new lean approach (SDESA)** to project planning and scheduling assisted with production operations planning by simulation;
- ✓**SDESA provides the platform to validate proposed framework and prototype solution**, leading to a highly predictable, more productive, and leaner system of bridge girder fabrication and installation.

Related Work on Simulation Modeling

- Hasan, M., Lu, M., and Bird, K. 2019. "Planning and Scheduling Bridge Girders Fabrication Through Shopfloor Operations Simulation". In *Proceedings of the 2019 European Conference on Computing in Construction*, July 10-12, 2019, Chania, Crete, Greece, 75–84.
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THANK YOU

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