IGLC 2021
LIMA, PERÚ - 29TH ANNUAL CONFERENCE
INTERNATIONAL GROUP FOR LEAN CONSTRUCTION

Early Due Low Uncertainty (EDLU) For Improving Supply Chain Performance under Order Variability in Precast Concrete Production

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AGENDA

- INTRODUCTION
- LITERATURE REVIEW
- SCHEDULING MODEL
- SIMULATION EXPERIMENTS
- CONCLUSIONS

1. INTRODUCTION

"Most of construction stakeholders expect to utilize prefabrication"
(Mc-Graw Hill Construction, 2011)

Faster | **Safer** | **Greener**

On-Site Construction
Traditional Method

VS

Off-Site Construction
Prefabrication & Modular

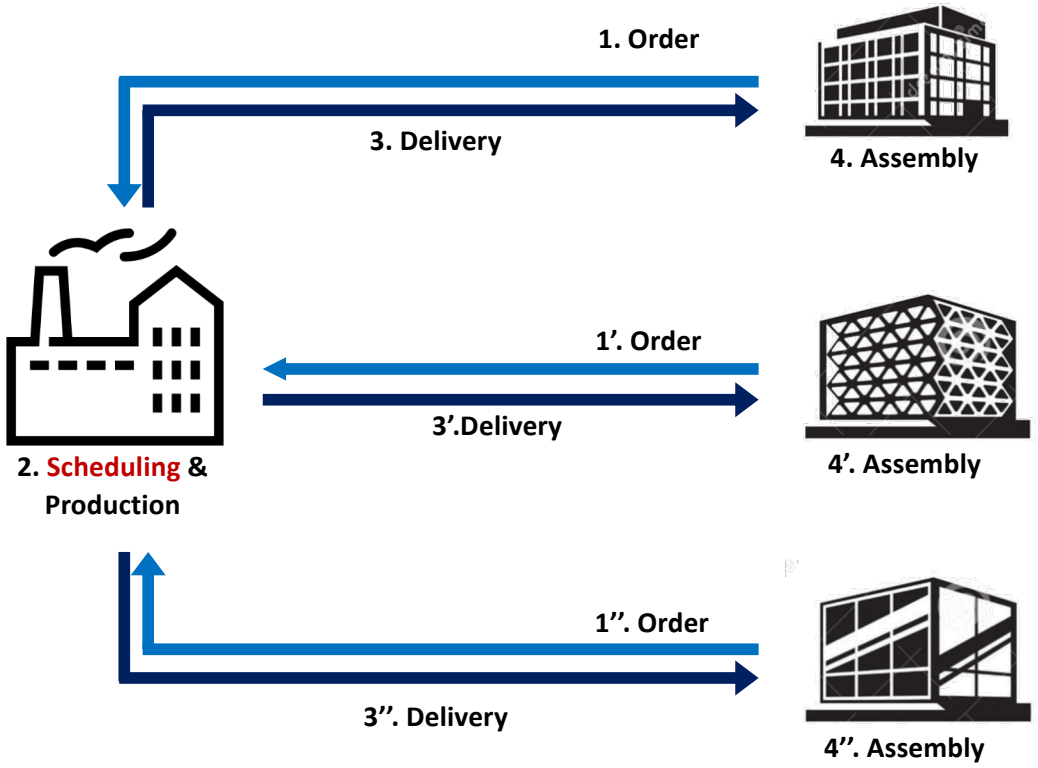
Typical traditional project schedule

(Image by vanguardmodular.com)

Typical modular project schedule

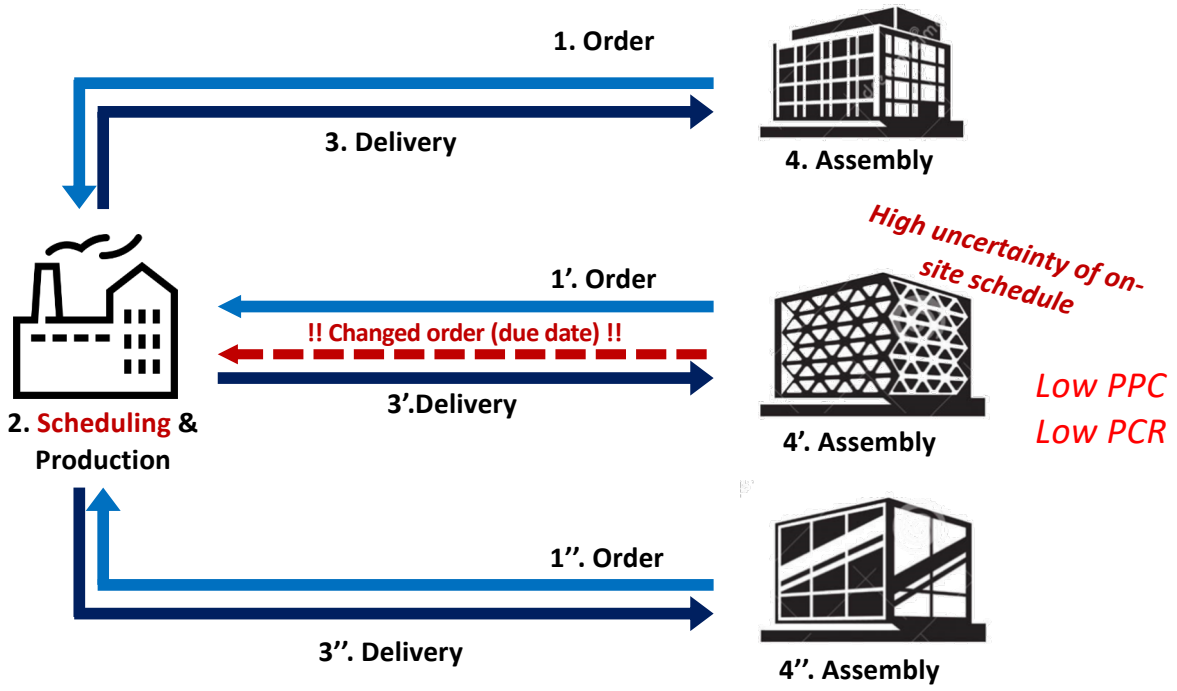
1. INTRODUCTION

“A precast concrete supplier needs to optimize his production schedule while meeting various demands from multiple customers”.



1. INTRODUCTION

"Contractor's order variability makes an impact on a supplier's production schedule and the reliability of supply chain".

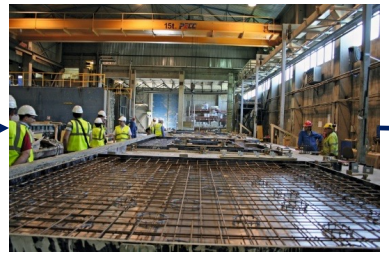


This study proposed a new dispatching rule taking into account a contractor's order reliability

2. LITERATURE REVIEW

PRECAST CONCRETE PRODUCTION

Formwork assembling (m1)



Rebar and other all embedded parts installation (m2)

Concrete casting (m3)

Concrete curing (m4)

Formwork dismantling (m5)

PC product finishing (m6)

2. LITERATURE REVIEW

A SUPPLIER'S PRODUCITON SCHEDULE AND DISPATCHING RULE

- Many construction fabricators have limited planning capacity not enough to develop a robust scheduling or schedule optimization responding to order variability (Kim et al. 2020)
- So, they have used dispatching rules in practice because of their simplicity and intuitiveness

EDD (Earliest Due Date)

- It has been widely used for production scheduling problem because of its simplicity and better performance than other rules (Chan and Hu 2002). It chooses the next job having earliest due date from the queue. This rule focuses on satisfying job due dates.

SPT (Shortest Processing Time)

- It chooses the next job having the shortest processing times from the queue. This rule has been known to be one of the best to reduce work-in-process inventory because the rule minimize the time a job stays in the shop (Weng and Ren 2006).

CR (Critical Ratio)

- It chooses the next job considering the available time divided by the total remaining process time of the job.

The existing rules didn't take into account the order uncertainty which may change due dates of orders

3. SCHEDULING MODEL (Proposed Rule)

A SUPPLIER'S PRODUCITON SCHEDULE AND DISPATCHING RULE

- This study propose a new rule of EDLU (early due and low uncertainty)
- The proposed rule takes into account the order uncertainty
- The PC production schedule can be more flexible by responding to order variability

EDLU (Early Due Low Uncertainty)

- The authors propose to shift the risk of production disruption to the party who creates the order variability (i.e, contractor who frequently changes the delivery order). Therefore, it was required that order with high uncertainty of the due date is started late among orders with a similar priority.
- The proposed dispatching rule uses EDD as a baseline because EDD has been popularly applied for PCs production scheduling because it has better performance compared to other dispatching rules (Ho 2018)
- The proposed rule evaluates the due date and the contractor's order uncertainty when the order's due date is confirmed. The proposed one evaluates the due dates giving priority to the order with early due date in their production sequence

3. SCHEDULING MODEL

DYNAMIC PREFABRICATED PRODUCT SCHEDULING (DPPSM) (Kim et al., 2020)

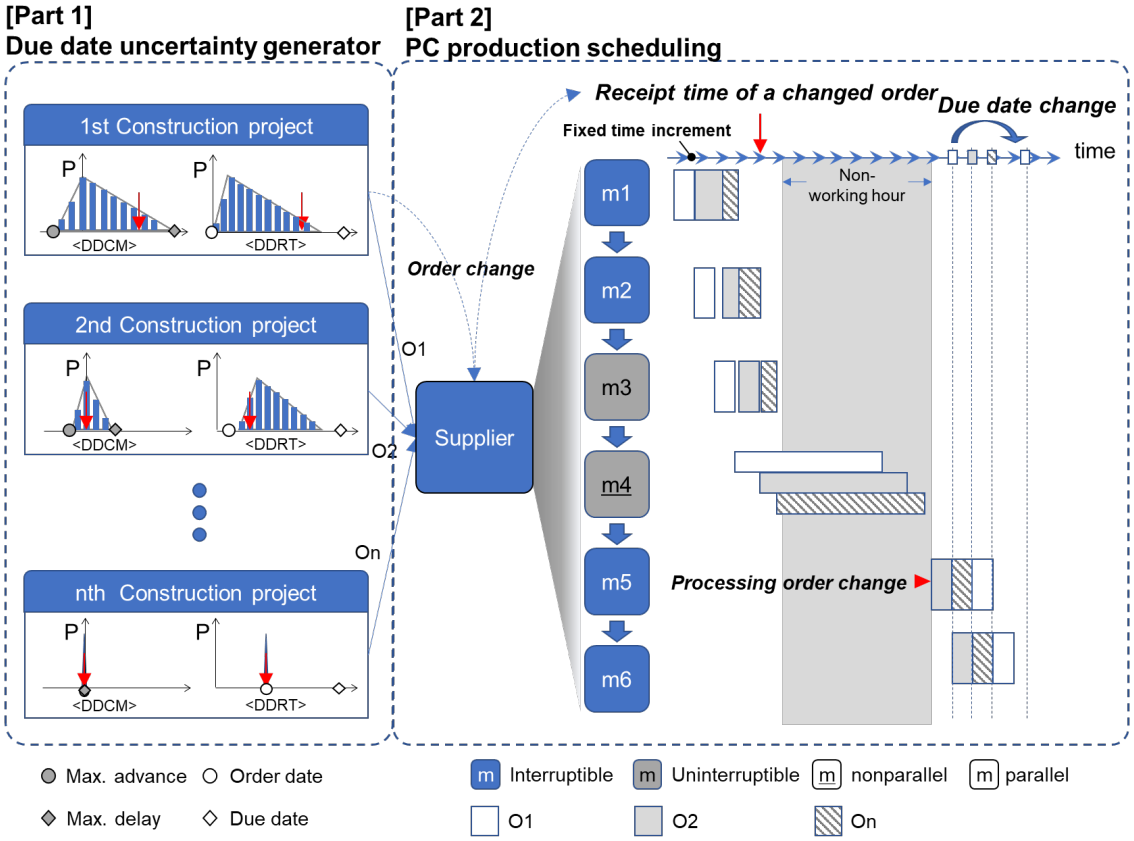


Fig 2. DPPSM (Dynamic Prefabricated Product Scheduling Model, Kim et al 2020)

4. SIMULATION EXPERIMENTS

DESCRIPTION OF SCENARIOS

- variable t : due date tightness level
- variable a : production load level
- variable u : uncertainty

<Table1. PCs Order Information>

No	Job	Product type	OD	ODD	Uncertainty	
					Min.Due date	Max. Due date
1	J1	P1	Day 1	OD + ***t***	ODD -1	ODD + ***u***
2		P2		OD + ***t***		
3		P3		OD + ***t*** + ***a***		
4		P5		OD + ***t*** + ***a***		
5		P7		OD + ***t*** +2***a***		
6	J2	P2	Day 1	OD + ***t***	ODD -1	ODD + ***u***
7		P4		OD + ***t***		
8		P8		OD + ***t*** + ***a***		
9		P9		OD + ***t*** + ***a***		
10		P10		OD + ***t*** +2***a***		
11	J3	P2	Day 1	OD + ***t***	ODD -1	ODD + ***u***
12		P4		OD + ***t***		
13		P6		OD + ***t*** + ***a***		
14		P8		OD + ***t*** + ***a***		
15		P10		OD + ***t*** +2***a***		

"Construction delays happens more frequently than early construction completion"

(ODD: original due date; OD: order date)

<Table2. Processing time>

Product type	Mold type	Processing time (h)					
		m1	m2	m3	m4	m5	m6
P1	A	2.0	1.6	2.4	12.0	2.5	1.0
P2	B	3.4	4.0	4.0	12.0	2.4	5.0
P3	A	0.8	1.0	1.2	12.0	0.8	0.1
P4	A	0.6	0.8	1.0	12.0	0.6	2.0
P5	C	3.0	3.6	2.4	12.0	2.4	3.0
P6	A	3.0	3.2	3.0	12.0	3.0	1.6
P7	C	1.3	0.9	2.4	12.0	1.9	1.8
P8	B	1.7	1.4	1.1	12.0	0.9	0.7
P9	A	2.2	1.8	1.2	12.0	2.3	0.7
P10	C	1.6	3.2	2.3	12.0	2.1	2.7

4. SIMULATION EXPERIMENTS

SIMULATION RESULTS

<Table 3. Simulation Results of Dispatching Rules>

Best value

Scenario (*Suta*)	EDLU	CR	EDD	SPT
S111	742.4 (0, 0%)	699.2 (-43.2, -5.8%)	723.8 (-18.5, -2.5%)	490.7 (-251.7, -33.9%)
S113	331.4 (0, 0%)	316.2 (-15.2, -4.6%)	330.2 (-1.2, -0.4%)	364.6 (33.2, 10%)
S121	365.0 (0, 0%)	407.1 (42.1, 11.5%)	384.1 (19.1, 5.2%)	311.5 (-53.5, -14.7%)
S123	131.2 (0, 0%)	138.1 (6.9, 5.3%)	132.4 (1.2, 0.9%)	232.9 (101.7, 77.5%)
S131	152.0 (0, 0%)	158.3 (6.3, 4.2%)	154.0 (2, 1.3%)	173.1 (21.1, 13.9%)
S133	31.4 (0, 0%)	39.4 (8.0, 25.5%)	32.3 (0.9, 3%)	136.0 (104.6, 333.2%)
S311	407.6 (0, 0%)	417.9 (10.4, 2.5%)	417.7 (10.1, 2.5%)	337.9 (-69.7, -17.1%)
S313	158.3 (0, 0%)	167.4 (9.1, 5.7%)	165.4 (7.1, 4.5%)	249.8 (91.4, 57.8%)
S321	178.4 (0, 0%)	190.4 (12.0, 6.7%)	182.6 (4.3, 2.4%)	190.3 (11.9, 6.7%)
S323	56.4 (0, 0%)	61.1 (4.6, 8.2%)	59.5 (3.1, 5.4%)	148.8 (92.4, 163.6%)
S331	51.2 (0, 0%)	60.5 (9.3, 18.2%)	52.1 (1.0, 1.9%)	101.4 (50.2, 98.1%)
S333	12.3 (0, 0%)	17.7 (5.4, 44.2%)	13.3 (1.0, 7.8%)	82.1 (69.8, 567.8%)
S511	218.1 (0, 0%)	232.2 (14.2, 6.5%)	226.8 (8.7, 4.0%)	226.7 (8.7, 4%)
S513	87.1 (0, 0%)	93.1 (6.0, 6.9%)	96.3 (9.2, 10.6%)	172.1 (85.0, 97.6%)
S521	88.2 (0, 0%)	103.1 (14.9, 16.9%)	94.1 (5.9, 6.7%)	128.4 (40.3, 45.7%)
S523	31.7 (0, 0%)	36.9 (5.2, 16.2%)	36 (4.2, 13.3%)	98.3 (66.6, 209.8%)
S531	25.5 (0, 0%)	27.2 (1.6, 6.3%)	26.2 (0.7, 2.7%)	62.2 (36.6, 143.4%)
S533	9.0 (0, 0%)	9.8 (0.8, 9.2%)	9.2 (0.2, 2.2%)	51.9 (42.9, 476.4%)

- The EDLU showed better performance in most of scenarios
- In case of scenarios with tight due date such as S111 and S311, SPT was the best rule showing the lowest tardiness, which was as known (Weng and Ren 2006).
- These results show that the EDLU tends to be superior to using the existing rules as the due date uncertainty increases.

5. CONCLUSIONS

- In this simulation experiments, the authors tested four different dispatching in job shop scheduling for precast concrete production when **there exists order variability by a contractor** → **the proposed rule shows better delivery performances** in terms of the average lead time and its variance.

- **In light of lean construction principles**, the simulation results suggest the followings:
  - ✓**Order variability leads to variance of prefabricated product delivery**. The best way to reduce order variability is to improve a contractor's planning reliability. The lean construction literature has shown that the planning reliability makes an impact on project schedule and productivity of trades on sites. The simulation experiments suggest that the order variability makes a negative impact on the lead time and its variance of prefabricated products.
  - ✓**EDLU is more effective than traditional dispatching rules when order variability increases**. The proposed EDLU may help the precast concrete suppliers develop their job shop schedule when there is order variability.

- This study supposed that the due date uncertainty has the uniform distribution. The authors will conduct the further study to verify the effectiveness of the proposed model with the distribution shape of the uncertainty obtained from real construction projects.

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THANK YOU!

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