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A Dynamic Scheduling Problem in Cost Estimation Process of EPC Projects

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Background

About EPC Project

EPC (Engineering-Procurement-Construction) Project

- Contractors design and build unique products based on the client requirements.
- Contractor has a solo responsibility for the project as a lump-sum contract.
- Contractor is selected by client through competitive bidding.

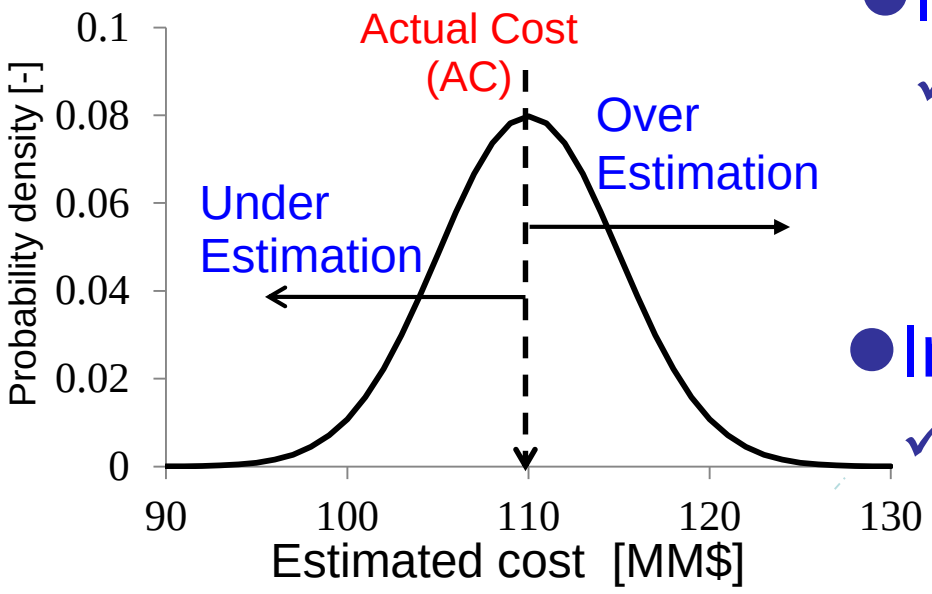
Typical Example of EPC Project: Construction, Civil engineering, Plant Engineering, Information System Development, etc.

EPC contractors have been suffered unstable business results.

Background

Cost estimation & contractor's profit

For stable profit from EPC projects, contractor must estimate the project cost accurately.



- In Case of Over Estimation:
  - ✓ Contractor could not accept the order and hence obtain no profit.
- In Case of Under Estimation:
  - ✓ Contractor would increase the chance of accepting the order.
  - ✓ However, the profit could be below the contractor's expectation, and possibly suffers a loss on this order.

"Accurate cost estimation" is critical for the contractor to gain stable profit.

Background

Cost estimation & contractor's profit

For accurate cost estimation, experienced and skilled human resources, i.e., engineering MH (Man-Hour) for cost estimation, are required.

① The volume of total MH for cost estimation is limited

② Orders arrive randomly

Order selection & Appropriate MH allocation to randomly arrival orders is required in cost estimation process.

Research Objectives

Develop a simulation-based heuristic scheduling method in cost estimation process;

① Dynamically decides bid/no-bid on the orders at each order arrival,

② Allocates MH to the chosen orders under the constraint of total MH,

so as to improve the expected profits from EPC projects.

A Model

of

Project Cost Estimation Process

About Project Cost Estimation Process

① The project cost estimation process is a series of activities;

- ✓ Starts with the arrival of bid invitations (orders) that arrive randomly,
- ✓ Closes by the date of bidding.

② MH is dynamically allocated to the orders waiting for cost estimation based on the MH availability, expected profits, and so on.

③ When the available MH is not enough to estimate cost accurately, no-bid on the order can be decided.

Assumptions of the model (Section 3)

① Cost is estimated through three estimation classes: Class 4, Class 3, and Class 2 one by one until the bidding date.

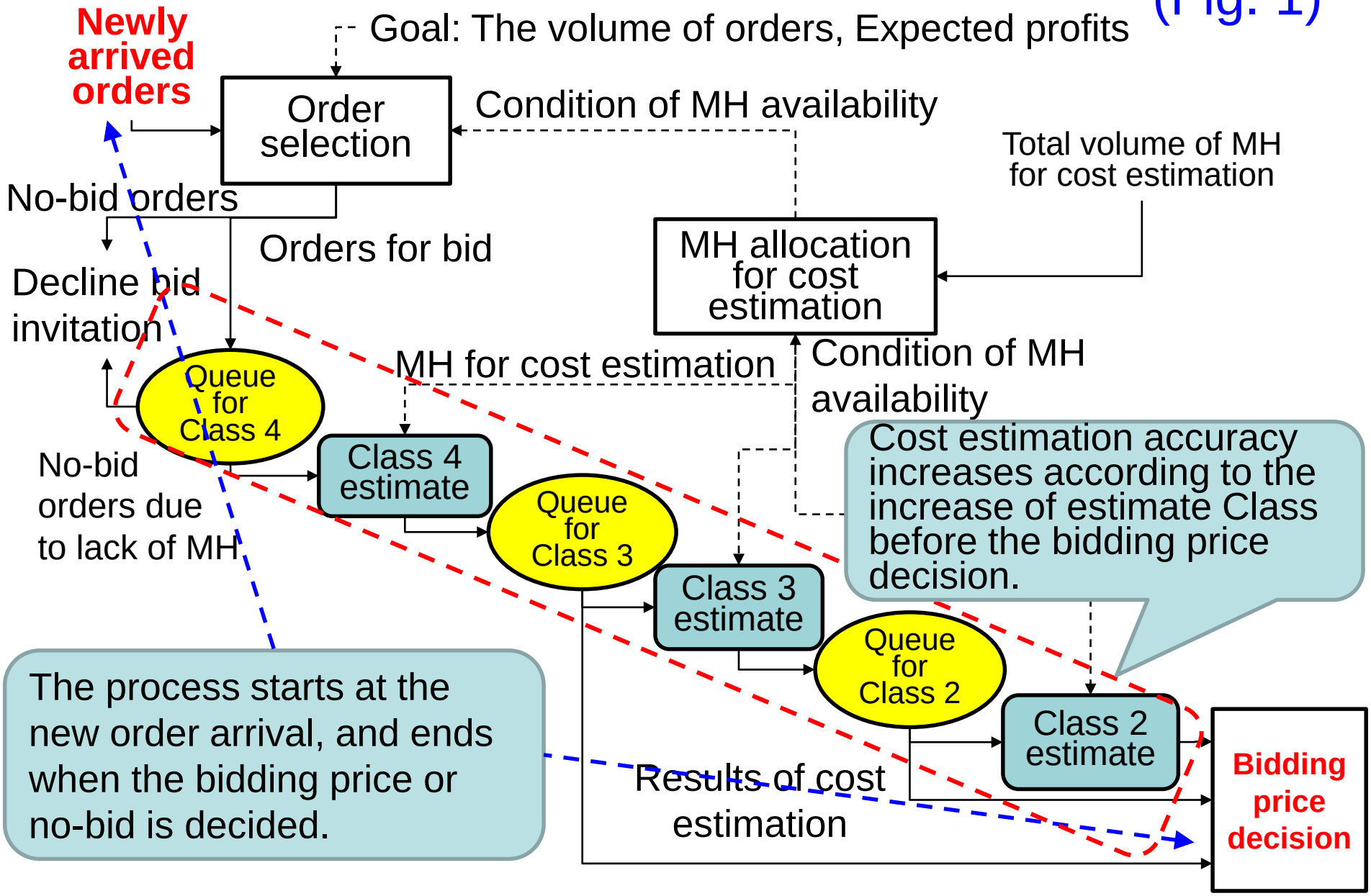
② Each Class needs a certain amount of MH and a period of time for cost estimation.

③ No-bid on the order or Class 4/Class 3 estimate is decided when MH or period of time is not enough to estimate cost.

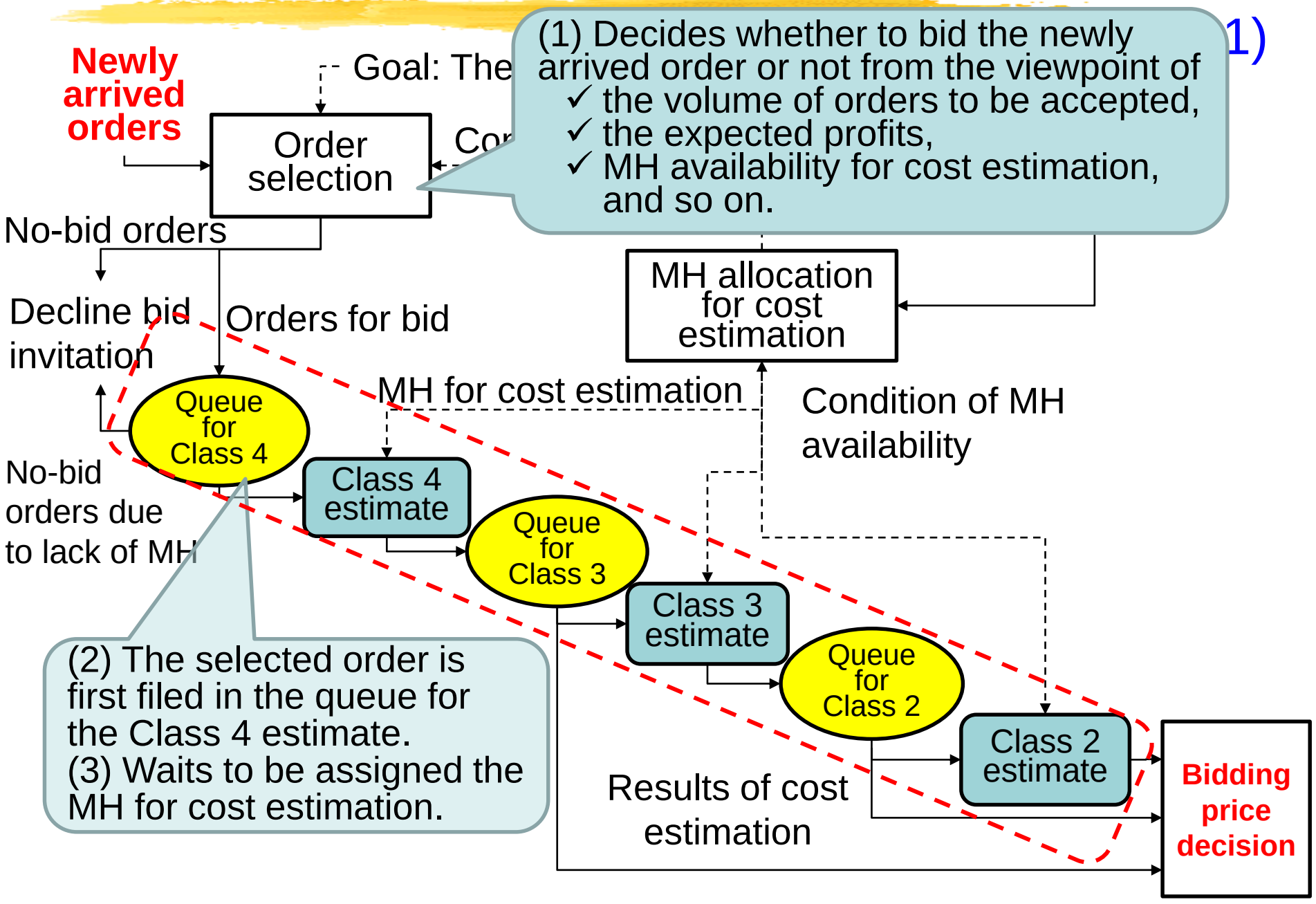
④ The cost estimate classification matrix (AACE, 2011) can be used as the cost estimation accuracy in each class.

The AACE cost estimate classification matrix illustrates typical ranges of accuracy.

A project cost estimation process model (Fig. 1)

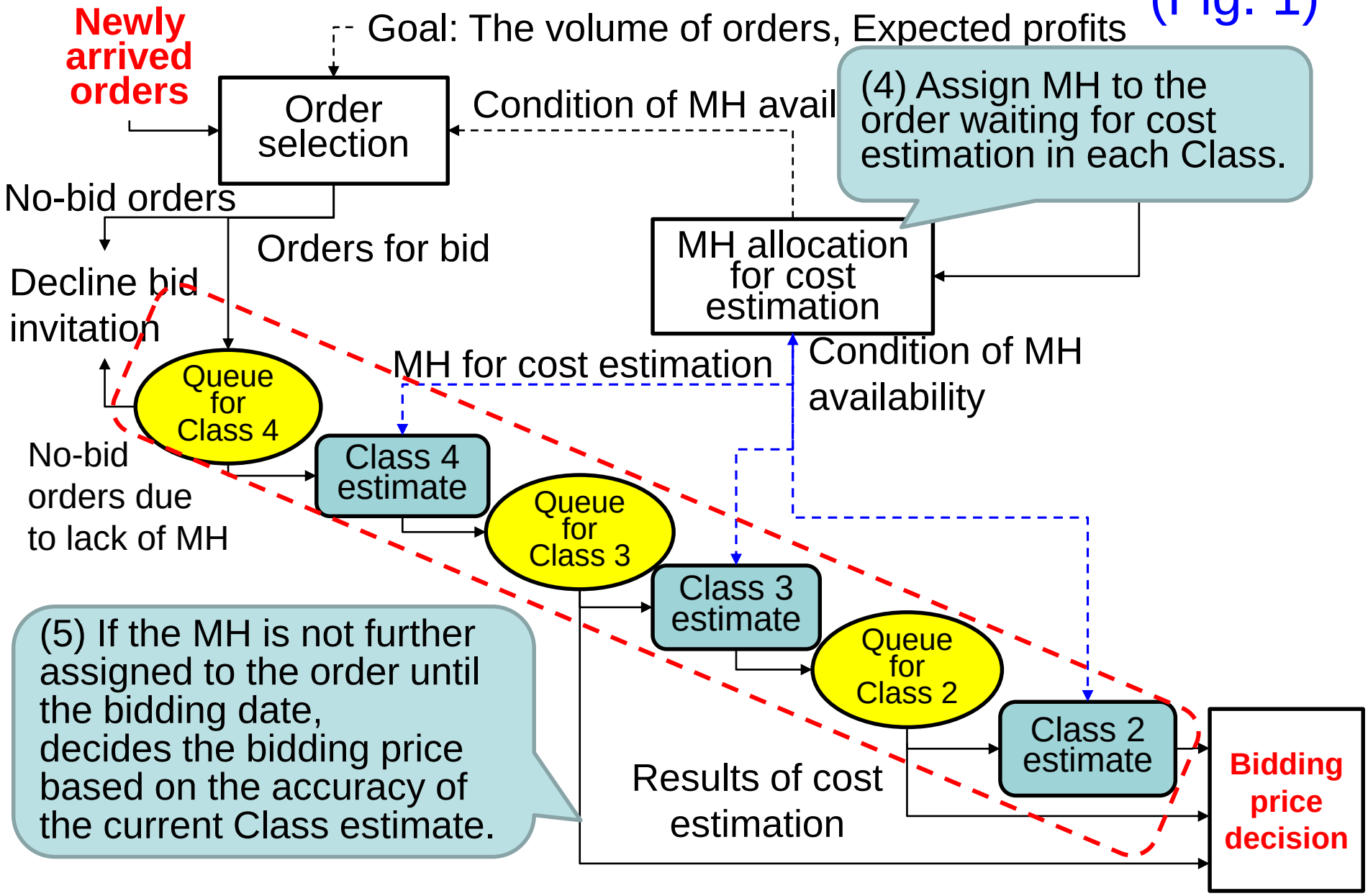


A project cost estimation process model



A project cost estimation process model

(Fig. 1)



Simulation-based Heuristic Scheduling Method

① **Order Selection Mechanism**

② **Allocation of MH for Cost Estimation**

Order Selection Mechanism

Two steps of the order selection method.

Step 1: Calculate the EPPC, expected profit per MH for cost estimation of the new arrival order *I*, as follows:

$$EPPC_i = EP_i \ / \ EM_i \qquad (1).$$

Step 2: Make the bid/no-bid decision on the new arrival order by a threshold function $MHU_{up}(EPPC_i)$.

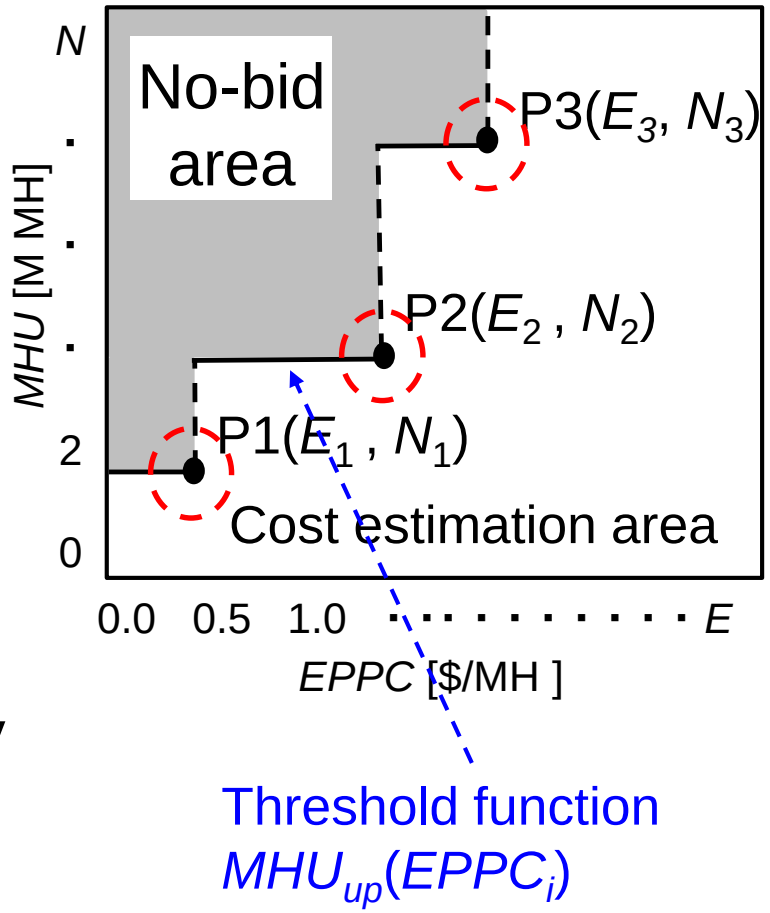
$EPPC_i$: The expected profit per MH for cost estimation of order *i*,
EP_i : The expected profit of order *i*,
EM_i : The volume of MH required to estimate the cost of order *i*.

Determination of Threshold Function

① A simulation-based search method by using the project cost estimation process model is developed.

② The method searches three threshold points, P1(E_1, N_1), P2(E_2, N_2) and P3(E_3, N_3), sequentially by applying them in the order selection mechanism.

Area of bid/no-bid decision



Allocation of MH for Cost Estimation

① A dispatching approach is used.

When MH is released, an order waiting for cost estimation is selected based on the rules.

② The selected order is subsequently assigned the required MH for its estimate Class.

③ If the required MH is more than the MH available, the selected order waits in the queue until the required MH is released.

Numerical Examples

Numerical examples

Analyze & discuss the performance of the developed method from the following perspectives:

① Effectiveness of the threshold function, and order selection rules,
② Performance of dispatching rules.

Design of Simulation Experiments

Setting of Cases

① Orders (Table 1):

- ✓ Three order sizes, i.e., Small, Medium, Large.

② Cases: Combination of two types of case

- ✓ Three cases: Case 1, Case 2, and Case 3 that have different expected profits.
- ✓ Three sub-cases: Case A, Case B, and Case C, based on the order arrival intervals defined by the triangular distribution (Table 2).

Setting of Cases

③ Probability of order acceptance (Table 3):

- ✓ Triangular distribution

④ Cost estimation conditions of each cost estimate Class (Table 4):

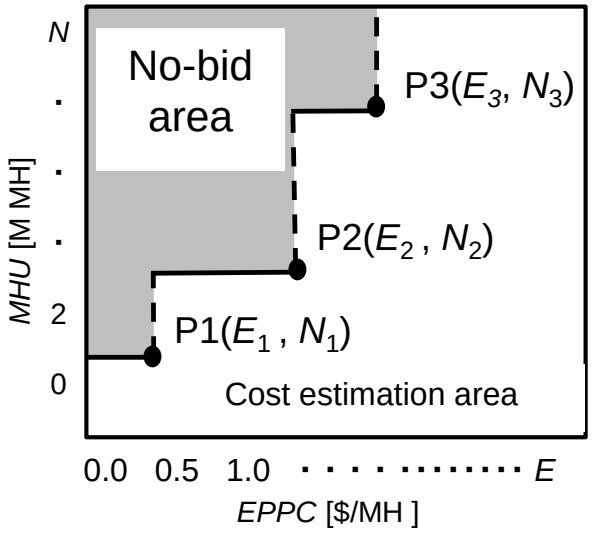
- ✓ Total periods available for cost estimation (due date for bidding),
- ✓ Required periods & MH for cost estimation.

Order Selection Rules

Two rules are evaluated for comparison:

① No selection: All the arrived orders are selected for cost estimation.

② MHU basis: Orders are selected for cost estimation by the threshold function.



Dispatching Rules

Two rules for selecting an order in a queue:

① FIFO: Orders are selected for allocating MH on a first-in first-out basis.

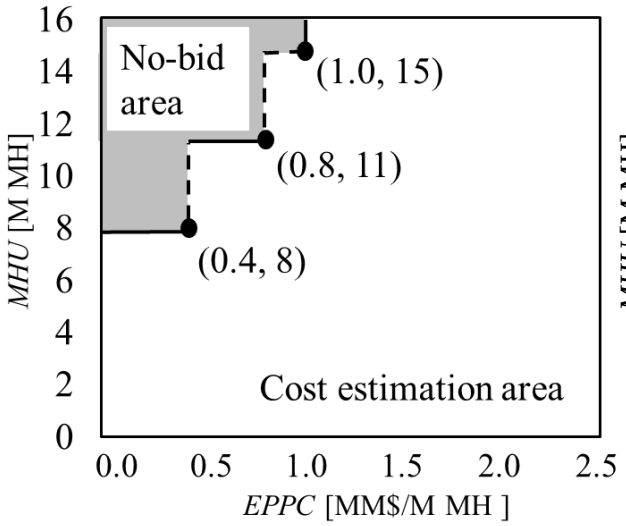
② HEPF: Order of the largest increment of *EPPC* is selected first for allocating MH.

Results of Simulation Experiments

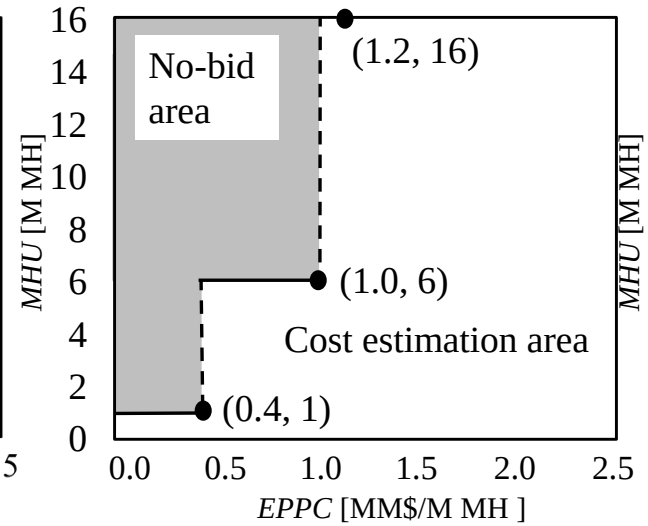
Area of Bid/No-bid Decision

Threshold Function $MHU_{up}(EPPC_i)$

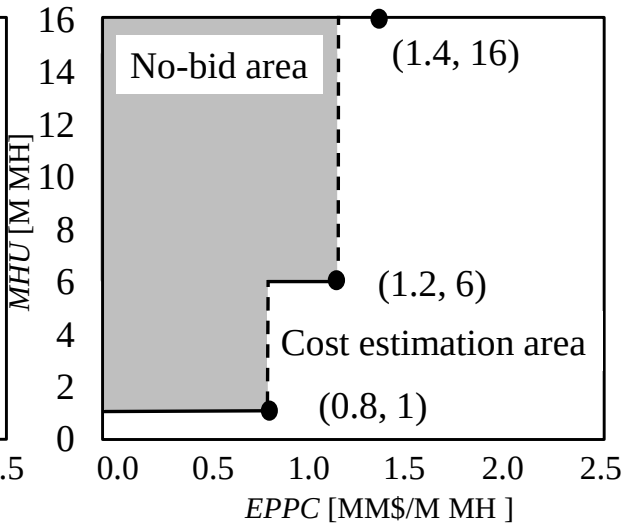
Case 1.A. (Fig. 3)



Case 1.B. (Fig. 4)



Case 1.C. (Fig. 5)

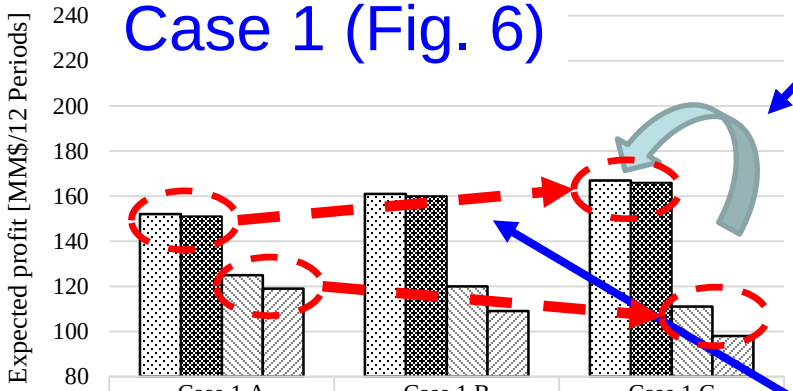


Small ← – – – – No. of newly arrived orders – – – – → Large

- ✓ No-bid area becomes wider according to the increase of the number of arrived orders in the cost estimation process.
- ✓ Contractors should pay attention to its MH utilization for cost estimation especially when the number of arrival orders is limited. (Case 1.A.)

Effectiveness of Order Selection Rules

Case 1 (Fig. 6)

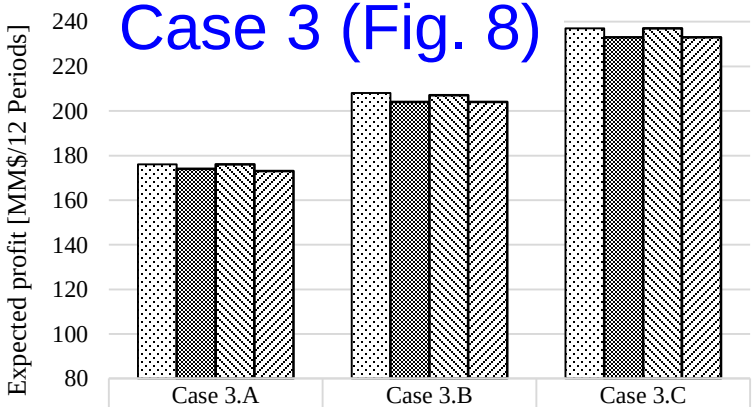


	Case 1.A	Case 1.B	Case 1.C
MHU basis HEPF	152	161	167
MHU basisi FIFO	151	160	166
No slection HEPF	125	120	111
No selection FIFO	119	109	98

MHU basis rule increases 50% in the expected profits.

- Expected profits by the MHU basis rule increases according to the increase of the number of arrived orders.
- In case of No Selection rule, expected profits decreases.

Case 3 (Fig. 8)



	Case 3.A	Case 3.B	Case 3.C
MHU basis HEPF	176	208	237
MHU basisi FIFO	174	204	233
No slection HEPF	176	207	237
No selection FIFO	173	204	233

Performance of the MHU basis rule depends on the difference of expected profits among cost estimation Classes.

➔ See Table 2

Effectiveness of Order Selection Rules (Cont.)

Ratio of cost estimate class in Case 1 HEPF rule (Table 5) (MHU: MHU basis, No: No selection) [%].

	Case 1.A		Case 1.B		Case 1.C	
	MHU	No	MHU	No	MHU	No
No-bid	38.7	0.0	50.4	0.0	62.0	0.0
Class 4	0.0	0.0	0.0	0.1	0.0	0.6
Class 3	7.6	50.1	8.5	71.9	6.2	87.0
Class 2	53.7	49.9	41.2	28.1	31.8	12.3

- ✓ MHU basis rule makes many Class 2 estimate.
- ✓ No. of no-bid orders is also large in the MHU basis rule.

MHU basis rule allocates MH to the more profitable Class estimate.

Expected profits: Class 2 > Class 3 > Class 4

Performance of Dispatching Rules

- ✓ HEPF rule performs slightly better than FIFO. (Fig. 6-8)
- ✓ Dispatching rules make no significant difference in the expected profits, especially when the MHU basis rule is used for order selection.

Order selection rule has more impact on the expected profits than dispatching rule.

Conclusions

Conclusions

① Developed method in cost estimation process works well to select orders & allocate MH for cost estimation appropriately so that the expected profits from orders are maximized in the dynamic order arrival situations.

② Dispatching rules, HEPF and FIFO, make no significant difference in the expected profits, especially when the MHU basis rule is used for order selection in our experiments.

Conclusions

Further research

① An advanced procedure to effectively determine the threshold function should be devised.

② A mechanism that changes rules of the order selection & MH allocation dynamically according to the change of order arrival intervals, order sizes, and so on, should be developed.

Thank you very much
for your kind attention.

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