Development of the Prototype Simulation System about the Bid Rate

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Introduction-1: A threshold price

In Japan, when government and local agencies order public works, contract offices are mandated to set ***threshold prices.***

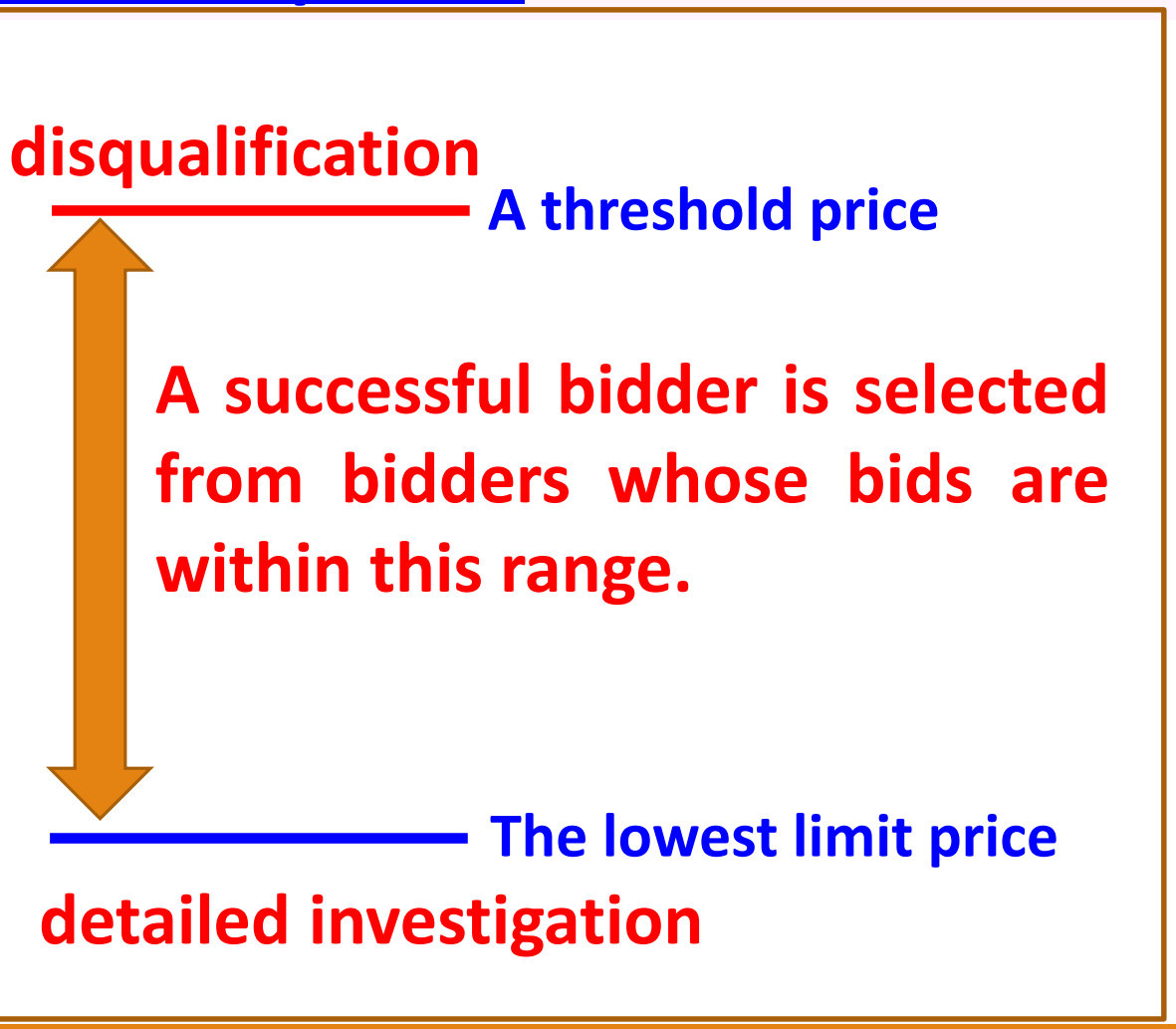
A threshold price is ***the upper limit*** of the biding price.

The contractor who bids exceed the upper limit price is

disqualified in bidding.

The lowest limit price is set as calculated from **the threshold price.** The contractor who bids below the lowest limit price is

asked closely the reason of such low price.



Introduction-2: A cost estimation system

In order to calculate the threshold price, a large quantity of database and a complicated system named **"a cost estimation system"** implemented detailed logics for calculation is required.

JACIC was established as a foundation authorized by the Ministry Land, Infrastructure, Transport and Tourism (MLIT).

MLIT is responsible for public works administration.

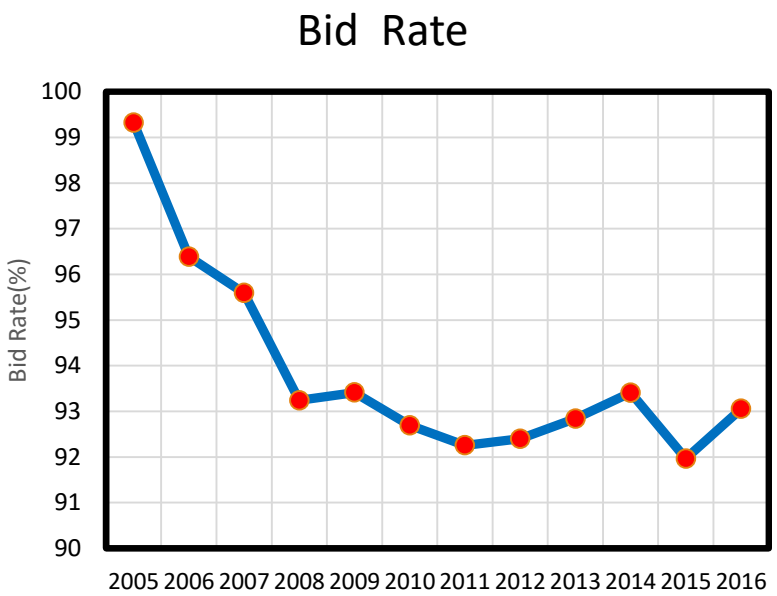
To promote the smooth procurement of public works

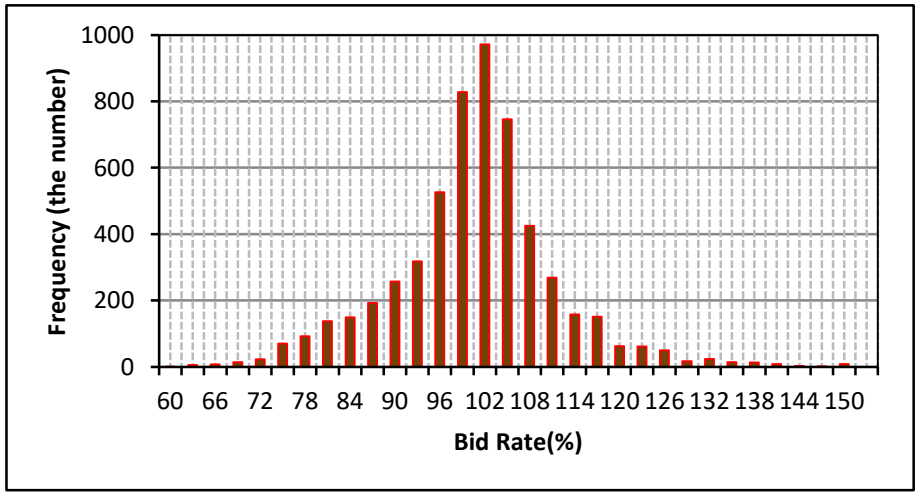
JACIC has been provided

the data and cost estimation systems

Research object

In recent years, because of increase in the number of low-priced bids as a result of intensification of order-taking competition, there had been growing concern about deterioration of public construction caused by **corner-cutting works**, **the hard work of subcontractors and workers**, and so on. Therefore MLIT makes effort to let threshold prices to reflect the market situation by reviewing "a cost estimation system". As one idea to solve this problem, **we propose the method to check threshold prices by calculating bid rates before notifying an item publicly**.





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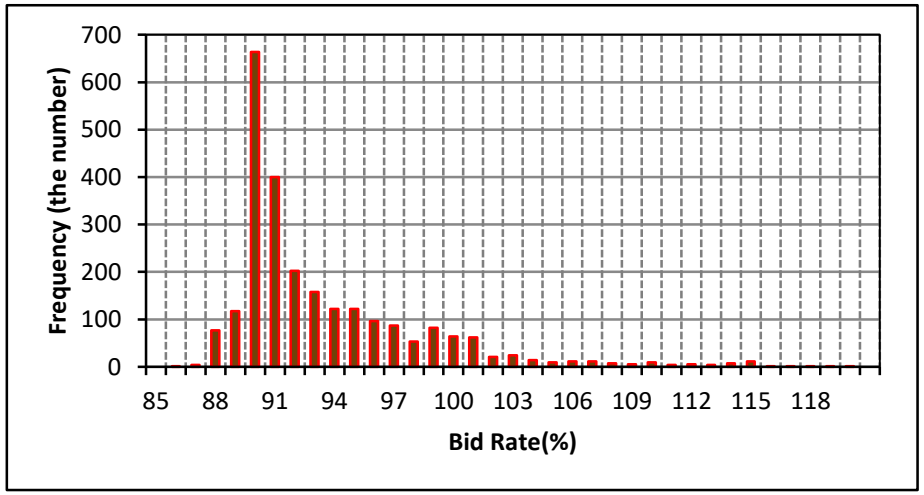
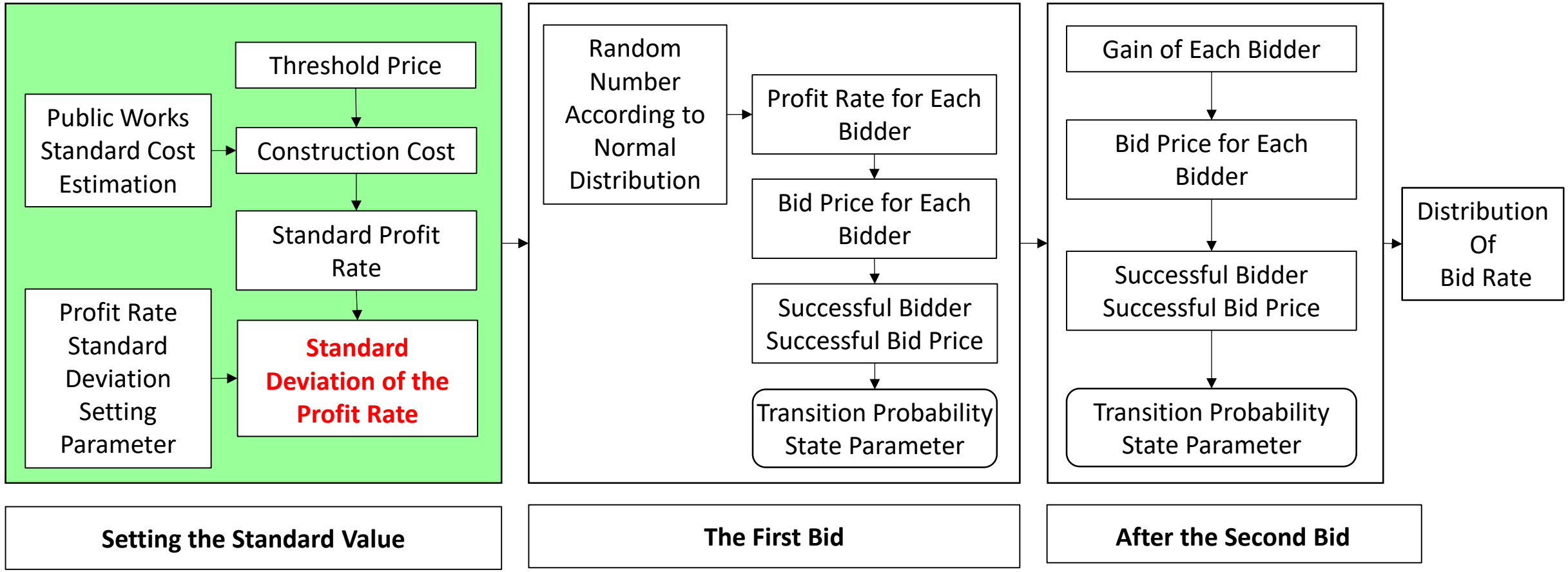


Outline of our model-1: Setting the Standard Value

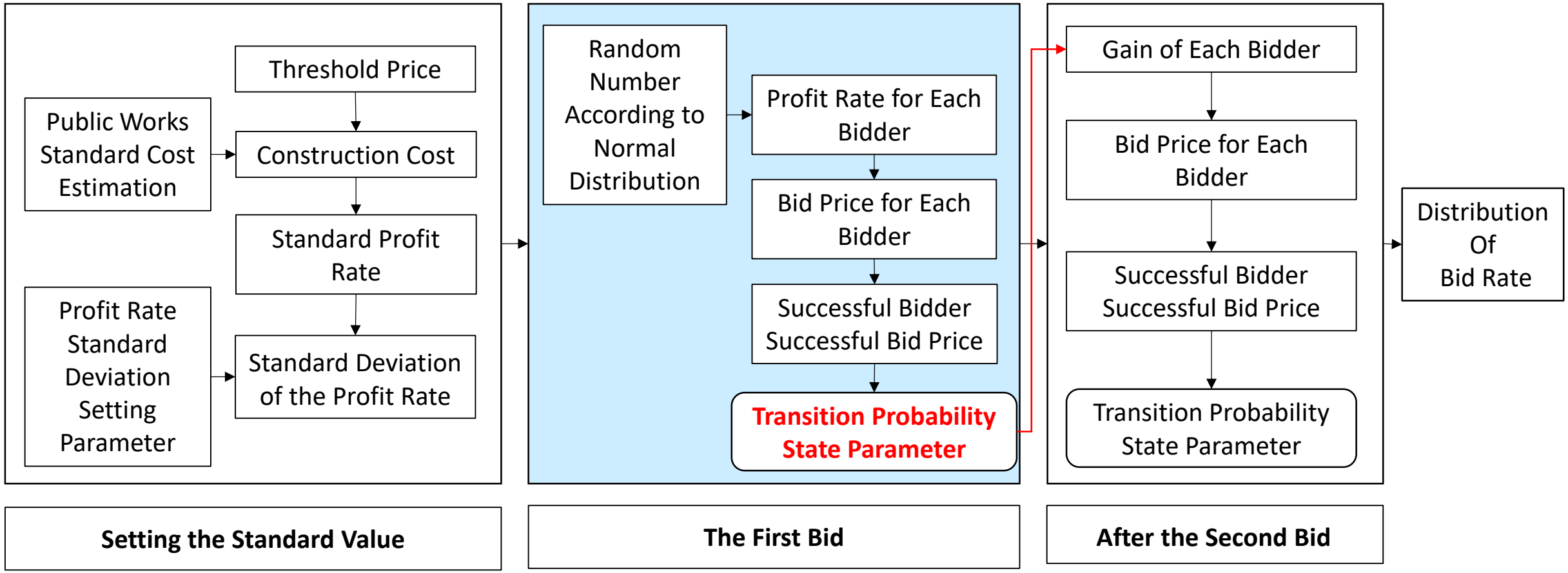


Our model consists of three phases as shown in this figure.

The purpose of first phase is to **gain the standard deviation of the profit rate** which is the base of the profit rate for each bidder in next phase.

The threshold price is an amount of money that the bidders calculate from notification contents when the contract office notifies publicly.

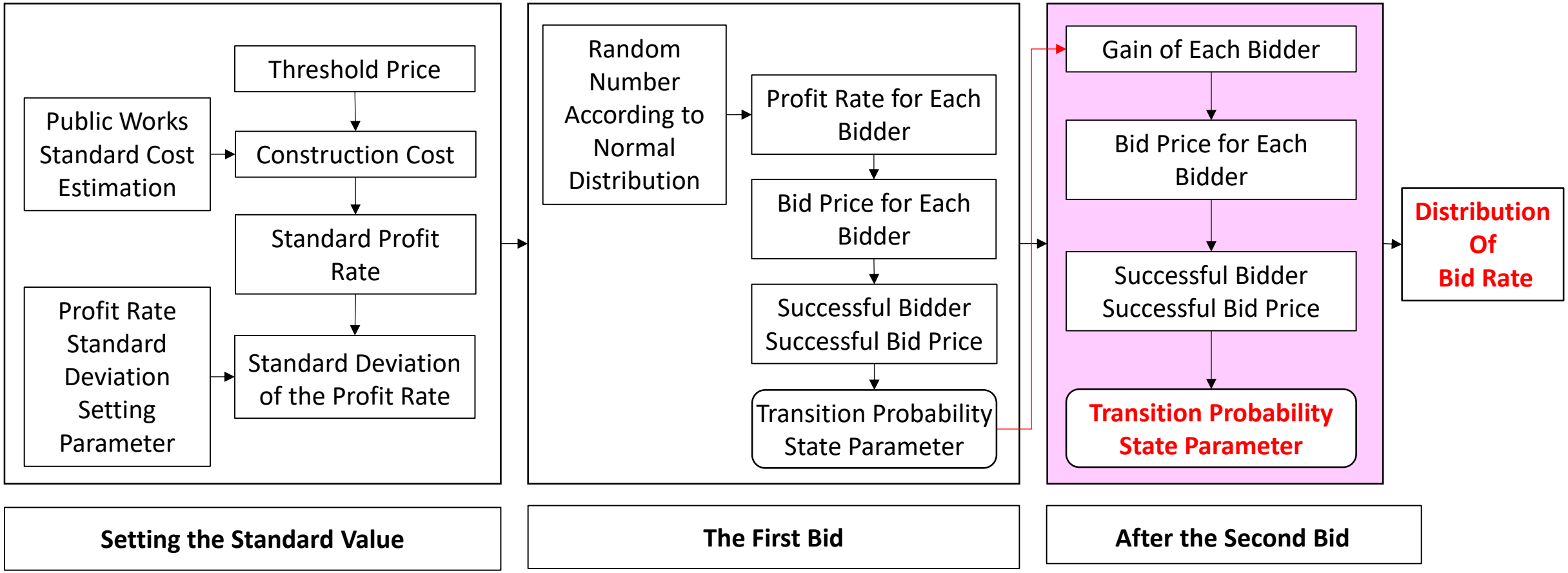
Outline of our model-2: The First Bid



We simulated **the first bid price and the first bid rate as the normal bids that are bidden without any strategy**, and **after the second bid, bidders behave strategically based on values using the idea of reinforcement learning**.

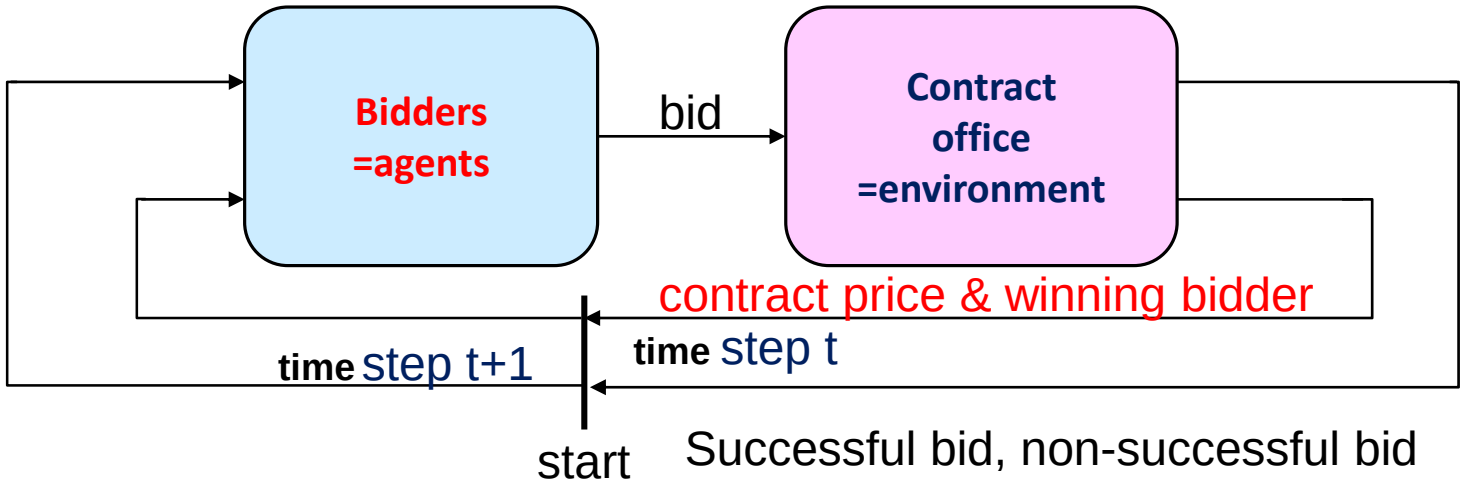
In the first bid phase, each bidder's profit rate is calculated by standard profit rate with the random number according to normal distribution to set the bid price for each bidder.

Outline of our model-3: After the Second Bid



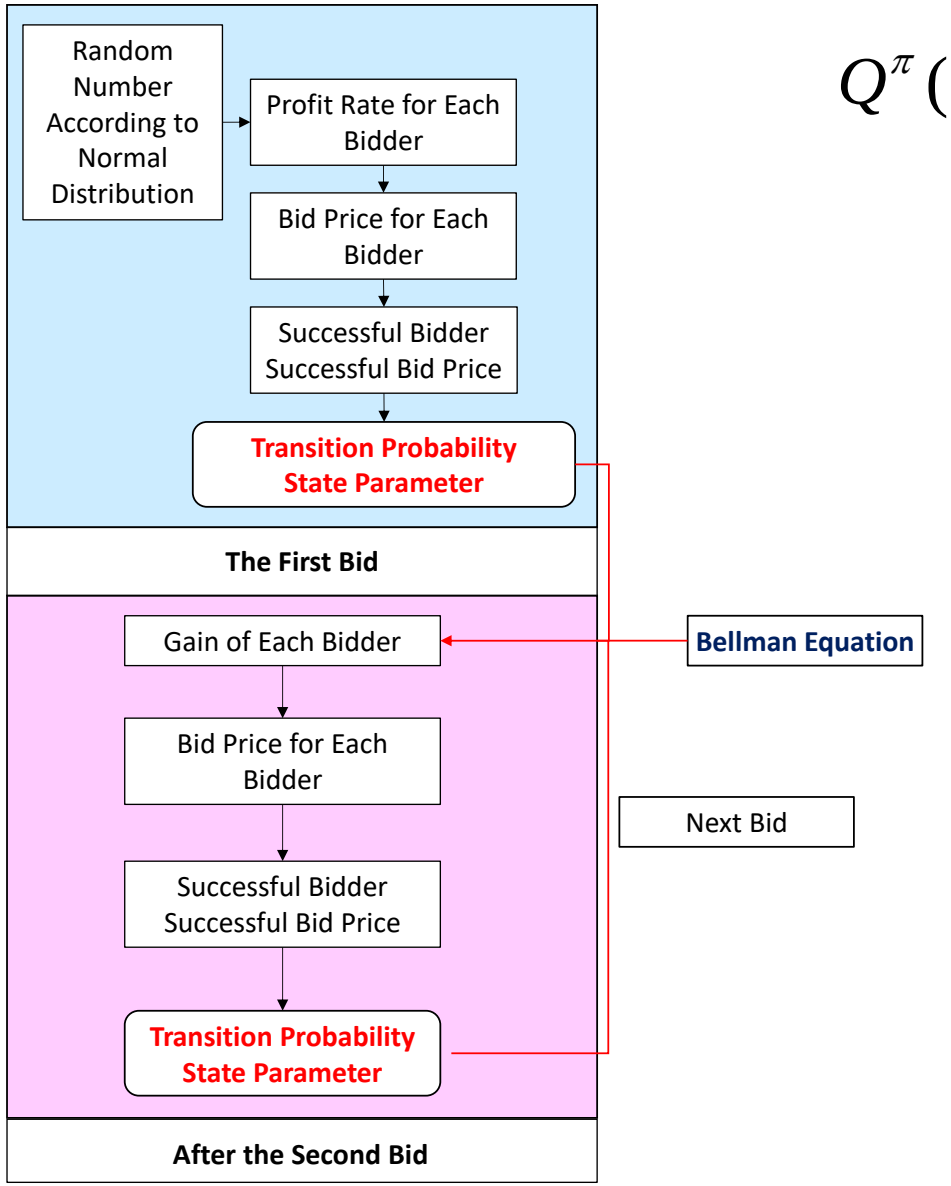
In after the second bid phase, the bid price is calculated based on **Bellman Equation** by the Dynamic Programming. Bellman Equation is used as a basic idea of reinforcement learning.

Outline of our model-4: Framework of Reinforcement Learning for Bid Market



To build our simulation system, we applied a multi-agent simulation model in which bidders are agents and **the contract office is an environment**. We applied how to decide the behavior of the agents to the idea **of reinforcement learning** in this model. In reinforcement learning, **the relationship between the environment and the agents is such as shown in this figure**. The interaction between a contract office and the bidders continue. The bidders set the bid prices and the contract office responds to those bid prices and presents new bid item to the bidders. The contract office also gives the contract price to the winning bidder. The contract office and bidders interact at each of a sequence of the bidding time, t=0, 1, 2, 3, ...

Outline of our model-5: After the Second Bid -Bellman Equation-



$$Q^{\pi}(\mathrm{s},\mathrm{a}) = \sum_{s' \in S} p(s'|s,a)(r(a,s,s') + \gamma \sum_{a' \in a(s')} \pi(a'|s')Q^{\pi}(s',a'))$$

Where a is an action of the agent,
a' is the action of next time step,
s is a state of agent determined by an environment,
s' is the state of next time step,
$\gamma \in [0,1)$ is the discount factor (=0.8),
$\pi(a'|s')$ is probability of the action a' with condition s' (=1.0),
$Q^{\pi}(s,a)$ is an action value (Gain of Each Bidder) when the state is s and the action of an agent is a.
$P(s'|s,a)$ is Transition Probability State Parameter.

Simulation-1: Setting the parameters

This table shows **the distribution of the number of bidders** who bid for general public works ordered by Kanto Regional Development Bureau in 2016 fiscal year. The composition ratios of the number of bid items are large in order of one bidder, two bidders and three bidders. We should simulate the bidders' behavior to win a competition of bid market, therefore the number of bidders should be plural. And if the number of bidders is two, the bidders are only just two whether a winner or a loser. Thus we set the number of the bidders at three.

Number of the Bidders	1	2	**3**	4	5	6	7	8	9	10	over 11	Sum Total
Number of the Bid Items	81	78	**58**	48	47	35	33	17	12	12	50	471
Composition Ratio(%)	17.20	16.56	**12.31**	10.19	9.98	7.43	7.01	3.61	2.55	2.55	10.61	100.00

The table which I show bellow shows **the composition ratios of the number of items** in that bidders participate are large in order of one item, two items. The data source is same as the number of the bidders shown in the table I showed on the top. In reinforcement learning, the agents learn in a repeated bid. Therefore one item is not appropriate to our model. And the bidder who participate only in two items par year has only one chance to learn. The agents should get opportunities of learning as much as possible within the actual data. Thus we set the bid participation number of the items at four.

Bid Participation Number of Items	1	2	3	**4**	5	6	7	8	9	10	over 11	Sum Total
Number of Biddera	88	54	41	**27**	16	16	17	9	8	14	72	362
Composition Ratio(%)	24.31	14.92	11.33	**7.46**	4.42	4.42	4.70	2.49	2.21	3.87	19.87	100.00

Simulation-2: Setting the parameters [Status and bid level & Precondition]

[Status and bid level]

This table shows the combinations of the successful and the non-successful bids and the classification of the active level of receiving the order.

Status	The First Bid		The Second Bid			The third Bid
Number	Success	Non-success	Success	Non-success	Level	Level
1	○				middle	
2		○			high	
3	○		○			low
4	○			○		middle
5		○	○			middle
6		○		○		high

Low :0.75
Middle:0.50
High :0.25

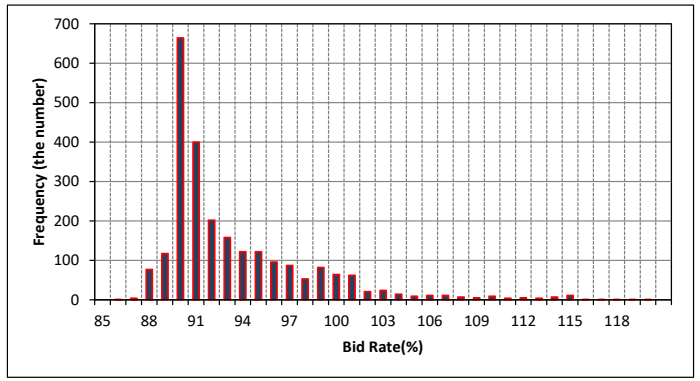
[Precondition]

According to the results data of the general public works ordered by Kanto Regional Development Bureau in 2016 fiscal year, the number of bid times is 2,458. And as mentioned above, we let the number of bidders and the number of bid times per one bidder to four and three respectively. We should let the data size of actual data and results estimated by our simulation model at the same level as much as possible. Therefore, we set the notification number of times of in one year at 200. The number of the bidders is 4, the number of times of bids per one bidder and one year is 3. The multiplication result of the notification number of times of one year is **2,400**. As mention above results data is **2,458**.

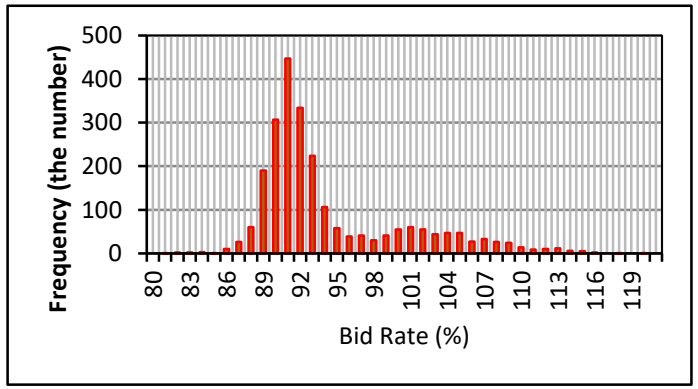
Simulation-3: Simulation Result

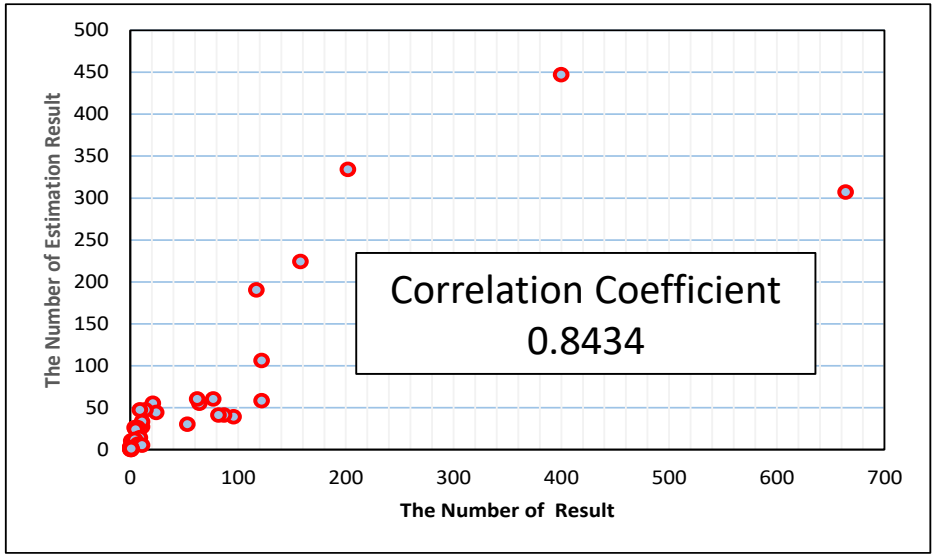
The left figure shows the result level of the frequency of the bid rate in 2016. The figure in the center shows the simulation result. The figure in the center reproduces the left figure intuitively. The right figure shows the number of the actual levels and the simulation results those are the same bid rates, to compare them quantitatively.
A coefficient of correlation of the real data and simulation result is 0.8434, hence we judged the result to be desirable. According to the above results, it may be said that the simulation result reflect an actual tendency to a certain degree.

the result level



simulation result





Conclusion and unfinished problems

As I mentioned before, we confirmed that our prototype model almost reproduces results data.
However, the following problems are left unfinished.

(1) Extension to Generalization
We think that it should be done to ensure this model generally to test by other regions and the data of other years.

(2) Learning Algorithm
In this study, the agent as the bidder learns from experience of success and failure of the bid, and he predicts a future profit by Bellman Equation. We think that we should try to apply some other algorisms to improve our model. Such as, Sarsa or Q-learning.

Thank You For Your Attention