The Relationship between the Efficiency of Auction and Preference Elicitation Cost based on Experimental Approach

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1 Introduction

In this study, we analyze the effect of preference elicitation mechanisms on the efficiency of auction results via laboratory experiments. An accurate assessment of potential user demand is important for the service providers of transportation services and reservation systems. However, the user interface and preference elicitation method can impact the results elicited from users.

In auction and reservation systems such as tradable permit system in transportation services, it is important for service providers to be able to predict potential user demands. Many previous studies on auction-based schemes for transportation systems and services such as a tradable credit scheme (Viegas, 2001; Yang and Wang, 2011; Wu et al., 2012; Nie and Yin, 2013) and a tradable permit system (Verhoef et al., 1997; Akamatsu, 2007; Wada and Akamatsu, 2013; Hara and Hato, 2017) exist. However, studies evaluating the cognitive cost of users' bidding behavior and empirically establishing a relation between the efficiency of auction and elicitation method have not been reported.

With respect to the cognitive cost of preference elicitation in an auction, we should think of the following three problems:

1. Do cognitive costs of preference expression exist in reality?
2. If they do exist, to what extent can the cognitive cost be evaluated?
3. Is it possible to design preference elicitation mechanisms that can reduce such cognitive costs?

This study aims to answer these three questions through empirical analysis using experiments. The contributions of this study can be summarized in the following five points.

1. We designed and executed experiments to analyze differences in elicitation mechanisms.
2. We introduced a survey system based on the Bayesian Truth Serum (Prelec, 2004) that encourages subjects to improve their response accuracy.
3. Based on the experiment, we empirically showed that valuations and the number of representations vary depending on a preference representation system.
4. The differences in the number of representations resulted in a thin market. A thin market means a market with a low number of transactions. As a result, the differences in the number of representations reduce the efficiency of the auction results.
5. We showed that we can significantly improve the efficiency of auction via increasing the number of preference representations using the preference elicitation mechanism.

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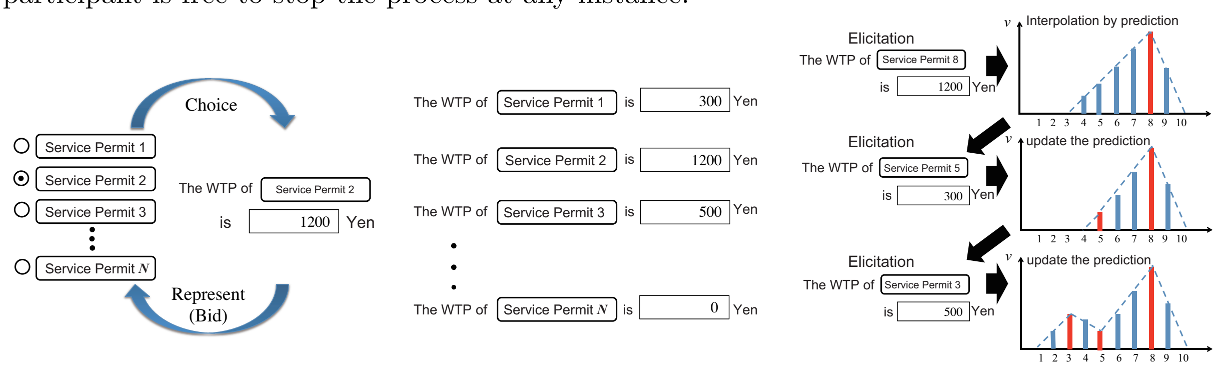
2 Experimental Design

The objective of our laboratory experiment is to demonstrate the existence of cognitive cost of individuals in representing their willingness to pay (WTP) for transportation services.

We contacted 1647 participants in the Tokyo metropolitan area through a marketing research company and divided them into three random groups for a randomized controlled trial (RCT). Next, each participant indicated their WTP for transportation services on our website. The situation presented was the reservation of a seat in a commuter train and each participant was required to represent their WTP for the reserved seat in each time slot. The number of time slots was 20.

Figure 1 shows the representation method that each group used to indicate their WTP. In the first representation (step-by-step representation), each participants chooses the most desirable permit and he/she indicates their WTP. This process is repeated. In the second representation (all-in-one representation), each participant simultaneously fills in their WTPs. In the third representation (preference prediction representation), first, each participant chooses the most desirable permit and he/she indicates their WTP. Second, the system predicts their WTPs for the other time slot permits. If the participant does not like the result, he/she modifies the valuations. This process is repeated. For each representation mechanism, the participant is free to stop the process at any instance.



(a) step-by-step representation (b) all-in-one representation (c) preference prediction representation

Figure 1: Three preference representation mechanisms.

In our experiment, we analyzed the differences in preference representation mechanism using RCT. Therefore, if cognitive and representation costs were not present, the result of the WTP should be same. Figure 2 shows the result of average WTP in each preference elicitation mechanism. Interestingly, the case that attracted the highest WTP is the reserved seat in the commuter train whose arrival time was 8:30am. In addition, all preference representation mechanisms show the early arrival cost and the late arrival cost, and the slope of late arrival cost is observed to be larger than that of early arrival cost. However, the most important difference is that the distribution of preference prediction mechanism is tail-heavy. In fact, the average number of representations is 2, 1, and 7. Hence, the preference prediction mechanism drastically improves the number of responses.

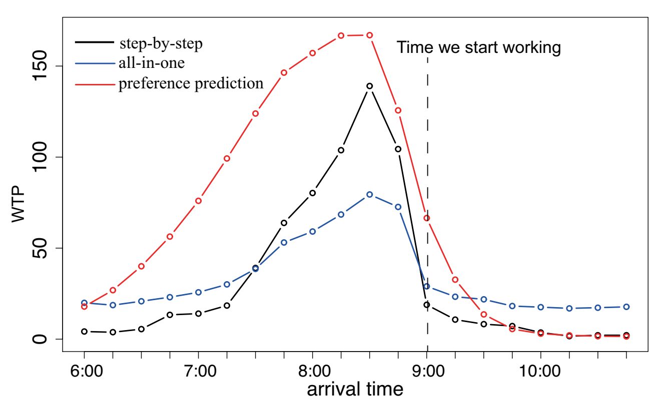


Figure 2: The difference among preference representation mechanisms.

3 Relation between Auction and Preference Elicitation

Next, we analyzed the effect of the preference elicitation mechanism on the efficiency of the auction results. Because the number of preference representations is different for each mechanism and the low-rank time slot tends not to be represented in the usual mechanisms, the elicitation mechanisms have a strong effect on the allocation results.

We assume that users are interested in only a single time slot of the transportation service and that the objective of the service provider is maximizing social welfare. Under this assumption, it becomes a usual combinatorial auction problem and a Vickrey–Clarke–Groves (VCG) mechanism. The price of each time slot is determined as a VCG price. This allocation problem is expressed as follows:

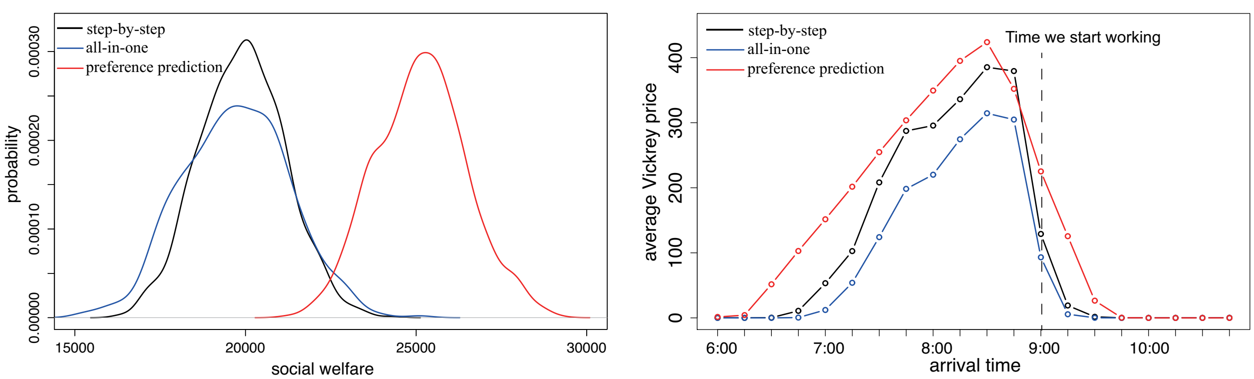
$$W(\boldsymbol{v}) = \max_{\boldsymbol{x}} \sum_{t \in T} \sum_{iinI} v^i(t) \cdot x^i(t) \tag{1}$$

subject to

$$\begin{aligned} &\sum_{t \in T} x^i(t) \leq 1 && \forall i \in I \\ &\sum_{i \in I} x^i(t) \leq \mu && \forall t \in T \\ &x^i(t) \in \{0, 1\} && \forall i \in I,\ \forall t \in T \end{aligned}$$

wherein $\boldsymbol{v}^i = (v^i(1), \ldots, v^i(t), \ldots, v^i(|T|))$ is the private valuation vector of user $i \in I$, $x^i(t) \in \{0, 1\}$ is the discrete variable which represents the allocation result of user i at time slot t. The constraint conditions are single-unit demand and the capacity limit of time slot t less than μ.

Figure 3 shows the allocation results and VCG paymens via re-sampling 100 users in 1000 iterations. After re-sampling 100 users, we compute Eq.(1) and obtain the allocation result, social welfare, and the VCG payments, which represent the price of each time slot. From the result, our proposed preference prediction mechanism drastically improves the efficiency of auction result, while the VCG payments do not change in a like manner.



(a) The distributions of social welfare each preference representation mechanism

(b) The VCG payments of each timeslot in each preference representation mechanism

Figure 3: Distribution of social welfare and VCG payments

4 Conclusions

We designed and performed an experiment to analyze the differences in preference representation mechanisms for transportation systems. As a result, we showed that the valuations and the number of representations vary depending on the preference representation system used. Furthermore, the preference representation system used had an impact on the efficiency of transportation service auctions. Finally, we showed that the auction efficiency can be significantly improved via increasing the number of preference representations using the appropriate preference prediction mechanism.

References

[1] Viegas, J., 2001. Making urban road pricing acceptable and effective: Searching for quality and equity in urban mobility. Transport Policy 8 (4), 289–294.

[2] Yang, H. Wang, X., 2011. Managing network mobility with tradable credits, Transportation Research Part B, 45, 580–594.

[3] Wu, D., Yin, Y., Lawphongpanich, S., Yang, H., 2012. Design of more equitable congestion pricing and tradable credit schemes for multimodal transportation networks. Transportation Research Part B, 46, 1273–1287.

[4] Nie, Y., Yin, Y., 2013. Managing rush hour travel choices with tradable credits scheme. Transportation Research Part B, 50, 1–19.

[5] Verhoef, E. T., Nijkamp, P., Rietveld, P., 1997. Tradable permits: Their potential in the regulation of road transport externalities. Environment and Planning B: Planning and Design, 24, 527–548.

[6] Akamatsu, T., 2007. A system of tradable bottleneck permits for transportation networks, JSTE Journal of Infrastructure Planning and Management, 63, 287–301 (in Japanese).

[7] Wada, K., Akamatsu, T., 2013. A hybrid implementation mechanism of tradable network permits system which obviates path enumeration: an auction mechanism with day-to-day capacity control. Transportation Research Part E, 60, 94–112.

[8] Hara, Y., Hato, E., 2017. A car sharing auction with temporal-spatial OD connection conditions, the proceedings of the 22nd International Symposium on Traffic and Transportation Theory.

[9] Prelec, D., 2004. A Bayesian truth serum for subjective data, Science, 306 (5695), 462–466.