Exploring self-organisation for car-sharing systems

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***Abstract* — In this paper, an exploration for the possibilities for self-organisation of car-sharing systems is discussed. This is executed by applying the design principles that Ostrom defined for the successful management of common-pool resources (CPR) through self-organisation. Therefore, the car-sharing is viewed as a common-pool resource so that these design principles can be applied. The effects of the presence of the design principles are measured by implementing them in an agent-based model for car-sharing. The results show that a combination of the design principles can be beneficial for the car-sharing system. And therefore, new institutional settings can be developed based on the design principles and focussed on the self-organisation of these systems.**

Index Terms — Car-Sharing, Common Pool Resources, Design Principles, Self-Organisation

1. Introduction

In the Netherlands, car-sharing is regarded as an important part of the transition towards a more sustainable transportation network [1]. Car-sharing services often use fuel-efficient cars leading to a reduction of the emissions in a city [2]. Next to that, studies in North-America have shown that the vehicles miles travelled decreases amongst users of car-sharing services with an average of 44% [3].

However, car-sharing systems have not always proven to be economically sustainable [4]. Next to that, the space in cities is limited, which constraints parking spaces for shared cars [5] [6].

The current institutional collaborations in car-sharing systems often rely on public-private partnerships [7]. Next to that, there is no evidence for cooperation between the companies. Therefore, in this research, a new type of system is envisioned that relies on self-organisation and collaboration between the companies.

The research question that will be answered is:

"What kind of institutional settings can be used to manage a car-sharing system?"

This work is structured as follows. In Section 2, the method that is used in this research is explained. In Section 3, the approach to explore the self-organisation is described. Section 3 shows the results, and in Section 4, the discussion is presented. Finally, in Section 5, the conclusion and future work are offered.

2. Method

To explore the institutional settings for the car-sharing system, an agent-based model (ABM) is constructed. With this type of computational modelling, the behaviour of "agents" is described with simple rules and through the interaction with other agents' results are obtained. It can be used for a wide variety of applications but is most useful when describing a complex system [8].

In transport studies, agent-based modelling is becoming more popular because of the ability to model the system with complex interactions between actors which assist in testing different complex scenarios [9]. The strength of this type of modelling to model the interactions in a system and test different situations is the reason this type of modelling is chosen in this research.

3. Approach to explore self-organisation

In this work, the self-organisation of car-sharing systems is explored. Therefore, it will first be examined as a common-pool resource to apply the design principles that Ostrom developed for the management of such systems.

Common-pool resources

For a resource to be classified as a common pool resource, it has to have two characteristics. The first one states that goods or services are diminished by consumption or use [10]. This can be found in car-sharing systems in the constraint of parking spaces. Governments are trying to reduce the traffic in cities by limiting parking facilities [11]. This reducing of parking spaces limits the capacity of a car-sharing service because it sets boundaries on the number of cars in the system. And through the use of subscribers the supply diminishes.

The second characteristic is the difficulty of restricting the use of the service [10]. It could be claimed that it is easy to exclude new users since it is a paid service and users have to be in possession of a driver license [12]. However, the goal of the fares in the system is to maintain the system and not to exclude potential users. If people are willing to pay for the use, their access is not retained. Another restriction to the use of car-sharing services is the driver license. This is to ensure safety on the road. In the Netherlands, 80% of the people aged 17 and older possess a driver's license [13]. Both these two elements are only limited restrictions to the use of the car-sharing service. Therefore, it can be concluded that access to car-sharing services in the places where there is a car-sharing service is difficult to restrict.

Design principles

Ostrom identified the conditions that will help to maintain the self-organising institutions to govern these common pool resources, "design principles for long-enduring common-pool resource institutions" [10].

The design principles describe similarities between self-organising systems, that have learned to adapt and learn over time to be robust to all sorts of disturbances [14]. On the next page in Table 1 the implementation of the design principles in the model is shown.

Design principle	Description of the implementation
Clearly defined boundaries	1) The number of users in the system 2) The number of cars can be limited 3) The number of companies can be limited
Congruence between appropriation and provision rules and local conditions	The users pay the price per distance covered in a shared car.
Collective-choice arrangements	The companies vote to determine the bottom-price. This affects the pricing of companies.
Monitoring	It is implemented as a probability of violating rules in combination with having a higher price than the current market price.
Graduated sanctions	In the model, this is implemented as a probability of getting sanctioned if a company has violated a rule
Conflict-resolution mechanisms	Not implemented in the model
Minimal recognition of the right to organise	Not implemented in the model
Nested enterprises	Not implemented in the model

Table 1. Implementation of the design principles in the model

4. Results

With the design principles implemented in the car-sharing experiments are executed to test the influence of the presence of the design principles. The design principles for clearly defined boundaries, congruence between appropriation and provision rules, local conditions and monitoring were varied throughout the experiments. The design principles for collective choice arrangements and graduated sanctions are altered in the experiments

Collective choice arrangements

Figure 1 shows the number of times a market price has occurred in a system where the design principle of collective choice arrangement is present. The market price is the average of all company prices.

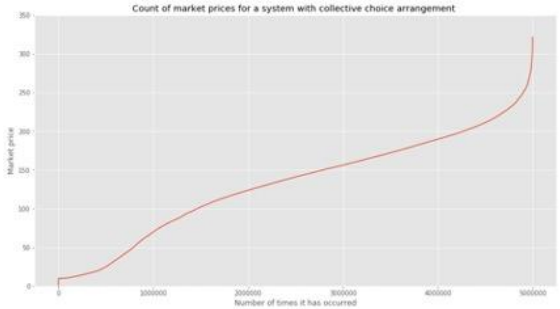

Figure 1. Count of market prices for a system with a collective choice arrangement

In Figure 2 on the next page, the results for a system without the collective choice arrangements present are displayed.

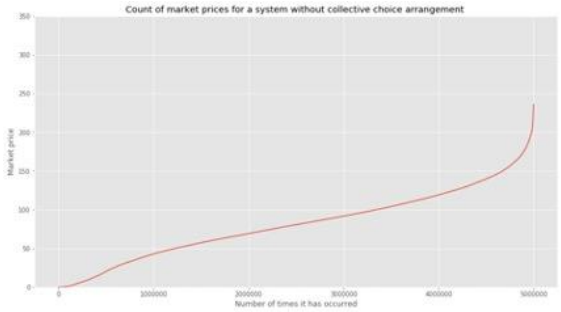

Figure 2. Count of market prices for a system without collective choice arrangements

From the results presented in Figure 1 and Figure 2 it becomes evident that the presence of the collective choice arrangements results in higher prices in the system. This subsequently results in higher company profits. The other benefit of having the collective choice arrangements is that there is a smaller chance of the companies violating the rules [15]. The collective choice arrangements did not improve the satisfaction rate or the number of times a subscriber had to search for parking in the model.

Graduated sanction

The presence of the design principle of graduated sanctions affects the combined profits of the companies. This can be seen in Figure 3. The combined profit of the three companies for a system with graduated sanctions and Figure 4. The combined profit of the three companies for a system without graduated sanctions.

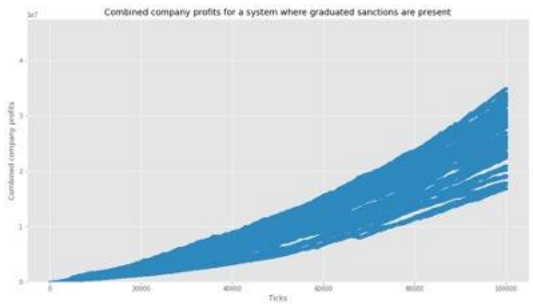

Figure 3. The combined profit of the three companies for a system with graduated sanctions

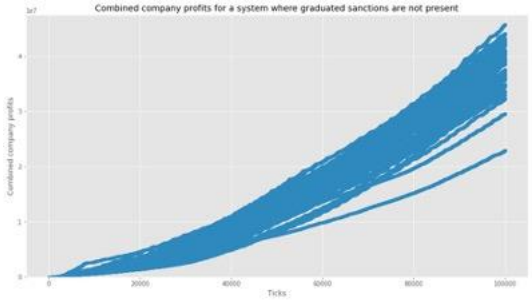

Figure 4. The combined profit of the three companies for a system without graduated sanctions

These results show that the profits in the system with graduation sanction are lower. This is the consequence of the companies paying the fines, which affects their profit.

Next to that, the graduated sanctioning also influenced the market prices in the system. This can be seen in Table 2 below.

	With graduated sanctions	Without graduated sanctions
Mean price	86.05	130.59
Standard deviation	39.69	66.61

Table 2. Summary of the mean prices with the standard deviation for a system with and without graduated sanctions

From the table, it is evident that the prices in the system with graduated sanctions are significantly lower. So, this design principle influences the price setting of the companies.

5. Discussion

This study has explored the institutional settings for car-sharing systems by applying the design principles of Ostrom and investigate their impact on the system. There are apparent differences between the systems that Ostrom and her colleagues studied and a car-sharing service.

The major limiting factor in this research is the simplification of the car-sharing system in the model. The model that was created resembles the main features of the car-sharing system but does not nearly capture all of its complexity and dynamics. Moreover, the model is based on literature and assumptions. Demand and the size of the map, for example, are two things that were assumed. However, the goal was to explore institutional settings by defining car-sharing as a common-pool resource; for this purpose, the model was sufficient. Next to that, is it not clear if the KPI's that where identified was the only influence that the design principles have.

6. Conclusion and future work

To conclude, this research has implemented the design principles of Ostrom in a model for car-sharing. This has explored new possible institutional settings for car-sharing and answers the research question:

"What kind of institutional settings can be used to manage a car-sharing system?"

Using the results of the literature review, the application of the theories and the output of the model. The design principles of Ostrom for the governance of common-pool resources can be related to car-sharing and are applied in the model. The design principles on the equivalence between benefits and costs, boundaries, and monitoring are implemented in the model. The data analysed from the experiments with the model suggest that a system with collective choice arrangements results in higher profits. The profits of companies decrease due to the presence of graduated sanctioning. But the prices are more stable, and therefore the profits for the companies are more predictable.

With these results, it can be concluded that there is reason to believe that the car-sharing system can benefit, depending on the rules that are created, from the implementation of the design principles. And therefore, the systems institutional settings could be created from the design principles and focussed on the self-organisation of these systems.

Future work

In future research, the model could be extended with the use of real-world data. This could reveal more in-depth the influence of the design principles on the real system and possible encourage car-sharing companies to investigate the possibilities for self-organisation.

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