A participatory game to test the introduction of a carbon credit scheme in city logistics

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Extended abstract

Objectives and motivation
The study of behavioural responses to urban freight policies and innovations requires a recognition of the fact that multiple stakeholders in a city (including consumers, retailers, shippers, carriers and municipalities) determine the effects together, often in close interaction. These stakeholders have different goals, constraints and modes of interaction; which makes the city resemble a distributed decision making system (Anand et al., 2014). In this system, parties are asymmetrically informed, are seeking for cooperation, and are behaving opportunistically to their own autonomous goals (Schneeweiss, 2003).

From the economic point of view, a new policy or initiative often involves extra cost to the stakeholders. Improper distribution of the extra cost could lead to unsatisfied stakeholders (those who are negatively affected by such policy) and eventually to failure of such initiatives. For instance, most UCC operations started with a huge subsidy from the government could not last long due to the high cost incurred to UCC. In another study, done in New York City, Holguín-Veras (2008) explains that the balanced cost distribution between the carrier and the shopkeeper is a necessary condition for the success of off-hour delivery by the carrier. Such situations point to the fact that the economic aspect of cost distribution also requires analysis from the viewpoint of multiple stakeholders. Their reactions to the extra cost give an indication as to whether such a concept has potential for solving city logistic related problems.

In this paper a new policy concept is introduced and tested: carbon credit points for urban delivery. The concept of delivery and price setting is inspired from the carbon credit system of the Kyoto protocol (United Nations, 2006). In the Kyoto protocol, the effect of carbon is considered at the global scale and as per the treaty each country that is part of this protocol is responsible for reducing carbon levels. The Kyoto Protocol introduced a medium called carbon credit to achieve the goal of CO2-reduction. Each county receives a certain carbon credit and each carbon credit permits emissions of one ton of CO2. If a country has emissions of CO2 that is over its allowance, it incurs extra cost. Conversely, if a country is able to stay under its allowance, it can trade its credit with another country.

In city logistics, the delivery cap and price setting focuses on the direct objective to reduce the number of truck-km travelled by conventional vehicles (e.g. diesel and gas powered trucks), to achieve the higher goal of emission reduction. Distance travelled by these trucks is directly associated with issues such as congestion, pollution and safety related issues in the urban areas. Distance travelled depends on the use of UCC’s and type of truck, while demand is driven by consumers as well as order frequency and lot sizing behaviour of shops. The scenario takes the number of goods deliveries at shops as main point of intervention for the CCP policy.

The following research question is formulated: ‘Can the implementation of a carbon credit point concept create value for all stakeholders involved?’ To answer this question first a literature review is carried out to reveal the details of carbon market based mechanisms based on Kyoto Protocol and earlier executed researches concerning application of these mechanisms. The next step is the development of a participatory simulation game to introduce some variants of carbon credit point concepts. Some of the results will be presented in this paper.

General description
Earlier researches indicate three different types of carbon market based mechanisms: (– International Emission Trading (IET), Clean Development Mechanisms (CDM) and Joint Implementation (JI) –). These not only reduce the amount of emitted emissions but also encourage participants to achieve their target in a cost-effective way. Earlier researches have applied Kyoto Protocol’s mechanisms in various areas including supply chains, electronics, power plants and so on. In particular, the application of transport and logistics is mostly found in researches dealing with the emission trading mechanism. This result is strong in contrast with the other mechanisms, CDM and JI. The carbon credit point concept can be seen as an implementation of IET at city level.

We developed a participatory simulation game (PSG) for collecting information about interlaced behaviour of the stakeholders. According to Colella (2000), participatory simulation takes the simulation off of the computer screen and brings it into the experiential world of the player. In the PSG we put the decision maker in the dynamic setting of the ABM (Agent Based Model) and thus his/her decision making is now interfaced with decision choices of other agents of ABM. The decision making mechanisms of the agents follow the Belief-Desire-Intention architecture by Rao and Georgeff (1995). The BDI has a similar structure to the utility in the discrete choice analysis where agent would choose the alternatives (e.g. Actions) that maximize its utility based on the assigned specific weights (e.g. Beliefs). By bridging an agent based simulation model with the human players, we can create an environment in which players are taking decisions based on underlying rules that are consistent and comprehensible.
The CCP scenario

An urban consolidation centres (UCC) is a city logistic concept that is intended to consolidate goods for delivery in the urban areas. UCC’s essentially separate the distribution activities inside and outside the city by transshipping at the city border. Large goods delivery vehicles deliver goods to UCC. The goods from different vehicles are consolidated in smaller trucks – often in an environmental friendly way (e.g. using electric trucks) to transport to the shops. The goods delivery of the shop agent is divided into two types: through UCC and direct delivery by carrier. The shop agent prefers to choose the delivery from carrier, even if it requires more costs, as delivery via UCC takes more time.

In the game, the vehicles of UCC are more sustainable alternatives than those of carriers. From the perspective of the municipality, UCC could be a way to reduce nuisances of city logistics by reducing the number of carrier vehicles entering the city at the same time. The municipality will encourage shop agents to use UCC by assigning a permit that allows limited number of the direct delivery. Thus shop agents should pay extra money for their own delivery via carrier or use UCC when exceeds the limit. At the beginning of every month, shops are assigned a certain amount of CCPs by the municipality. Shopkeepers can use CCPs to let their own carriers deliver goods. If they use all CCPs, it can be purchased from the municipality. In addition to allocating, the municipality also sells, purchases and manages CCPs. The current model offers shops the only way to earn extra CCPs by means of purchasing it from the municipality. The data is derived from 100 shopkeepers located in a part of the city of Rotterdam.

Results and conclusions

The results illustrate the impact of CCP setting on the goods transportation activities in the city. The comparison of KPIs indicates that the distance travelled by the carrier vehicles reduces by more than 30% in the CCP scenario compared to the distance travelled in the reference scenario. With the introduction of UCC, UCC vehicles are delivering goods to the shops in the city areas. The UCC vehicles are smaller in the size and use cleaner energy (e.g. electricity). In this view, the city is getting benefits due to less distance travelled by diesel operated large vehicles. Due to the introduction of UCC and the delivery point system, a shop is incurring an average cost increase. On the other hand, the municipality is generating net revenues by selling carbon credit points to the shops. Based on our first experiments we can conclude that the CCP scenario creates a situation where multiple stakeholders from a city logistics domain are interacting with each other to perform their activities in an optimal way. The scenario serves as a template for exploring other multi-stakeholder perspectives such as including congestion charges for carriers and transferring extra costs of the municipality to other actors. Recent research that has quantified the regional network benefit of shippers and carriers that use UCC (van den Berg, 2014) shows that there are additional benefits that can be redistributed. Eventually, the decision making of the stakeholders can be improved to include more sophisticated choice models and algorithms.

References


Keywords: Carbon Credit concept; Agent Based Modelling; Participatory Simulation Game, Multi stakeholders, reduction of vehicle kilometres.