# An agent-based model for feasibility and diffusion of crowd shipping

# An Agent-Based Model for Feasibility and Diffusion of Crowd Shipping*

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## 1 Introduction

In recent years, the sharing economy has revolutionized many different markets of different sizes. One relatively new example of the sharing economy is *crowd shipping.* In crowd shipping, packages are picked up and delivered by regular drivers using unused space in their vehicles. Unlike the big players (e.g., Uber and Airbnb), there is not much research being done on crowd shipping. In this thesis, an agent-based model was developed and simulated in order to gain insight into the feasibility and diffusion of crowd shipping based on results conllected from a survey.

## 2 Method and Results

A model was created, aiming to research two topics: (1) the diffusion (spread) of crowd shipping, by looking at the diffusion of a new innovation as explained by Bass [1], and (2) the feasibility of crowd shipping, by looking at the percentage of packages delivered. A survey has been conducted among around 85 people. The following subjects are most relevant to the model: (1) the flexibility of the person for crowd shipping; and (2) the expected payment for a package. Questions on when to do crowdshipping and what kind of rewards were desired were asked, but a large majority (70%) replied "commute" and "money", respectively.

The model was developed using RePast, an agent-based simulation platform. The model depicted two types of agents (Crowd Shippers and Regular Drivers) and the environment in which they moved. Both types of agents moved around on a grid, traveling between to their destination, while packages were dropped in the grid every few ticks (with every package having an origin and destination, as well as a reward associated with them). Only crowd shippers were able to pick up and deliver packages, drivers were not. However, drivers made a decision every 100 ticks to adopt crowd shipping or not, randomly chosen using the Bass method [1](see Equation 1), where $P(T)$ is the chance to adopt at time $T$, $p$ reflects the fraction of adopters that already adopted the product, $q/m$ represents the fraction of people the imitators comes in contact with, who have adopted the innovation, and finally, $Y(T)$ represents the number of previous adopters. In this way, adoption could be triggered in two ways: personal (through a bidirectional social network constructed at the beginning of the run) and mass media (through looking at the percentage of road users[1] who were crowd shippers).

$$P(T) = p + \frac{q}{m} Y(T) \tag{1}$$

The simulation starts with 5 crowd shippers and 195 drivers, i.e., 2.5% innovators. A crowd shipper generally moved between two points (home and work). Every tick, all packages in the model were screened[2]. For every package, the *decision to pick up and deliver the package* is calculated by looking at the extra number of cells a crowd shipper had to move to go to the package, move to the package's destination, and finally move to their own destination, as opposed to going to their own destination immediately. If this *extra distance* was smaller than the crowd shipper's *flexibility* (and the *reward* high enough for the crowd shipper), the package was selected and picked up by the crowd shipper. Using the survey results, we generated the flexibility of an agent using a uniform distribution$\sim [5, 19]$, and the expected payment of an agent using a uniform distribution$\sim [4, 6]$, for a trip of at most 20 minutes (or 20 spaces on the grid).

*Results.* Figure 1a and 1b, the average adoption curve and average delivery chart are shown. These curves are based on 5 consecutive runs of 2000 ticks each. The figure shows that the rate

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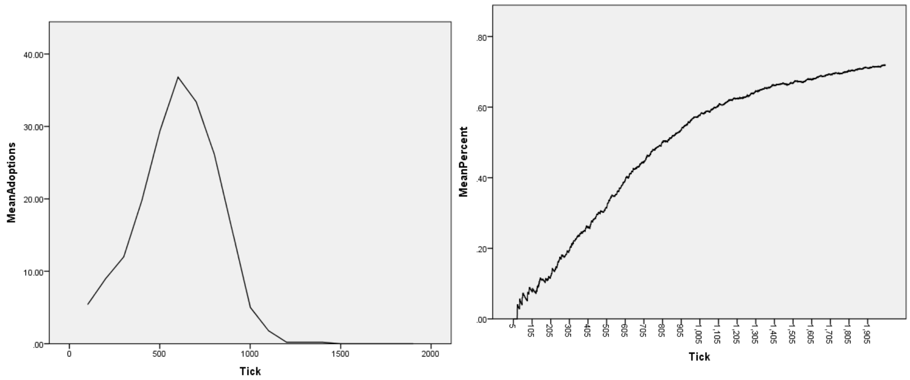
[1] It is assumed that all modeled road users are at least interested in adopting crowd shipping.

[2] Packages were removed after a certain amount of time to avoid clutter.




(a) Average Adoption curve per tick

(b) Average delivered packages (in percentage) curve per tick

Fig. 1: Adoption and delivered percentage packages of 2000 ticks.

of adoption follows a bell-shaped curve, which is similar to the results found in the literature on different application domains. The runs from the model showed that deliveries increase over time, in accordance with there being more crowd shippers due to adoption. Larger sets of users showed a significantly higher percentage of packages delivered.

Finally, when compared to the standard set-up, increasing the flexibility range of crowd shippers showed the biggest improvement of percentage of packages delivered (see Figure 2). Similarly, lowering the flexibility range of crowd shippers showed a significant decrease in percentage of packages delivered. For each range in Figure 2 (5-10 for LOW, 10-15 for MID and 15-19 for HIGH), five runs were averaged.

The following factors are identified as the most important for feasibility of the model (and reality): flexibility (as seen in Figure 2), reward (lower rewards led to much lower effectiveness) and starting base (larger groups of starting users led to earlier conversion of potential crowd shippers, leading to an earlier rise in percentage of packages delivered). For entrepreneurs who would like to start a crowd shipping business, incentivizing users with a higher tolerance to drive further will be key to the successfulness of crowd shipping.

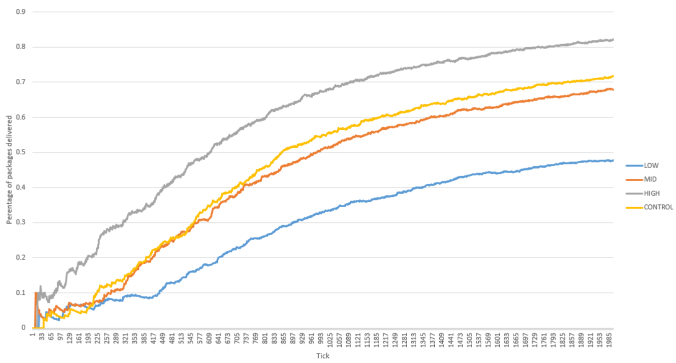



Fig. 2: Comparison of flexibilities

We have shown that there is certainly potential for crowd shipping if the right variables are met. In the future, we will work with crowd shipping companies and incorporate data collected from their platforms into the agent-based simulation model.

## References

1. F. M. Bass. A New Product Growth for Model Consumer Durables. *Management Science*, 15(5):215–227, 1969.