Rolling Stock Allocation and Crowd-Sensitive Passengers

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Complexity in Public Transport: http://www.computr.eu
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OVERVIEW

• The Model and Simulation Process
• Experiment 1: Information Policies
• Experiment 2: Rolling Stock Optimization
• Conclusions and Future Work
THE MODEL
THE EL FAROL BAR PROBLEM (ARTHUR, 1994)

• Population of 100 people (for example)
• Each person must decide whether to go to the bar or stay at home
• If more than 60% of the people go to the bar, their payoff is negative
• If less than 60% of the people go to the bar, their payoff is positive
• Staying at home always gives a neutral payoff
• Historic information is available, but there is no real coordination
THE MODEL

- A set $\mathcal{R} = \{1, \ldots, m\}$ of $m$ resources (interpret as train trips)
- A “soft” capacity function $\text{cap} : \mathcal{R} \rightarrow \mathbb{Z}^+$

- A set $N = \{1, \ldots, n\}$ of $n$ agents
- For every agent $i \in N$
  - A non-empty collection of route choices $C_i \subseteq 2^\mathcal{R}$
  - A scoring function $s_i : \mathbb{Q}^m \times C_i \rightarrow \mathbb{R}$

NB: This model has strong similarities with Congestion Games (Rosenthal, 1973),

- The game is repeated for a number of rounds so that the dynamics over time can be studied
THE MODEL

• For the sake of simplicity, we limit the scoring functions of the agents to the class of *threshold based scoring functions*.

• Given a threshold $\theta_i$ for a agent $i \in N$, we define the payoff as
  - $0$ in case the agent chose the empty set of resources
  - $-1$ in case *any* resource in the choice set had a utilization greater than $\theta_i$
  - $1$ otherwise

• This type of payoff structure is inspired by the El-Farol bar.
ITERATIVE SIMULATION

1. Let every agent pick a choice from its choice set.
2. Calculate an outcome and utilization vector.
3. Let every agent compute and process its payoff.
4. Let every agent process additional information on utilizations based on operator policy.
ITERATIVE SIMULATION

Performance Measures

- (tra) The fraction of agents utilizing a resource
- (pos) The fraction of agents with a strictly positive payoff
- (posc) Among the agents utilizing a resource, the fraction with a positive payoff
- (avg) The average payoff of the agents

Agent Type (2 of 4 types; for others see the paper):

- Average Utilization: 10% random choice, 90% lowest utilization observed
- Predictive: Random prediction heuristics; switch to the one which was best historically
EXPERIMENT 1: INFORMATION POLICIES
SINGLE ORIGIN DESTINATION / PASSENGER INFORMATION

Travel by PT? Which timeslot?

Information

Passengers

Choices

9:00
9:15
9:30
...

Utilization & Payoffs
We experiment with four implementations of the information policy:

- **Private**: You only get information for a train service you travelled with.
- **Adaptive**: Same information as ‘Private’ and you get utilizations for services with less than 40% utilization.
- **Estimate**: You get accurate information for the ‘Private’ case and for all other trains the utilization is rounded up to the nearest 25%.
- **Full**: You get accurate information for all train services.
### CHANGING THE CAPACITY/POPULATION RATIO

#### (a) Fraction of agents who travel ('tra') in a high capacity scenario

<table>
<thead>
<tr>
<th>'tra' HC</th>
<th>private</th>
<th>adaptive</th>
<th>estimate</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.63</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td>Average</td>
<td>0.77</td>
<td>0.90</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.91</td>
<td>0.97</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>

#### (b) Fraction of agents who travel ('tra') in a low capacity scenario

<table>
<thead>
<tr>
<th>'tra' LC</th>
<th>private</th>
<th>adaptive</th>
<th>estimate</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.20</td>
<td>0.40</td>
<td>0.46</td>
<td>0.51</td>
</tr>
<tr>
<td>Average</td>
<td>0.42</td>
<td>0.48</td>
<td>0.52</td>
<td>0.56</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.75</td>
<td>0.75</td>
<td>0.75</td>
<td>0.78</td>
</tr>
</tbody>
</table>
# Changing the Capacity/Population Ratio

(c) Fraction of agents who travel by train with a positive payoff ('posc') in a high capacity scenario

<table>
<thead>
<tr>
<th>'posc' HC</th>
<th>private</th>
<th>adaptive</th>
<th>estimate</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.90</td>
<td>0.90</td>
<td>0.89</td>
<td>0.87</td>
</tr>
<tr>
<td>Average</td>
<td>0.95</td>
<td>0.93</td>
<td>0.91</td>
<td>0.90</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.99</td>
<td>0.97</td>
<td>0.93</td>
<td>0.92</td>
</tr>
</tbody>
</table>

(d) Fraction of agents who travel by train with a positive payoff ('posc') in a low capacity scenario

<table>
<thead>
<tr>
<th>'posc' LC</th>
<th>private</th>
<th>adaptive</th>
<th>estimate</th>
<th>full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Average</td>
<td>0.49</td>
<td>0.35</td>
<td>0.27</td>
<td>0.19</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.94</td>
<td>0.68</td>
<td>0.42</td>
<td>0.26</td>
</tr>
</tbody>
</table>
EXPERIMENT 2: ROLLING STOCK ALLOCATION
A LINE SCENARIO

• Consider the following public transport line

  A  B  C  D  E

• Suppose we let a train move between A to E and back eight times in a day.
• At every station, train units can be coupled and decoupled
• Overnight, the rolling stock inventory at stations must be balanced

• We can now obtain a rolling stock circulation network for this scenario
MODEL OVERVIEW

Travel by PT? Which timeslot?

Operator

How much rolling stock?

Capacity

Utilization

Demand

Passengers

Crowding / Satisfaction

Operator Capacity Utilization

How much rolling stock?
We optimize capacities according to the principles of a single type rolling stock circulation (but this is not a limitation of the model). The demand in this model is based on the observations during the simulation.

- Initial demand: 1, 5 or 10 units
- Capacity: 10 seats per unit
- Demand: average during recent period + 2 * std. Dev
- Replanning period: 1, 5 or 10
- Costs:
  - Moving a unit: 1
  - Storing a unit: 0
  - Using a unit: 1000
OBSERVATIONS

- The effect of the number of default units is marginal outside of the first period.

Start with 1 Unit
OBSERVATIONS

- The effect of the number of default units is marginal outside of the first period.

Start with 5 Units
OBSERVATIONS

- The effect of the number of default units is marginal outside of the first period.

Start with 10 Units
OBSERVATIONS

- Longer reschedule periods seem to outperform shorter ones, but keep the system in “chaos” longer
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- Longer reschedule periods seem to outperform shorter ones, but keep the system in “chaos” longer.

Reschedule every round

Tra: 0.16  
Cost: 3000  
Units: 3
OBSERVATIONS

- Longer reschedule periods seem to outperform shorter ones, but keep the system in “chaos” longer

Reschedule every 5 rounds

Tra: 0.38
Cost: 6700
Units: 6.5
OBSERVATIONS

- Longer reschedule periods seem to outperform shorter ones, but keep the system in “chaos” longer.

Reschedule every 10 rounds

- Tra: 0.44
- Cost: 7000
- Units: 7.2
CONCLUSION AND FUTURE WORK
CONCLUSIONS AND FUTURE WORK

Conclusions

• Our model allows to simulate and analyze crowding effects within public transport systems.
• Two example studies to demonstrate our model:
• As a result, we believe this framework to be viable for more studies and experiments.
  – Suggestions are welcome!

Currently Working on

• Analyzing survey data to better understand behavior
  – Big experiment with 500 bachelor students with different treatments:
    • Quality of Information
    • Dependency of crowding on last choice
    • The occurrence of ‘big’ disruptions
• Extension of experiment 2
  – Threshold demand policy: if utilization below a certain threshold, decrease demand. If utilization above certain threshold, decrease demand.
Thanks for your attention!

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