Sequential planning model for on demand delivery services

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Abstract

Consumer behavior undergone a profound change. Quickly, service becomes an important consumer expectation. However, the planning of this service affects resource efficiency. In our paper we assume that traditional planning procedures are not as effective as sequential planning. The article describes a system of equations that can model this planning method. The representation of the results shows the differences between traditional and sequential planning.

Keywords: Dial a Ride, sequential planning, last mile delivery, on-demand, passenger transport

JEL code: R41

INTRODUCTION

The technological development in recent years have a serious impact on consumer behaviour. This is accompanied by an increase in the quality of transport services. This is how companies want to gain a market advantage. Such a service is, for example, door-to-door transport in both passenger and freight transport. However, traditional design and operational procedures are not necessarily suitable for performing these tasks. Transportation tasks must be replanned at tight intervals because of the constantly evolving claims for quick service to ensure the efficient use of means of transport. But it requires a new method of planning and decision-making.

1. CONCEPT OF SEQUENTIAL PLANNING

The basis for efficient person and freight transport and resource utilization is to optimize vehicle routes and capacity utilization. These systems are characterized by inflexibility on account of traditional planning procedures. They are usually organizing transports several hours or even a day in advance, it cannot provide an immediate solution to sudden claims. These solutions do not provide the level of service required for on-demand needs (Agatz et al., 2012).

This special area of route planning is addressed by the "Dial a Ride". It assumes such dynamic route needs, it takes them into account, including for the new and existing tasks continuously updates and optimizes vehicle routes, considering such important parameters, such as vehicle capacity, driving time of drivers, etc.

Since the 1970s articles and research related to this topic have been published continuously, however, none of them provides a fully usable solution to the on-demand consumer expectations that characterize today (Daganzo, 1978; Psarafits, 1982; Psarafits, 1986).

We believe that the use of a delayed decision provides a more optimal solution than immediate intervention, on the other hand, we could lose certain revenues. Delayed decision making is called sequential decision making. The bottom line is that the decision maker just watches the process for a while before making a final decision. Observations shows that most

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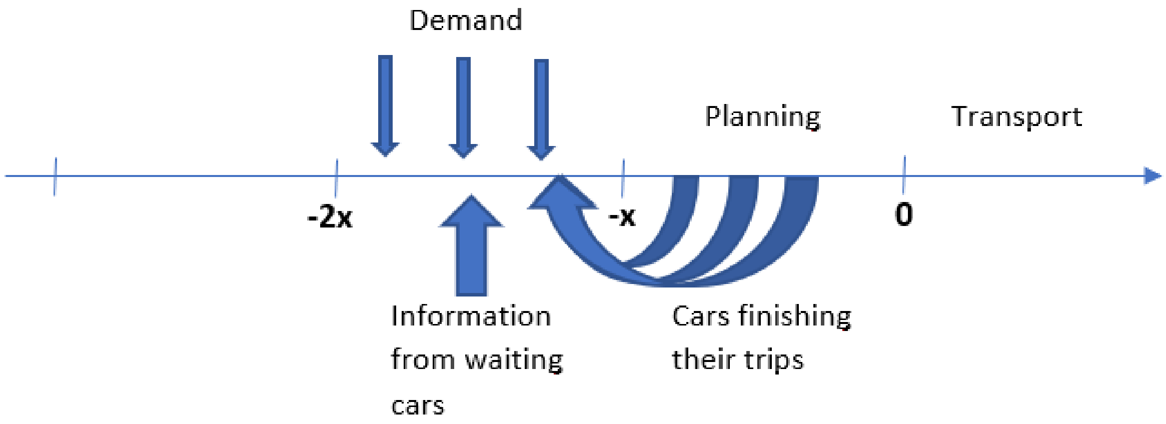
sequential decision problems involve implicit and explicit costs (d'Orey et al., 2012; Ciari et al., 2013). The “stop rule” specifies when to stop observations and when to resume them. The goal of optimizing sequential decision making is to find a stopping rule, which maximizes the process considering both losses and gains, including monitoring costs. The optimal stopping rule can therefore be called an optimal strategy or an optimal policy.

Figure 1 Structure of sequences



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2. MODELS FORMULATION

For getting an insight into the behaviour of the transport process when it is stopped periodically, we will examine a simplified taxi transport model.

$$V = V_R + V_W \qquad (1)$$

$$\alpha_E = \frac{V_W}{V} \qquad (2)$$

where V the number of vehicles, V_R the number of running vehicles with passengers, V_W the number of waiting vehicles, α_E the rate of waiting vehicles.

The approximate average shortest distance on a given territory between two points is a square function of *A/N* (Christofides–Eilon, 1969, Clarke–Wright 1964, Gillett–Miller, 1974), where *N* is the number of points on the area, *A* is the territory (km^2) and *dE* is the empty running.

$$dE = k\sqrt{A/N} \qquad (3)$$

This is the distance a taxi needs to travel from its waiting point to the place of the demand. The average speed is v, the average travelled distance (with passenger) is d, with normal distribution in length even distribution territorial. Using these data, a vehicle’s trips average total length is

$$dx = dE + d \qquad (4)$$

According to Figure 1. information about demands and the free cars arrive at the period *(-2x;-x)*. The number and location of the waiting cars are known. Some cars will finish their trips during the time period of *(-x; 0)*, that is they will be free. So *x* is the planning time in hours and t_x is the travel time in hours. We estimate the expected empty distance of a trip with the above-mentioned square function. In this the number of cars (*N*) is the function of t_x. With this the empty running distance is

$$dE_x = k\sqrt{\frac{A}{V_W + V_R * \frac{x}{t_x}}} \qquad (5)$$

and the whole length of the trip is:

$$d_x = d + dE_x = d + k\sqrt{\frac{A}{V_W+V_R*\frac{x}{t_x}}} \quad (6)$$

The total cycle time for a vehicle consists of the travelling and the waiting time during the planning period. Our hypothesis is that the travel times' distribution is normal, therefore according to Figure 1. a vehicle needs to wait an average of *x/2* time before it can start for picking up its passenger. Thus the total cycle time is:

$$c_x = t_x + t_w = \frac{1}{v}\left(d + k\sqrt{\frac{A}{V_W+V_R*\frac{x}{t_x}}} + \frac{x}{2}\right) \ldots. (7)$$

According to (7) during an hour a car is able to turn

$$c_H = \frac{1}{c_x} = \frac{1}{\frac{1}{v}\left(d+k\sqrt{\frac{A}{V_W+V_R*\frac{x}{t_x}}}+\frac{x}{2}\right)+\frac{x}{2}} = \frac{1}{\frac{1}{v}(d+dE_x)+\frac{x}{2}} \quad (8)$$

times. With this the distance performed is:

$$D_H = c_H * d_x = \frac{d+dE_x}{\frac{1}{v}(d+dE_x)+\frac{x}{2}} \quad (9)$$

Having these values, the costs of the vehicles and drivers, the total performance and so on can be estimated. If the tariff system is known, the change of the profit can be shown as well, i.e. a function of x, or α.

3. EXAMINATION OF THE MODEL

The territory of example is 500 km^2. The number of taxi cabs in the example is 2,000. The average travelling route of a passenger has been taken for 6 km, and in every cab sits one passenger. The estimated average speed of the vehicles is 25 km/h. The suggested correction factor is 1.5. The demand collection time for sequential planning is 0.1 hour.

We examine events at quarter-hour intervals in this example. Only 250 passengers check in in 15 minutes around 4 a.m., it increases according to a sine curve up to 7 hours, then decreases the demand exceeds capacity (2,240) at peak times, that is, multiple tasks must be rejected.

In the example, the task starts when the demand occurs, and it ends at a same height with it. We can observe that around half past six we run out of available taxis, from there practically all taxis work till about 9 p.m. From this time, all new claims must be rejected till quarter to 8, in the absence of a vehicle. It shows this well, that the curve of demands and rejected demands overlap over several periods.

After quarter to eight those tasks, which started around half past six arrive, these vehicles can be restarted. That's why the number of rejected claims falls spectacularly, but only temporarily. However, new passengers can be picked up again. These the new passengers, because the turnaround time is long, arrive just before 8 p.m. From here it is possible to receive new passengers again, and as the number of demands decreases, the vehicle fleet can already meet these needs.

A total of 31,632 claims for travel were made during the period studied in the example. In addition to the traditional control mode, we could only carry 12,240 passengers (Figure 2).

According to Figure 3 it can be seen that the fleet is able to pick up new passengers at peak times, with limited capacity. This is because, when the available taxis are run out at half past five, they arrive earlier at the end point of the trips as a result of their shorter cycle times. The cycle time could be shorter, because the needs and the vehicles are grouped together, and it did not happen individually. The number of lost orders has decreased, and a total of 20,241 passengers could be served (Table 1), 65% more than with traditional transport organization.

Table 1 The number of lost passengers

Time	Lost passengers normal	Lost passengers sequential
5:30	115	115
5:45	1,429	494
6:00	1,667	602
6:15	1,879	943
6:30	2,052	987
6:45	1,240	1,239
7:00	1,175	1,176
7:15	2,244	1,309
7:30	2,186	1,122
7:45	2,070	1,135
8:00	1,903	838
8:15	760	760
8:30	395	395
8:45	277	276

Source: Own editing

Figure 2 Demands, changes in the number of passengers carried and denied with conventional planning

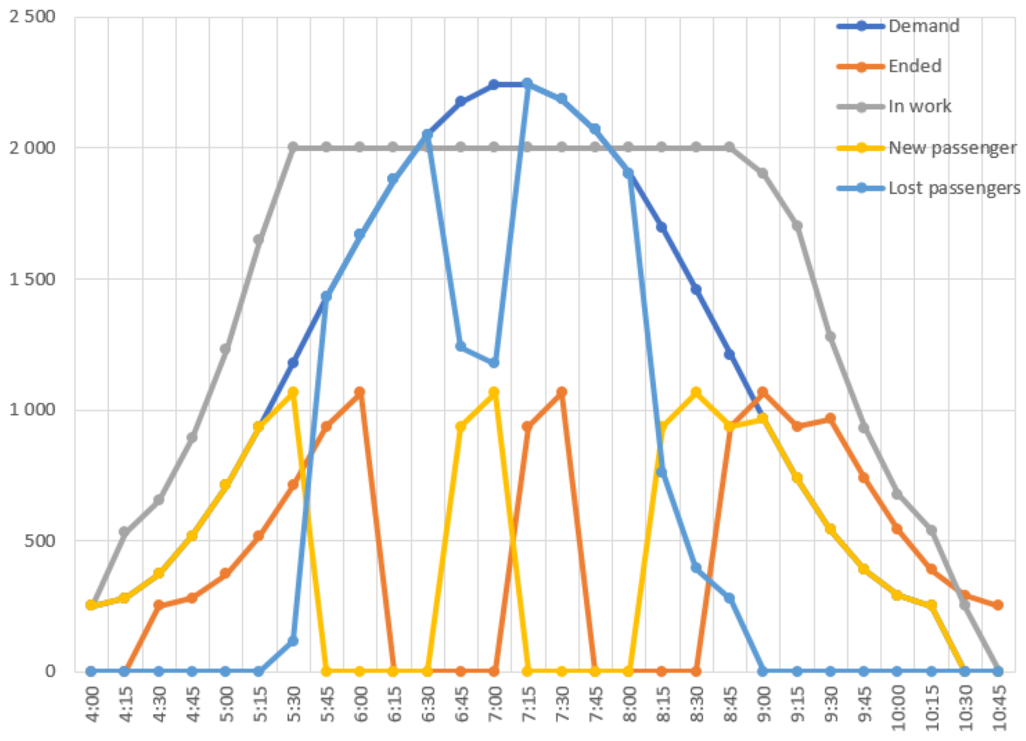

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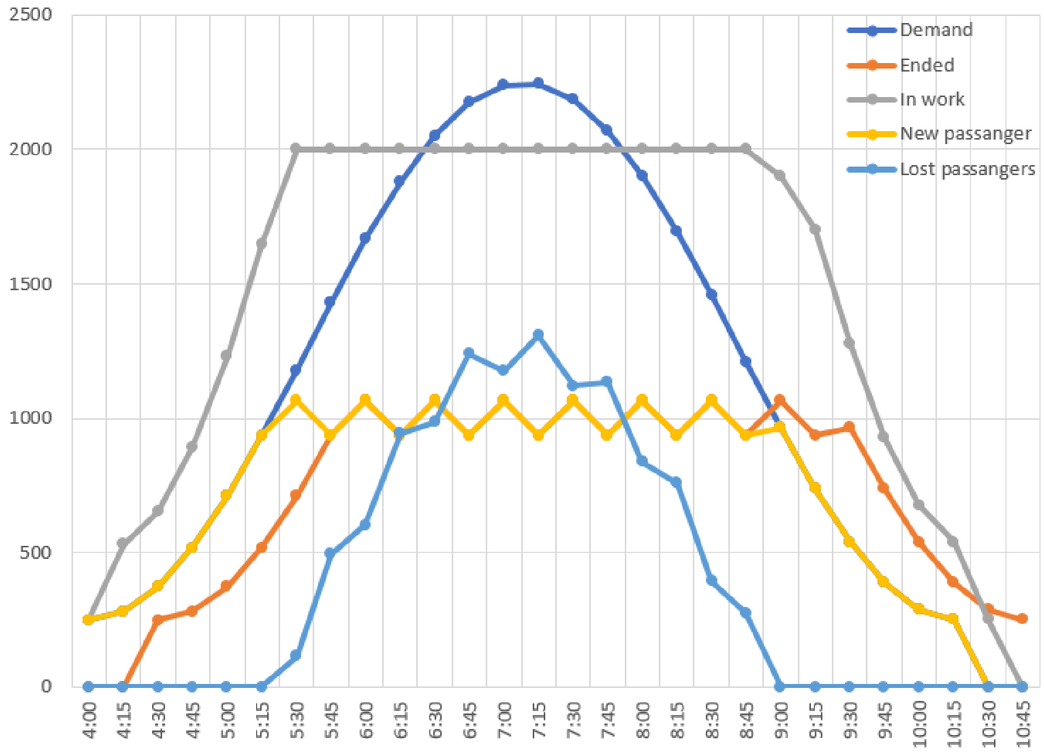
Figure 3 Demands, evolution of the number of passengers carried and denied with sequential planning



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4. CONCLUSIONS

Delayed decisions can lead to better and more cost-effective solutions, than with traditional on-demand systems. Operating companies can maximize the capacity utilization of their fleet, and this will also reduce CO2 emissions. To compare the two methods is important to develop an immediate assignment program. It is essential not only for determining the differences between the results, but it can be later an auxiliary part of the system for connecting vehicles to urgent transport tasks.

On the area of both personal and freight transport, the result obtained here on the effects of delayed decisions can help. The length of the system pause affects the efficiency of the result; this requires needed further research.

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