A model of the determination of the public transport lines in the public transport system

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Abstract. The issue of human resource planning for public transport (drivers) is a combinatorial optimization problem. It is desirable to compromise between the quality of the solutions and the calculation time, which determines the heuristic procedures that can effectively and efficiently lead to solutions as close as possible to other types of real-time computing. The effort of using mathematical computational algorithms and the lack of generality of heuristic methods have led to the finding of programming methods that combine optimization models with heuristic procedures. The planning problem for public transport drivers can be solved initially by setting out more specific actions, with the application of specific calculation algorithms covering all the workings of the bulk transport medium on the route considered at minimum cost. Many times, even in short paths, optimization is required by using computational algorithms.

1. Introduction
An organizational system can be regarded as a set of working processes structured into two main subsystems: the management subsystem and the production subsystem. A work process consists of a set of activities carried out in a coordinated way in an organizational and technical environment.

These activities together achieve the business objective. Each work process is activated in one organization, but it can interact with work processes in other organizations. Workflow Management is a field of economics that studies concepts, methods and techniques used in designing, managing, configuring, executing and analyzing work processes, and for which software technologies and an implementation framework have been developed [1].

A workflow management system is a generic software system that is governed by explicit process representations in order to coordinate the execution of work processes [2].

The Service Generic Service (SServ) model of activity highlights in an approach derived from the service loop and interactions between stakeholders: the service provider (together with sub-suppliers in its supply chain and subcontracting), the customer (service consumer), competitors and compliance bodies (national and EU operational framework, authorities).

2. Presentation of the model for the establishment of transport lines
In the technical literature, the technique used consists in eliminating potential courses characterized by: long breaks, breaks in the wrong hours of the day or very few activities, or after a rest break of work capacity [5]. Similarly, systems based on heuristic procedures can be used to select possible changes of interest and to eliminate fewer effective changes.
One of the included algorithms examines all PoWs (possible leadership missions) possible to determine the possibility of intersecting two consecutive PoWs. Since each PoW has to start, end or break at a crossing point (bus), reducing the number of such points of change will result in less turnout potential. However, it is necessary to generate a sufficiently large number of daily interests of potential interest. The quality of the final solution is dependent on the quality of the daily changes and their number; the number of participations can be determined in a controlled manner by an appropriate method. The problem of workforce planning (driver-driver means of transport) is formulated as follows:

\[
\min \sum_{j \in P} c_j x_j, \text{ in the presence of restrictions (1), (2) end (3):}
\]

\[\sum_{j \in P} a_y x_j \geq 1, \forall i \in I \quad (1)\]
\[\sum_{j \in P} b_y x_j \geq 1, \forall i \in I \quad (2)\]
\[x_j \in \{0, 1\} \forall j \in P \quad (3)\]

where:

\[I = \{i, PoW\}\]
\[P = \{j, \text{ the daily candidate}\}\]
\[C_j = \text{shift cost } j\]
\[X_j = \{1, \text{if turn } j \text{ is in solution}\}
\]
\[0, \text{otherwise}\}\]
\[a_{ij} = \{1, \text{if PoW belongs to } j\}
\]
\[0, \text{otherwise}\}\]

\[b_y, u_j = \text{real values that represent the operational properties of the solution.}\]

Each row of matrix A corresponds to a PoW and each column (or variable) corresponds to a daily change defined by PoW defined by non-zero elements. It is said that line i is covered by column j. Restrictions (1) require that each PoW be part of at least one round of the solution. Restriction (2) determines the fulfillment of the operational targets of the solution (e.g., the ratio and weight of the types of attributions, their multitude or estimation of the allocated time). These restrictions make it impossible to solve the problem because the advantage of using the pattern model associated with the restrictions (1) cannot be exploited. Including the restrictions (2) in the objective function, with corresponding penalty coefficients, solves this problem.

In practical implementation, the previous wording is simplified and restrictions R2) are not used. The form used is that of a configuration problem. Overlapping is permitted through "inequality" restrictions, which means that more than one passenger transport covers the same PoW. Determining the types of tasks is a special case where the restrictions (1) are of the equality type. Practically, this type of model requires the presence of a single driver - the driver of the means of transport in each means of transport at any time.

The major difficulty with this model is that if there is a limited number of general exchanges, a feasible solution cannot be guaranteed. This is why, in practice, it starts with the application of the model for determining the types of tasks, although the number of templates in the final solution can often be very similar. There is a possibility to reduce programming errors by applying \(d \geq \) rules. We can also use greedy values to get good initial solutions; the results of applying the initial solutions may become superior to the value of the optimum solution, and then use a linear relaxation to establish a lower edge associated with the optimum solution [4].
The difference between the established limits can be reduced by applying the primary and double heuristics and improving the lower margins can also be achieved by relaxing with Lagrange.

Planning algorithms also include a relaxation method for partition pattern models that also allow PoW omissions (also called omissions), that is, those PoWs that are not associated or are not covered by any feasible route.

Omissions are obviously undesirable because they correspond to the driver-free race - the drivers of the allocated means of transport and should therefore be penalized in the objective function. In practice, omissions will be attributed to crews that use extra work time or group them together with omissions from other breeds, sometimes ignoring the restrictions. The organization and establishment of public transport means that the service provider (transport company) can use specific methodological management services to help them organize both human resources (drivers - motorists) and technological means of transport - means of transport, trolleybuses etc.).

The recipient of the transport service may be the city municipality, and the service provider is a transport company [3]. The following requirements can be formulated for this transport service:

- Total length of the route: 12 km;
- Number of stops (stops) on the route: 15;
- Average bus stop time in 1.2 min;
- Number of traffic lights on the route: 22;
- Speed limit for bus traffic on the route: 50 km / h;
- Freight request for passengers: Monday to Friday (on weekdays): from 6:00 to 10:00 and 14:00 to 18:00; Saturday: 18:00-22:00; Sunday: 18:00-22:00;
- Frequency of bus stops arriving in weekly hours, presented in the following table 1.

| No. | Day of week    | Time interval (min.) | Time interval between consecutive arrivals (min.) | Bus requisitions (Pcs.) |
|-----|---------------|----------------------|-----------------------------------------------|------------------------|
| 1.  | Monday-Friday | 22:00-6:00h          | 12                                            | 5                      |
|     |               | 10:00-14:00h and     |                                               |                        |
|     |               | 18:00-22:00h         | 6                                             | 10                     |
|     |               | 6:00-10:00h          | 4                                             | 15                     |
|     |               | 22:00-6:00h          | 12                                            |                         |
| 2.  | Saturday      | 6:00-18:00h          | 6                                             | 10                     |
|     |               | 18:00-22:00h         | 4                                             | 15                     |
|     |               | 22:00-18:00h         | 12                                            |                         |
| 3.  | Sunday        | 18:00-22:00h         | 6                                             | 10                     |

For transport service planning, it is first calculated as the global date for the trip to the route required by a bus starting from the route characteristics, the dismantling time of the buses in the stations, the imposed speed limit and the technical characteristics of the buses (acceleration, braking). Thus, the total dismantling time of a bus in the stations on the route is:

\[ T_{ss} = 15 \times 1.2 \text{ min.} = 18 \text{ min.} \]

and the total bus stop time at the traffic lights on the route, assuming the worst case in which it should stop 30 sec.

At all intersections it is:

\[ T_{si} = 22 \times 30 = 660 = 11 \text{ min.} \]

resulting in the total disassembly time of a bus:

\[ T_{s} = T_{ss} + T_{si} = 29 \text{ min.} \]

which we increase to 30 min. to provide additional reserve.
Considering that the average speed of a bus (without considering 30-minute stops, but only accelerations / braking and other stops due to traffic conditions) is 24 km/h and nothing with \( T \) the total time needed for these traffic conditions of the entire 12 km route result:

\[
T \text{ (min)} - 30 = \frac{12 \text{ km} \times 60 \text{ min}}{24 \text{ km}} = 30 \text{ min},
\]
resulting in a \( T = 60 \text{ min} \) for the entire route.

Estimating this duration has been validated experimentally, simulating the route to be achieved in different time zones of weekdays. In such a situation, taking into account the shortest arrival intervals and 4 minutes, imposed during the peak periods of demand for passenger transport, there is a need for a fleet of at least 15 buses to meet the frequency requirements of arrival in stations in peak time intervals.

In order to meet the requirements of passenger transport safety that require regular maintenance, maintenance and periodical technical inspections of the means of transport (buses) the fleet is supplemented with a number of 5 buses, thus reaching 20 units. The table presents buses arrival time requirements at different time points of the weekdays and planning the transport service in bus terminals to cover all time intervals according to the required requirements. The need for buses resulting from the application of the model, respectively the method for the example presented, figure 1.

![Figure 1. Required buses for public passenger transport (Monday-Friday).](image)

### 3. Conclusions

The proposed method also provides experimental results on the complexity of SServ system modeling and the transposition of this generic model into information systems for typical classes of serifs (in this case public transport services). Macro-service management (MS) is approached as a core element in the lifecycle of a service; Within this component, customer requirements are met within the Client Command Management (MCC) component and transferred to the MSC Organization and Configuration Service (MSC) component of the MS through the bidding request. The goal of the OCS is to automatically achieve a human and technological capacity capability that covers demand, under conditions of quality and timing of the requested service. To this end, the methodology for creating a service is used, which highlights three major design steps:

1. service planning;
2. defining and sequencing the activities that make up the service;
3. allocating resources to the service.

The creation of the service allows, besides assessing the realization possibilities according to the requirements imposed by the client (date and time of supply, technical and quality conditions),
estimation of the costs necessary for the realization. These elements will be confirmed to the customer through the offer - as a direct result of the interpretation of the results of the OCS process.

In the presented model, reference is made to the available methods and algorithm in the OCS library that was created to allow for the calculation of an optimal cost-to-cost solution with respect to restrictions imposed not only on the customer’s specification but also on legislation, competition.

The experimental results obtained validate the software modeling and implementation solutions proposed for the SServ generic system, with the particularity for the class of public transport services. Orientation to the activity (or operations) of the service system allows repeated iterations of the OCS sequence of organizational and configuration processes, involving the client (through negotiations), and by which value is accrued.

In order to ensure proper interactivity with the client, within Macro-Service Component and Service Level Agreement (ANS contract) provide the client with a range of front-office web services for specification requirements, bid visualization and analysis, negotiation, billing, and billing, as well as assessment and communication by the customer of the perception of the quality of the service provided.

Experimental implementation and validation of the OCS model as a basic component of public transport management demonstrates the concept of openness according to which the SServ service model, which is transposed into the Service Oriented Architecture (SOA) architecture, has been developed.

4. References
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