Evaluation of multiple optimisation techniques for the identification of tours within multi-period ODs

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Due to the significant momentum that innovative urban mobility management policies have started getting recently, the need for detailed information regarding mobility patterns and travel behaviour is becoming of paramount importance. Although, new technological advances (e.g. mobile phone/GPS tracking) have enabled the extraction of relevant information, the value of traditional sources like standard Origin-Destination (OD) matrices is still substantial. Despite their undoubtful value and wide use, ODs suffer from the limitation of the assumed independence between the trips included in them. As a result, ODs cannot prove particularly useful sources of information in cases where detailed travel behaviour information is necessary, for instance in the case of the evaluation of new mobility paradigms (e.g. Mobility as a Service) or the introduction of urban mobility management policies. In this study, we explore the possibility of alleviating this limitation by identifying the sequences of trips (trip-chains) people complete during their day using information retrieved from typical OD matrices. More precisely, the individual trips included in multi-period and trip-purpose segmented OD matrices are optimally combined in trip-chains whose origin and destination are a home location (a.k.a. tours). These tours stretch both in space and time in the sense that the trips consisting them take place in different locations and points in time (time-periods). The methodology is divided in two main parts, the with the first being related to the identification and the reduction of the problem's search space and the second to the determination of the optimal combination of tours which represents the initial OD matrices as accurately as possible.

In the first part, the available ODs are traversed in order to identify all plausible combinations of trips which can lead to trip-chains originating and ending at the same home location. This kind of trip-chains are often referred in the literature as tours (O'Fallon & Sullivan, 2005). The identification of all the plausible tours within ODs is achieved using graph theory concepts. The resulting tours are produced in such a way that assures their chronological validity meaning that the trips consisting a tour do not take place in a non-chronological order. For instance, a trip of a tour completed in the afternoon cannot precede one completed in the morning. The methodology is fully flexible and allows for the application of any type of filtering mechanism to exclude illogical tours (e.g. tours which are completed by incompatible transport modes). The resulting set of plausible tours is referred as the '*candidate tours* *set*' and forms the input for the following optimisation process. A possible caveat of the methodology is the size of the candidate tours set. Providing an exceptionally large candidate set increases manifold the complexity of the optimisation problem and subsequently the required time for its solution. In many cases, the immense size of the candidate tours set can render the identification of a solution infeasible, therefore, an approach suitable of restraining the number of the candidate tours is required. A possible approach is the use of information regarding observed tours' characteristics. The set of candidate tours can be considerably limited by excluding tours with unlikely profiles in relation to the observed data (e.g. tours with a high number of intermediate trips, tours with unrealistic total distance covered, tours with unlikely departure profiles, etc.).

The second part of the methodology entails the determination of the candidate tours' combination whose aggregation re-constructs the original ODs as accurately as possible. In other words, the optimisation routine is responsible for identifying the number of times each candidate tour should be used so that the difference of trips between the original ODs and the trips present in the used tours is minimised. This definition classifies the problem as a NP-hard combinatorial one. In order to address it efficiently we engage three different, in terms of structure as well as in terms of the concepts involved, optimisation routines, namely a Genetic Algorithm (GA), a Simulated Annealing (SA) and a Branch and Bound (BaB) algorithm. GAs is a population-based stochastic approximation method, suitable for addressing complex combinatorial problems, at least as a first attempt. SA and BaB are selected for fine-search and tuning the solution provided by GA. The different optimisation techniques are assessed in terms of the maximum problem size which can handle, their optimality, as well as the time and computational power requirements. Moreover, we explore the possibility of identifying potential synergies between them in order to create a hybrid optimisation routine able to deal with the presented problem more efficiently.

The evaluation of the suggested methodology is based on a test framework developed specifically for this purpose. An artificially created set of tours stretching throughout a day is converted into multi-period OD matrices. These OD matrices are then used as input to the suggested methodology and the results between the three optimisation approach alternatives are compared. Another dimension being evaluated is the effect of the OD matrices' '*density*' on the solutions. The term '*density*' is borrowed from the field of graph theory and is a measure used to calculate how close the number of edges in a graph is to the theoretical maximum. Since OD matrices can be expressed as graphs, their *density* can be directly calculated. High-density OD-matrices are more likely to present larger *candidate tours sets* in relation to low-density ODs of similar size. In order to examine the effect of '*density*' on the overall process and outcome, two sets of artificially created tours are generated in order to synthesise a corresponding number of low- and high-density input OD matrices.

The desired outcome of this study is to identify the most appropriate optimisation technique to extract tours within multi-period OD matrices depending on the characteristics of each case as well as to provide insights regarding the benefits and drawbacks of each approach.