Method for the organization of daily activity chains

Domokos Esztergár-Kiss[1], Dénes Válóczi[1]
[1] Budapest University of Technology and Economics, Department of Transport Technology and Economics

Abstract

In the field of transportation the organization of daily activity chains has become more stressed, because the fast execution of the numerous tasks is a primary aspect. In order to reach high performance in the organization of the tasks, the attributes of the demand points, the transportation network and the external circumstances, as the changing traffic situation also have to be taken into account. A theoretical model was developed to organize and supervise the daily activity chains. Our aim is to improve the basically for logistic processes used TSP method and apply it for personal transportation purposes. The method offers a location based service, which results the optimal order of the tasks based on subjective parameters.

Keywords: daily activity chains, method development, TSP, flexible points, priorization of activities

1 Introduction

The ITS developments are widely spread in the field of passenger transportation. One direction of them is the LBS (= Location Based Services) technology, which uses the geographical data of a journey in order to utilize the demanded services of the passengers. The service is realized by the passengers' mobile devices using ITS, mobile internet and localization technology. With this extra information the passengers can plan their daily journeys in a more intelligent and optimized way.

The organization of the daily activity chains has been scrutinized in many articles [Hin12], [Tim03], [Mil03] and books [Tim05]. Organizing the chains some periodical repeated activity can be revealed (e.g. going to the office), which depends on the demographical [Ker07], on the spatial situation [Bul08] and on the personal characteristics of the user [Kan10]. More measurements were conducted in order to define the visited points, the average travel distance and time [Kam11], and in general the way of organizing the chains [Nij12], [Doh05]. Nevertheless only few articles were written in the topics related to the spatial and temporal solutions [Doh06], to dynamic planning [Roo05], [Nij09], [Mar11] and to resolving possible conflicts [Aul08].

For sorting and ordering each activity the TSP (= Traveling Salesman Problem) method offers a solution [Rei94], [App07], which popular version is often called VPR (= Vehicle Routing Problem) [Tot02], [Gol08]. The solution for this problem was developed already 50 years ago, and since numerous versions were implemented. The basic problem is that an order has to be set among the points to be visited according to a specified aspect. This aspect could be travel distance, cost, number of transfers or the combination of these.

Basically the TSP method is used in logistics systems, but we propose an application for passenger transportation. In our case another constraint has to be defined, because the opening times of the shops and institutions have to be considered. Therefore our proposed algorithm is based on the TSP-TW (= TSP Time Window) version. Numerous articles deal with the problems and solutions of the TSP-TW method [Bal11], [Kos92], [Dum95], [Sav92], [Kol87], [Ghi11], [Das12]. The method has to be extended with flexible points, which are variable in time and space. The aim of the research would be to prove the benefits of this method compared to the basic TSP method.

2 The concept of the method

While establishing activity chains it is assumed that the passenger is already aware of the activities, which he/she would like to realize on the given day. The aim of the method is to set an order of the activities using the existing data (time, location, importance). The nowadays available methods (Fig. 1.), which we call basic TSP are based on activity points, which have to be explored and cost functions, which describe the values among the points.

We consider a TSP method flexible, if – according to the subjective demands of the travelers – some points can be arbitrarily replaced with another point of the same function. Therefore using the flexible TSP method a solution could exist, which would not exist using the basic TSP.

The idea of the predictive TSP can be explained as an extension of existing services , which can be derived from the demands. These latent demands of the passengers can be guessed from the demands of passengers with similar characteristics.

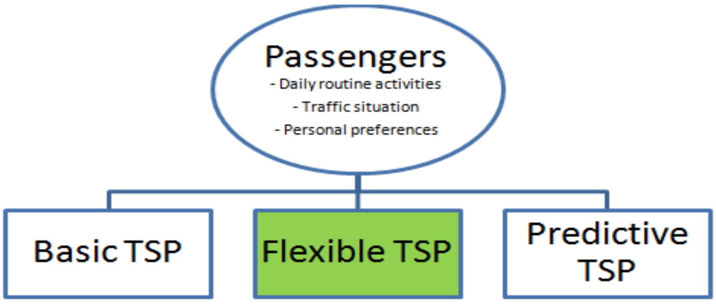

Figure 1: Types of TSP methods

In this research we consider the flexible TSP, which includes the following steps:

1. Definition of the daily activity chain:

- The list contains all the regular and non-regular activities of a passenger.
- The spatial and temporal parameters of the regular activities are usually fixed (e.g. school, workplace), while in many cases the non-regular activities are flexible.
- We assume that the passenger knows the activities of the certain day in advance and prepare the list of them, in which the time windows (TW) and processing time, which is the time spent at the points (TP), are also set.

2. Solving the basic TSP:

- The originally chosen points of the activity chain are the inputs for a TSP-TW method.
- The TSP-TW algorithm calculates an order of the points, which result could be the basic for a comparison with the proposed method.
- We generally assume that the basic problem is solvable, thus each point is reachable during the given TW (the TW-s are long enough and the TD-s are short enough).

3. Priorization of the activities:

- To each point a value is assigned, which represents its importance.
- The regular points of the activities get usually high priority, because they are spatially and temporally bounded, while the non-regular activities get lower priority.
- The subjective parameters are defined, all non-regular activities get a priority according to the personal demands and characteristics of the passenger.

4. Replacement of the flexible points:

- In the case of the flexible points the demanded service is reachable in more spatial places (e.g. instead of the point C, also in the point C'). Thus a new set of points could be installed, which is a new version of the activity plan, and the total travel cost could be reduced (Fig. 2.)

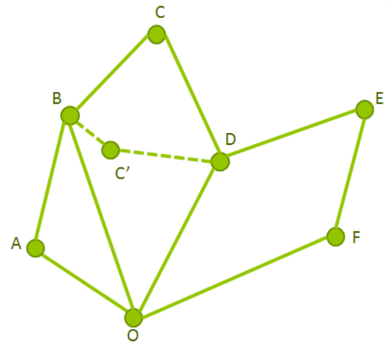

Figure 2: Presentation of the flexible points

- The search for new points in the case of flexible demands is conducted according to the spatial distance with weighting, thus the closer is the new point to an existing point, the higher is its weight.
- Using the subjective parameters a further modification of the points is possible, but it has to be taken into account, when the passenger wants to perform the activity.
- If the basic problem would not be solvable (e.g. 2 points have the same TW, and the travel time is too long between them), it could be solved with the spatial and temporal replacement of the points (Fig. 2.).

5. Optimization:

- For each version a TSP-TW is calculated.
- The version with the lowest total journey time (T) is chosen.
- The result of the basic TSP-TW is compared to the best version of the flexible TSP.

Concerning the points (Fig. 3.) the real time window (TR) of the arrival is defined by the original time windows (TW), which are usually the opening times of the shops and by the processing time (TP), which is the time needed for some operations executed (e.g. shopping). An average TP value (TP_a) can be defined, which can be modified to a minimal value (TP_m), if a delay occurs. The TP_m value is the time, which has to be minimal spent at the given point.

$$TR = TW - TP_a \tag{1}$$

By the flexible points if the next point (in the figure the point C) is not reachable during the travel time (TT) between the two points, then the algorithm searches for another point (C'), which is the closest to the prior point. Thus the needed activity can be performed at the new point (C').

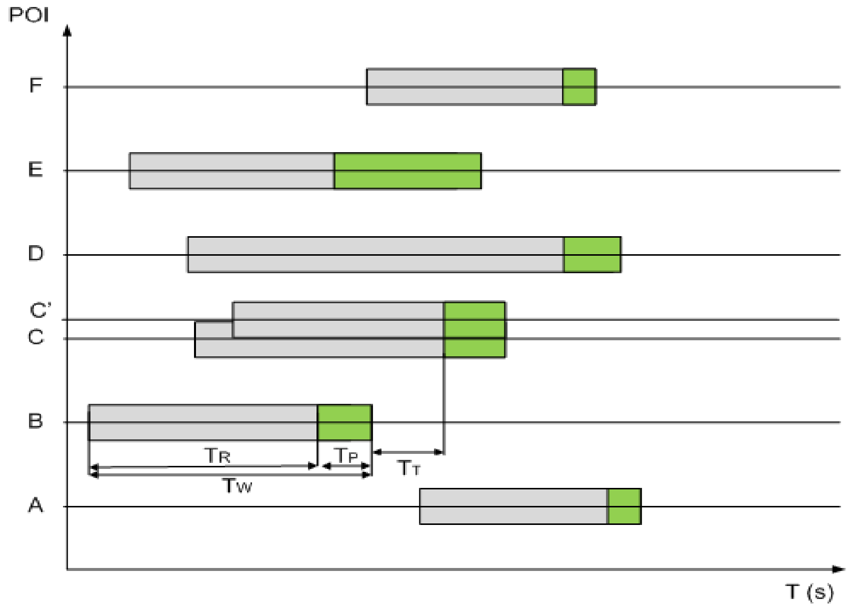

Figure 3: Temporal reachability of the points

The following constrains have to be fulfilled when using the model:

- each time window (TW) is at least as long as the processing time (TP),

$$TW \geq TP \tag{2}$$

- a point is reachable, if the real time window (TR) and the demanded time window of the passenger (TD) suits the processing time interval (TP),
- each (already replaced) point is reachable during the travel time (TT),

$$TT \geq TR_n - TR_m \tag{3}$$

- the total journey time (T) is the sum of all travel time (TT) and processing time (TP) and potentially waiting time (Twait), which can occur between the points.

$$T = \sum TT + \sum TP + \sum T_{wait} \tag{4}$$

3 First steps of the application's realization

The first step of the implementation is the elaboration of a data model (Fig. 4.), which is important to the construction of the daily activity chain. The model contains a Passenger table, where data about the passengers are stored. Some personal parameters belong to all passengers, which can be found in the Preferences table. These could denote preference of the transportation mode, disabilities or other factors. All preferences can be set in the interval of 1-5, which defines, how much the passenger demands the given service.

The certain points are contained in the POI table, which describes the name of the point, its address, opening hours and other information. These POI-s can be classified into types (e.g. food, sport, institutes and other categories), which is important because usually the passengers do not search for specific shops, but activity types. Using these categories finding the demanded activity becomes easier.

The most important table is the Activity, where the passengers can construct their daily activity chains. To each activity, which can be realized at the point (POI), belong time intervals. The duration, the time when passenger would demand the service (TD) and the processing time (TP), which is the duration of the service. The POI_ID field is optional, when filled, it is a fix point. Furthermore the priority should be filled, which denotes the importance of the activity. These can take the following values:

- 1: fix point, definitely has to be arranged on the certain day,
- 2: temporally fix, but spatially flexible,
- 3: temporally and spatially reduced flexible, namely the point has to be visited on the given day,
- 4: totally flexible, the point could be shifted to another day if necessary (e.g. if reaching the point would take more, than 1 hour and the schedule is too tight).

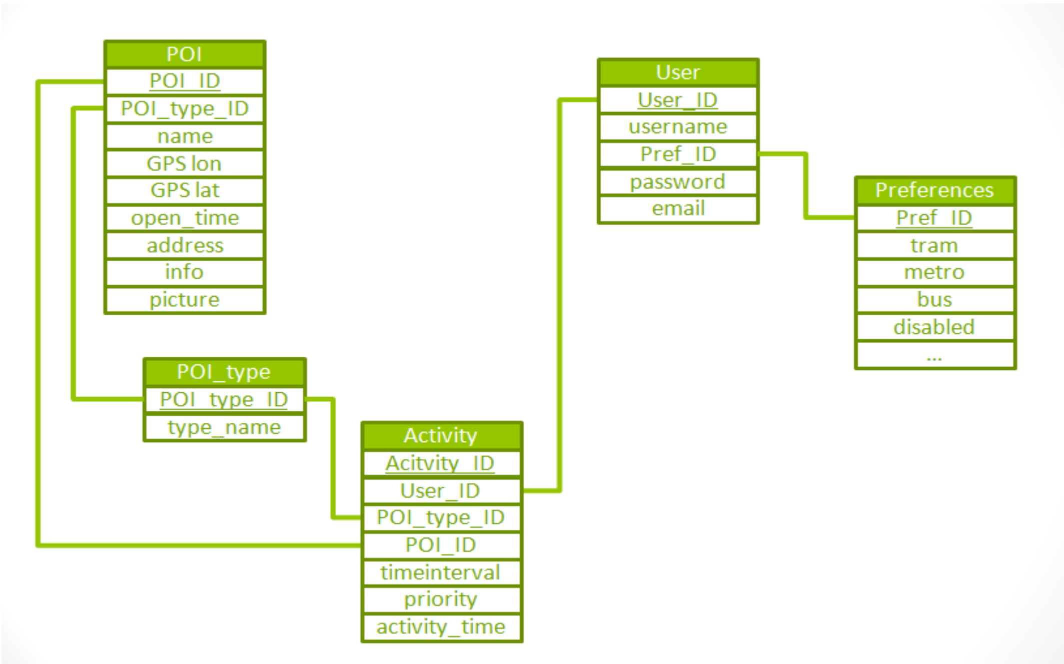

Figure 4: Data model and connections

In the next step using the TSP-TW method the travel times can be calculated and optimized according to the activity chain. Then the order of the points to be visited can be defined. The exact elaboration and implementation of this algorithm is the next relevant step of the research.

4 Further development

The theoretical model building has to be followed by the elaboration of practical part of the method and the analysis with VISUM simulation models. Still already some extensions and development directions emerged during the research process.

In our model we assumed that the passenger's start and end point is the same location. In the most cases it is valid, because usually the daily activity chains start from home and after finishing all activities the destination is home again. But in some cases the destination can be different, which requires another TSP method.

In the general case the cost function possesses fix values, thus among each points a fixed travel time (TT) is defined, but considering the actual traffic situation, the elements of the matrix could be changed in every hour. Using the same method the results of traffic jams and accidents could also be built in the model, which means the changing of the travel times.

The travel times could be defined according to the time tables of the public transportation and using real-time data the proper travel times could be assigned, which would contain the waiting times, the transfer times and the delays.

The cost matrix could be interpreted as a general resistance function, which takes into account the travel times, the costs, the number of transfers and the personal preferences.

Enhancing the dynamics of the model the changes of the activity plan during the day could be taken into consideration (Fig. 5.). Compared to the original activity chain (Activity) some changes could occur, as appearing a new demand (and a new point) or a delay at a point (Changes). Thus the daily plan has to be re-planned and recalculated during the day (Algorithm). Using this method the real activity list could be followed and modeled (real Activity). Using the predictive TSP also the latent demands of the passengers could be served, and other services could be recommended for the certain passenger based on crowd sourcing data.

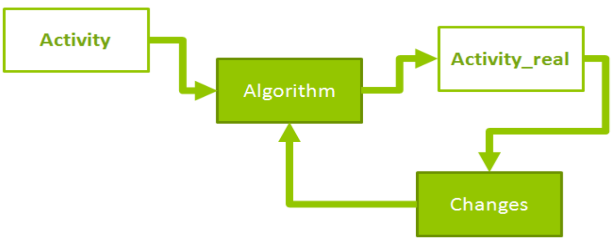

Figure 5: Dynamic modeling

5 Summary

The organization of the passengers' daily activity chains is a complex ITS development field, which can be solved using the TSP-TW method. In the article we explored the problems of the organization and elaborated a method, which introduces flexible points and priorization. The highest priority means an important task, which definitely has to be arranged on the certain day. Lower priorities mean that the task can be even shifted to another day if necessary. Thus better results can be achieved than using the general TSP method. As the first step of the research a data model was defined, which contains data of the passengers, the points and the activities. Using this database an algorithm can be executed, which results in an optimal order of the points to be visited. The future development directions were also specified.

Acknowledgement

TÁMOP-4.2.2.C-11/1/KONV-2012-0012: "Smarter Transport" - IT for co-operative transport system - The Project is supported by the Hungarian Government and co-financed by the European Social Fund.

References

[Hin12] J. HINE, Md. KAMRUZZAMAN, N. BLAIR: "Weekly activity-travel behaviour in rural Northern Ireland: differences by context and socio-demographic", Transportation, January 2012, Volume 39, Issue 1, pp. 175-195.

[Tim03] H. TIMMERMANS, P. VAN DER WAERDEN, M. ALVES, J. POLAK, S. ELLIS, A.S. HARVEY, S. KUROSE, R. ZANDEER: "Spatial context and the complexity of daily travel patterns: an international comparison", Journal of Transport Geography, 2003, Vol.11, Issue 1, pp. 37–46.

[Mil03] E.J. MILLER, M.J. ROORDA: "Prototype Model of Household Activity-Travel Scheduling", Transportation Research Record: Journal of the Transportation Research Board, 2003, Issue 1831, pp. 114-121.

[Tim05] H. TIMMERMANS: Progress in activity-based analysis, Elsevier Science Ltd, 2005, ISBN: 9780080445816

[Ker07] J. KERR, L. FRANK, J.F. SALLIS, J. CHAPMAN: "Urban form correlates of pedestrian in youth: differences by gender, race-ethnicity and household attributes", Transportation Research Part D, 2007, Vol.12, Issue 3, pp. 177–182.

[Bul08] R.N. BULIUNG, M.J. ROORDA, T.K. REMMEL. "Exploring spatial variety in patterns of activity-travel behaviour: initial results from the Toronto travel-activity panel survey (TTAPS)", Transportation, 2008, Vol.35, Issue 6, pp. 697–722.

[Kan10] H. KANG, D.M. SCOT: "Exploring day-to-day variability in time use for household members", Transportation Research Part A: Policiy and Practice, 2010, Vol.44, Issue 8, pp. 609–619.

[Kam11] M. KAMRUZZAMAN, J. HINE, B. GUNAY, N. BLAIR: "Using GIS to visualise and evaluate student travel behavior", Journal of Transport Geography, 2011, Vol.19, Issue 1, pp. 13–32.

[Nij12] L. NIJLAND, T. ARENTZE, H. TIMMERMANS: "Incorporating planned activities and events in a dynamic multi-day activity agenda generator", Transportation, 2012, Vol.39, Issue 4, pp. 791-806.

[Doh05] S.T. DOHERTY: "How far in advance are activities planned? Measurement challenges and analysis", In Transportation Research Record: Journal of the Transportation Research Board, 2005, Issue 1926, pp. 40-49.

[Doh06] S.T. DOHERTY: "Should we abandon activity type analysis? Redefining activities by their salient attributes", Transportation, 2006, Vol.33, Issue 6, pp. 517-536.

[Roo05] M.J. ROORDA, E.J. MILLER: Strategies for Resolving Activity Scheduling Conflicts: An Empirical Analysis – Progress in Activity-Based Analysis, Elsevier, Oxford, 2005, ISBN: 0080445810, pp. 203-222.

[Nij09] E.W.L. NIJLAND, T.A. ARENTZE, A.W.J. BORGERS, H.J.P. TIMMERMANS: "Individuals' activity – travel rescheduling behaviour: experiment and model-based analysis", Environment and Planning A, 2009, Vol.41, Issue 6, pp. 1511 – 1522.

[Mar11] F. MARKI, D. CHARYPAR, K.W. AXHAUSEN: "Continuous activity planning for a continuous traffic simulation", In Transportation Research Record: Journal of the Transportation Research Board, 2011, Issue 2230, pp. 29–37.

[Aul08] J. AULD, A.K. MOHAMMADIAN, T. SEAN, S.T. DOHERTY: "Analysis of Activity Conflict Resolution Strategies", Transportation Research Record: Journal of the Transportation Research Board, 2008, Issue 2054, pp. 10-19

[Rei94] G. REINELT: The traveling salesman: computational solutions for TSP applications, Springer-Verlag Berlin, Heidelberg, 1994, ISBN:3-540-58334-3.

[App07] D.L. APPLEGATE, R.E. BIXBY., V. CHVÁTAL, W.J. COOK: The Traveling Salesman Problem: A Computational Study, Princeton University Press, 2007, ISBN: 9780691129938

[Tot02] P. TOTH, D. VIGO: The Vehicle Routing Problem, SIAM, 2002, ISBN: 978-0-898715-79-8, pp. 157-186.

[Gol08] B.L. GOLDEN, S. RAGHAVAN, E.A. WASIL: The Vehicle Routing Problem: Latest Advances and New Challenges, Springer, 2008, ISBN: 978-0-387-77778-8, pp. 389-417.

[Bal11] R. BALDACCI, A. MINGOZZI, R. ROBERTI: "New State-Space Relaxations for Solving the Traveling Salesman Problem with Time Windows", INFORMS Journal on Computing, 2011, Vol. 24, Issue 3, pp. 356-371.

[Kos92] Y.A. KOSKOSIDIS, W.B. POWELL, M.M. SOMOLON: "An Optimization-Based Heuristic for Vehicle Routing and Scheduling with Soft Time Window Constraints", Transportation Science, 1992, Vol. 26, Issue 2, pp. 69-85.

[Dum95] Y. DUMAS, J. DESROSIERS, E. GELINAS, M.M. SOMOLON: "An Optimal Algorithm for the Traveling Salesman Problem with Time Windows", Operations Research, 1995, Vol. 43, Issue 2, pp. 367-371.

[Sav92] M.W.P. SAVELSBERG: "The Vehicle Routing Problem with Time Windows: Minimizing Route Duration", INFORMS Journal on Computing, 1992, Vol. 4, Issue 2, pp. 146-154.

[Kol87] A.W.J. KOLEN, A.H.G. RINNON KAN, H.W.J.M. TRIENEKENS: "Vehicle Routing with Time Windows", Operations Research, 1987, Vol. 35, Issue 2, pp. 266-273.

[Ghi11] G. GHIANI, E. MANNI, B.W. THOMAS: "A Comparison of Anticipatory Algorithms for the Dynamic and Stochastic Traveling Salesman Problem", Transportation Science, 2011, Vol. 46, Issue 3, pp. 374-387.

[Das12] S. DASH, O. GÜLNÜK, A. LODI, A. TRAMONTANI: "A Time Bucket Formulation for the Traveling Salesman Problem with Time Windows", INFORMS Journal on Computing, 2012, Vol. 24, Issue 1, pp. 132-147.

Corresponding author: Domokos Esztergár-Kiss, Budapest University of Technology and Economics, Department of Transport Technology end Economics, 1111 Muegyetem rkp. 3-11., Budapest, Hungary, +36-1-463-1029, esztergar@kku.bme.hu