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# Secure Travel Planning Using a Heuristic Algorithm

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**Abstract**

Security perception in the urban area has a significant effect on travel behaviour, preferences, and tour planning. The perceptions of security risks can vary depending on factors, such as age, gender, and previous experiences. This study aims to consider security risks when developing travel plans and schedules for various activities. An improved heuristic algorithm, based on the Travelling Salesman Problem with security parameter and flexibility aspects, is proposed. Public transport is considered in three situations: fixed, flexible, and flexible-security situations. The outcomes demonstrate that the flexible situation significantly decreases travel times by 21% compared to the basic (fixed) situation. At the same time, with a slightly increased travel time the security risk can be avoided in the flexible-security situation. Travelers can enjoy a higher quality of travelling and enhanced personal experience by minimizing the journey duration and the impact of security risks on the tour schedule. The proposed method provides significant benefits for transport operators by increasing the efficiency of the transportation system and higher customer satisfaction.

**Keywords**

security, travel planning, flexibility, travelling salesman problem, genetic algorithm

## 1 Introduction

Travel behaviour and tour planning in urban contexts are significantly affected by perceptions of security. People are more willing to engage in travel activities and discover new areas when they recognize a higher level of security (Jonas et al., 2011). Security, besides other factors, are among risks and challenges to travelers that may influence the image of a destination. Travelers' views of the attractiveness of a site are often dependent on preconceptions rather than actual reality (Chew and Jahari, 2014). Knowledge, experience, age, gender, attitudes, and emotions, influence consideration and decision about the seriousness and acceptability of risks. However, the decisions and behaviour are highly connected to the ideas of risk and perceived security (Conchar et al., 2004). Successful tour planning depends on several factors, where establishing an environment that promotes security for travelers is a significant issue (Araña and León, 2008). Travelling and conducting activities involves some level of risk, and how that risk is perceived varies from person to person (Pizam and Mansfeld, 2006). Providing information on security is important for travelers, but usually this kind of information is not present in traveler information systems (Beecroft and Pangbourne, 2015; Mahdi and Esztergár-Kiss, 2021). Incorporating the security feature into the journey planning will improve the quality of the provided service. Therefore, the objective of this research is to integrate the security aspect into travel planning and provide optimal schedules with the goal of improving the overall travel experience.

There are three stages of planning for a tour: before, during, and after the journey (Sylejmani et al., 2017). This study focuses on the planning tour before the journey phase and by considering the security aspect. Planning and scheduling activity chains can be treated as a Travelling Salesman Problem (TSP). The TSP is used in tour planning to find the most effective route for visiting a set of places or activities, often with the purpose of minimizing overall utility (Király and Abonyi, 2011). Heuristic algorithms have been developed to overcome the computational challenges associated with optimally solving the TSP. Although they do not guarantee optimal results, heuristic algorithms provide a practical and efficient method to identify acceptable solutions in an equitable period of time (Ambati et al., 1991). The activity chain might involve multiple types of activities, such as sightseeing, leisure

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activities, shopping, or eating. The activity chain problem might be difficult to solve optimally, especially in case of many activities, because of the vast number of different combinations of potential activities (Esztergár-Kiss, 2020).

Travelers can prioritize security by avoiding locations with low security as part of their travel plan. This can be supported by providing alternative locations with similar activity purposes (e.g. suggest alternative restaurants in more secure area). Heuristic algorithms, especially the Genetic Algorithm (GA), can handle this issue by considering the flexibility of activities to find alternate locations with higher security levels (Rizopoulos and Esztergár-Kiss, 2020).

This study considers preferences and travel behavior to plan for a secure itinerary, where the decision-making of a traveler is based on maximizing satisfaction toward a secure journey. Also, it presents insights into how individuals prioritize and allocate their resources among different activities and travel possibilities (Zhang et al., 2002).

The adopted method was inspired by the ideas of heuristic solutions. GA is often utilized to optimize computational problems where the traditional algorithms might not be able to provide optimal or near-optimal solutions (Mirjalili, 2019). Particularly, GA has been used in this study for planning scheduling activities based on two main factors: travel time and security aspect (Nitisiri et al., 2019). The adopted heuristic algorithm combines the security component with travel time when planning activity chains. The presented solution helps travelers in making informed decisions, optimize their schedules, and enhance their travel experience.

## 2 Literature review

Several significant internal and external factors influence traveler decision-making (Mahdi and Esztergár-Kiss, 2022). The internal factors are family, age, income, inspiration and perception, internal perspective, personality, education, and culture. The external factors include demographic and social changes, travel security, technological breakthroughs, and changes in public transportation (Garg, 2013). Several previous studies have revealed that security plays a significant role in shaping the daily activity chain of travelers (Lam and Hsu, 2006; Suttikun et al., 2018; Valek et al., 2014). However, security aspect has not been explicitly addressed. Involving the security aspect into travel plans and schedules for various activities is essential for ensuring a secure and enjoyable experience for travelers.

Previous studies, especially those dealing with walking and bicycling, assessed the topic of security. A study of (Schneider, 2013) involved a survey of travelers about shopping centers, indicating that individuals select transport mode that have higher security levels. Similarly, (Alfonzo, 2005) suggested a "hierarchy of walking needs," which included a category mainly concentrated on security while considering traffic safety as a component of comfort-related needs. The study discovered that concerns related to security take priority over those associated with safety.

Travel time and overall comfort play crucial roles in decision-making. However, this does not diminish the importance of security. Instead, it emphasizes the need to consider security as an integral part of the broader framework of factors influencing travel behavior (Saelens and Handy, 2008). According to (Jang and Wu, 2006), the most frequently mentioned pull reasons for elderly people are security, historical attractions, cost, and ease of access. Another study found that women are significantly more concerned about crime at transport hubs and are more likely to be picked up when utilizing extreme-crime light-rail locations or while travelling at nighttime (Kim et al., 2007).

Researchers have faced difficulties in the field of scheduling issue solutions because of the enormous search space and calculation time. Numerical optimization approaches have been used to overcome these problems and to obtain definitive outcomes. An activity scheduling microsimulation model was created by (Miller and Roorda, 2003). The model used heuristic methods to organize activities and trip diary information. The model takes into consideration the time and duration of activities undertaken by household members. (Kang and Recker, 2013) presented a procedure for daily activity planning based on the place choice challenge. The optimal activities are selected from a set of specified sites and alternative places, where dynamic programming was used to overcome the issue of the large search space. Another study by (Charypar and Nagel, 2005) has tackled the problem of planning daily activity chains. The mathematical formulation utilized in the optimization system is based on geometric distance among activities. Another study focused on planning the daily activity chains for visitors using Electric Vehicles (EVs) in metropolitan conditions. The study proposes an approach that combines activity-based modeling and the GA context to generate schedules of activities while considering factors such as activity locations, transportation modes, and time of attendance (Rizopoulos and Esztergár Kiss, 2020). (Esztergár-Kiss et al., 2018) introduced a novel method to plan and schedule activity chains by considering the flexible demand points allowing for activities to occur at different times and locations incorporating three transportation modes: car, public transport, and a combination of both.

The simulation outcomes demonstrate 10% to 15% reduction in the total travel time. A similar study using an ant colony optimization algorithm is conducted for planning daily movement with adjustable mobility solutions. The results achieve about a ten per cent reduction in trip period by merging and corresponding various transportation modes. The approach shows that incorporating flexibility may enhance activity chain optimization and boost overall travel performance (Sabbani et al., 2019).

In summary, heuristic optimization approached are well elaborated, but more research is needed on the connection between security and planning, especially considering a larger set of activities. While previous research addressed scheduling issues using numerical optimization approaches, our study goes beyond integrating security considerations into the planning of daily activity chains.

## 3 Methodology

### 3.1 Mathematical formulation

The TSP is a common combinatorial optimization problem. In this study, a traveler has to visit various places before returning to the initial location, while each location can be visited once. Even if the limitations are straightforward, the problem becomes complicated to solve as the number of locations increases (Wu et al., 2021). Our objective is to determine a schedule of activities that reduces travel time considering the security risks. A set of activities are given $\{a_1, a_2, a_3, \ldots\ a_n\}$ and around each activity ($a_j$) the security situation $S(a_j)$ is recognized, while, the travel time is known for each pair of activities $T(a_i, a_j)$. The GA algorithm to solve the TSP is implemented using the features of generation, mutation, selection, and crossover (Mirjalili, 2019). The mathematical representation of Eq. (1) can be used to determine the scheduling of the activities that reduce travel time considering the security risks. Eq. (2) represent a constraint that takes the value 1 if the traveler moves from activity $i$ to $j$, and 0 otherwise. This constraint ensures that each activity can be visited once. In Eq. (3) it is referred to the distance between activities that is symmetric.

$$\min\ U = \sum_{i=1}^{n=1} \left( T\left(a_i, a_j\right) + \left(S\left(a_j\right)\right) * \beta \right) \tag{1}$$

Where:

$U$ is the utility function that provides the minimum overall travel time with the highest security (i.e., a destination with the lowest crime rate).

$T(a_i, a_j)$ is the travel time to move from activity $a_i$ to $a_j$
$S(a_j)$ is the security situation around activity $a_j$
$\beta$ is 1 if security risk is considered, and 0 otherwise.
Subject to:

$$\sum j = 1,\ \ j \neq i a_{ij} = 1,\ \ for\ i = 1, 2, \ldots n \tag{2}$$

$$a_{ij} = a_{ji},\ \ for\ i, j = 1, 2, \ldots\ldots n \tag{3}$$

### 3.2 Spatial flexibility

The spatial flexibility of destination refers to the opportunity of travelers to choose from a range of locations for their activities. Traditional planning methods consider fixed locations for activities assuming that people would regularly visit the same locations. While spatial flexibility emphasizes that travelers may choose a destination that serves the same purpose but offers a higher level of security or fulfils their intended preferences. In this study, the preferences of travelers are taken into account, and two distinct priorities were considered:

1. Fixed activity: The concept of a fixed destination implies that certain activities or tasks are associated with predetermined locations. For example, going to work or attending a particular event requires to visit a specific place.
2. Spatial flexible activity: The concept of a flexibility destination identifies that travelers have the flexibility to choose alternative places that perform the same purpose as the previous one. This flexibility permits individuals to consider the security factor and personal preferences when selecting their destination.

Fig. 1 shows five-activity chain (A, B, C, D, and E) in which the spatially flexible activity symbolized as C and the alternative location represented as $C_0$. This representation

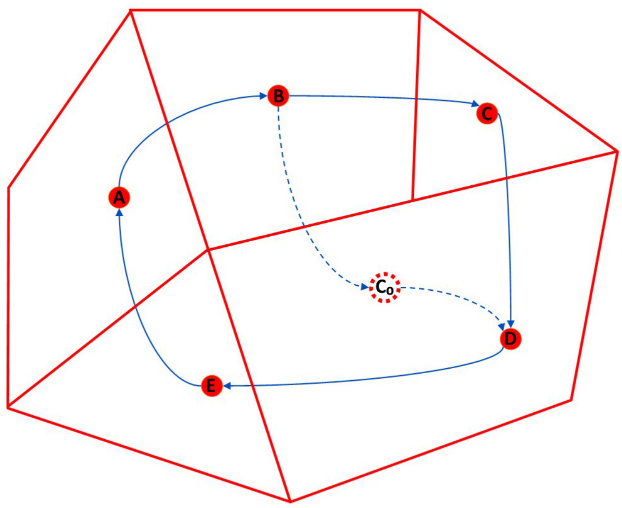


**Fig. 1** A representation of a flexible activity

shows the potential substitution of activity C with $C_0$ based on individual preferences and utility considerations. For instance, activity $C_0$ is placed in an area with a relatively higher level of security compared to the location of activity *C*. This visual representation highlights the possibility of selecting a spatially flexible destination offering improved security conditions.

This study proposes three situations: fixed, flexible, and flexible activities considering security. The fixed activities refer to the basic situation where a traveler assigns fixed locations without the possibility to choose alternative locations. The second situation refers to flexibility in terms of the location of the activity without considering security. In the last situation, the traveler is flexible in terms of the location of the activity with security considerations.

### 3.3 Data input and sources

The capital of Hungary (Budapest) is selected as a case study. For the calculations, the Open Trip Planner (OTP) is used that provides the travel time matrix between the activities, where public transport combined with walking was chosen as the main transport mode. The public transport data was retrieved from (BKK, 2022), that is the integrated urban transport management organization of the capital. Meanwhile, the security levels per district were taken from (Mahdi and Esztergár Kiss, 2021), as shown in Fig. 2.

Ten levels are used to express the security condition ranging from 10 (low-security level with a high number of crimes) to 1 (high-security level with a low number of crimes). The collected data were used to feed the GA algorithm together with the suggested activities usually set by


**Fig. 2** The spatial distribution of the security level per district

the traveler. Table 1 shows an example of the suggested activities, where the restaurant ($RE_0$) is set as a flexible activity to assess the proposed algorithm's performance.

## 4 Results and analysis

The consideration of the three situations is presented with public transport and walking modes. The situations are run with five randomly chosen activities in Budapest Table 1. The outcomes of the situations, including the order of activities, modes of transportation, and journey time, are reviewed in Table 2. In the first situation, the traveler is assumed to move from one activity to another with a fixed location. The total travel time needed for this journey is 68 minutes, and the restaurant activity ($RE_0$) is located in district 7 (Fig. 3), which has a relatively low-security level. This situation represents a baseline where there is no flexibility in choosing activity locations.

In the second situation, the restaurant is flexible, thus the algorithm substitutes the originally suggested restaurant ($RE_0$) with a restaurant in an alternative location ($RE_1$), which is within a one-minute walk from the hotel (HO) resulting in a total travel time of 54 minutes, as illustrated in Fig. 4. Adopting flexibility in the activity chain by substituting the restaurant location significantly reduced the total travel time. This demonstrates the optimization capabilities of the algorithm and the potential for improved travel efficiency through the flexible situations.

In the last situation, besides flexibility security is also considered, thus the algorithm suggests another restaurant ($RE_2$) with a total travel time of 56 minutes, but with an activity is found in a district with high security ranks (Fig. 5). It is worth mentioning that the spatial distribution of the security ranks of the case study can be obtained from (Mahdi and Esztergár-Kiss, 2021). While the travel time slightly increased in the last situation associated to the flexible situation, including security considerations allowed the traveler to avoid high risk areas. According to the findings, including flexibility and security concerns in travel planning can result in more effective and secure travel experiences. The proposed algorithm optimizes travel plans to

**Table 1** Example of the suggested activities

| Name of activity | Abbr | Latitude | Longitude | Type |
|---|---|---|---|---|
| Gellért Thermal Bath | GB | 47.483853 | 19.051818 | Fixed |
| St. Stephen's Basilica | ST | 47.501440 | 19.054146 | Fixed |
| Restaurant | $RE_0$ | 47.503258 | 19.066812 | Flexible |
| National Museum | NM | 47.491681 | 19.062164 | Fixed |
| Hotel | HO | 47.495021 | 19.049876 | Fixed |

**Table 2** The outcomes of the three situations

| Fixed situation | Order | HO-ST | ST-RE₀ | RE₀-NM | NM-GB | GB-H | Total travel time (68 min) |
|---|---|---|---|---|---|---|---|
| | Mode | Metro | Metro | Tram | Tram | Tram | |
| | Travel time | 10 | 16 | 17 | 12 | 13 | |
| Flexible situation | Order | HO-GB | GB-NM | NM-ST | ST-$RE_1$ | $RE_1$-HO | Total travel time (54 min) |
| | Mode | Tram | Metro | Bus | Walking | Bus | |
| | Travel time | 13 | 15 | 14 | 1 | 11 | |
| Flexible-security situation | Order | HO-ST | ST-NM | NM-GB | GB- $RE_2$ | $RE_2$-HO | Total travel time (56 min) |
| | Mode | Metro | Bus | Tram | Walking | Bus | |
| | Travel time | 11 | 15 | 13 | 3 | 14 | |

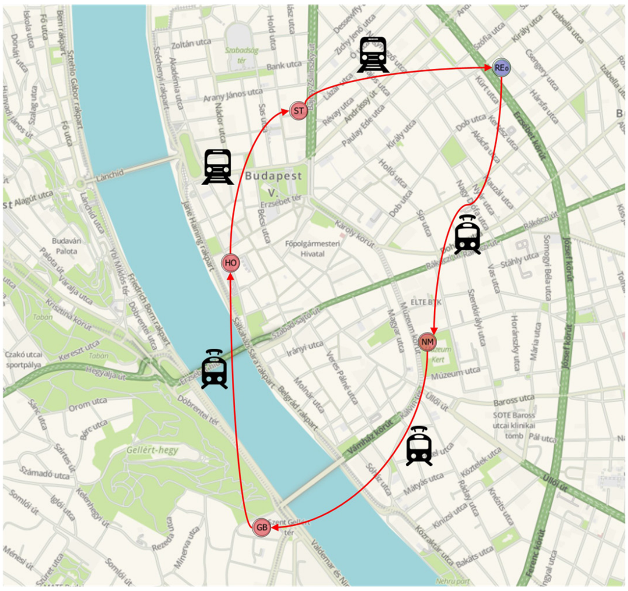


**Fig. 3** Optimization solutions for the fixed situation

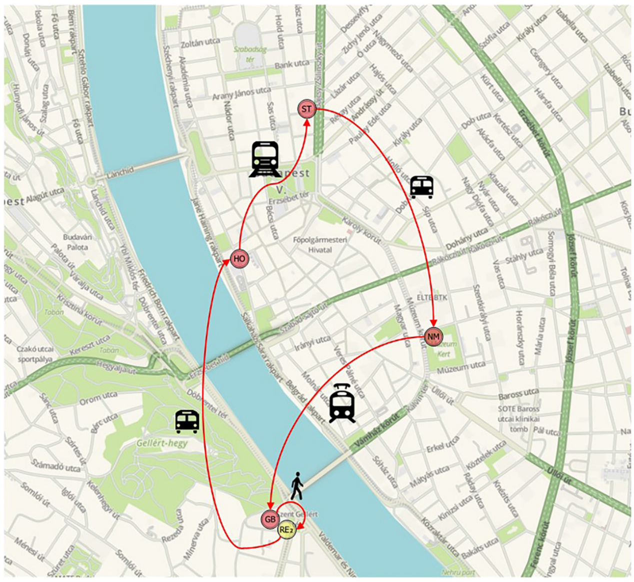


**Fig. 5** Optimization results for flexible-security situation

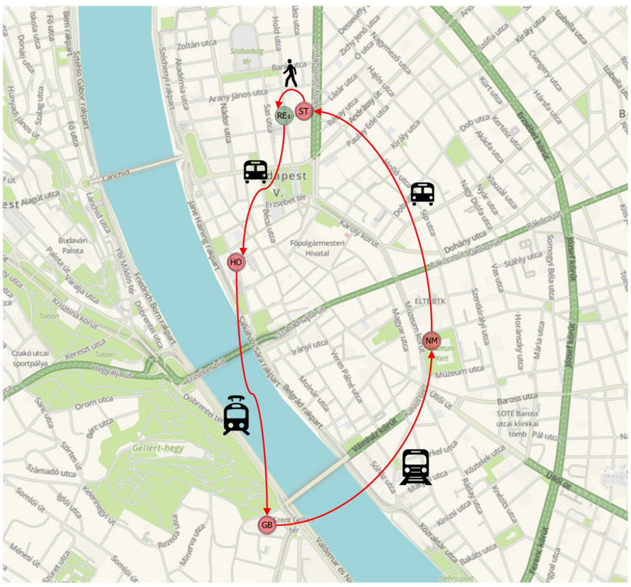


**Fig. 4** Optimization solutions for flexible situation

improve people's overall travel experience by allowing for alternate activity locations and considering security risks.

## 5 Discussion

This study focused on the perception of security in the urban environment and its influence on travel behavior, preferences, and tour planning. The proposed heuristic algorithm incorporates a security parameter and flexibility aspects to develop travel plans and schedules for various activities. The outcomes of the analysis comparing three situations (fixed, flexible, and flexible-security) shed light on the impact of security considerations on travel time and overall travel experience. In the fixed situation, where the traveler moves between activities with fixed locations, the total travel time required is 68 minutes. However, the introduction of flexibility in the flexible situation allows for the substitution of the originally suggested restaurant with an alternative location near the hotel, resulting in a reduced total travel time of 54 minutes. This demonstrates the optimization capabilities of the algorithm and the potential for improved travel efficiency through flexibility. Furthermore, the study introduces the flexible-security situation, which takes into account both flexibility and security. In this situation, the algorithm suggests a restaurant placed in a zone with a high security rank, which slightly increases the travel time to 56 minutes. The incorporation of security considerations provides an option for travelers who prioritize security and are willing to trade off a slightly longer travel time. Moreover, this study considers the impact of this influential feature on individual decision-making, where security risk perceptions vary based on age, gender, and previous experiences. The proposed model dynamically adjusts user preferences regarding security risks, meaning that the security levels can be set by the users. When the users indicate high priority for security, the algorithm prioritizes destinations located in areas with higher security levels. This flexibility allows the model to account for sociodemographic characteristics by adjusting preferences according to age, gender, and individual experiences, without the need for separate models for each characteristic.

The study's findings are consistent with the literature review, which emphasizes the security considerations in travel behavior (Schneider, 2013). Concerns related to crime often take precedence over traffic safety, and certain activities or groups may involve more pronounced security considerations (Alfonzo, 2005; Saelens and Handy, 2008).

The study's contribution lies in bridging a research gap by explicitly integrating security considerations into the planning of daily activity chains. Despite that previous studies used numerical methods to optimize the scheduling problems, the security aspect was not handled (Charypar and Nagel, 2005; Miller and Roorda, 2003; Kang and Recker, 2013). The combined solution delivers a complete and secure travel planning technique by adopting the security aspect and the preferences of travelers.

This study enriched the field of travel planning by incorporating flexibility and security considerations into an algorithmic framework. The proposed system provides a practical and efficient solution for travelers to plan their trips, optimize their schedules, and minimize security risks.

In fact, integrating the optimal solutions from the proposed model with city online route planning maps is not only feasible but can also provide significant benefits in terms of enhancing security for travelers, especially for older people or for solo travelers. Therefore, it is possible to develop a mobile app that simultaneously considers travel time and security risk knowing the spatial distribution of security level per district or street for more accurate outcomes. Practically, the existing route planner applications need to extend their input fields with security, and the calculation of the trips should be extended with the security levels of the locations.

This study has the potential to improve the travel experience and develop travel planning systems in urban environments by considering the needs and preferences of travelers. The results may have crucial implications for both travelers and transport operators through minimizing travel time, considering security risks and improving the overall travel experience. Moreover, using such a solution may support the increase of the efficiency of the transportation system.

Some limitations of this study should be realized. Firstly, only two factors were considered: travel time and security. Although these two factors are important in shaping journey planning, other factors, such as cost, accessibility, cultural preferences, environmental impact, and social factors, should be included in future works. Secondly, the proposed system could be compared with another algorithm to evaluate its performance. This would be valuable for future studies, where comparing the performances of various algorithms can provide valuable insights into their strengths, weaknesses, and applicability in different contexts.

## 6 Conclusion

This study considered the travel time and security aspects for providing secure trip planning. The spatial flexibility of the destination was utilized within an optimization framework. The three proposed situations, such as fixed destination, spatial flexible destination, and spatial flexible activities with security aspect, were assessed to evaluate the functionality of the adopted system.

The findings revealed the functionality of the proposed system in optimizing travel plans. The algorithm reduces the travel time and considers the security aspect by using the flexibility concept, namely there was a significant decrease in travel time in the flexible situation, at the same time the algorithm presented destinations within relatively high-security districts. This proposed solution enabled the minimization of security risks, providing travelers with secure travel experience. Therefore, the proposed system is a valuable tool for travelers, providing them with a flexible and efficient way to plan their journeys.

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