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HYBRID MODEL FOR MODELLING TRANSPORTATION CHOICES

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Abstract: *In this paper, we presented a hybrid model that models transport choices across a selected geographic area and considers numerous factors. The idea of our method is as follows: first we select a point on a given grid of points. This point represents our starting point. Based on a specified radius, for example, one hundred kilometres, we select all other points on the grid that fall within that radius. These points represent travel destinations from our starting point. We determine the fastest way to travel from the starting point to all other points, whether it is by train, airplane, train and airplane, or any other mode of transportation if there is no direct flight or train connection. After exploring all the possibilities, we sum up the travel methods from the starting point to all other points. This gives us the predominant mode of transportation within that radius, for example, train. We declare this point as the one for which, within the given radius, the fastest mode of transportation from the starting point to all other points is the train. Now, we move to an adjacent point on the grid and repeat the process. Once all points on the grid have been processed and we return to the initial starting point, we increase the radius to two hundred kilometres and repeat the process. It provides policymakers options for various analyses, which can contribute to more consistent decisions when creating policies and building infrastructure. Our model will enable a graphical display of geographical areas where rail or air transport will prevail as the best choice of transport modality. The distribution of choice will be displayed separately for different trip lengths. Thus, it will be possible to distinguish between the distribution of decisions for trips up to 100, 200... 1000 km, respectively.*

Keywords: *Breakeven distance, rail transport, air transport, total travel time, transport choice modeling*

INTRODUCTION

At a time when everything is changing rapidly, even more so after the global events of recent years, the European Union (EU) has realized that something additional needs to be done in the field of passenger transport as well. The EU Commission therefore presented an action package of measures for more efficient and sustainable travel. Part of this is also an action plan to boost long distance and cross-border passenger rail. The action plan provides a roadmap and further actions to make long-distance and cross-border passenger rail a more attractive travel option for passengers in the EU. According to the EU commission, the presented action plan shall develop synergies, with other relevant EU policies such as the revision of TEN-T guidelines and the implementation of ERTMS projects. In Europe, where passenger rail has been one of the main modes of transport for more than a century and a half, high-speed rail is highly promoted for long-distance travel. But how will this affect other modes of transport. The promotion of the high-speed railway, if it is successful, will surely be reflected in a change in the travel behaviour of the population [1].

The construction of new high-speed rail (HSR) lines naturally has a major impact on the provision of air services. However, it is not always a matter of competition between the two modes of transport. In some cases, HSR services can also play an intermodal complementary role with air transport. The scientific literature in the last decades consistently try to show that the competitiveness of HSR strongly depends on the length of the route, HSR seems to be more efficient on medium distances than on short or long routes. On shorter distances, efficiency is transferred to the side of road transport, and on longer distances to the side of air transport [2].

High-speed rail was initially developed as a mode of inter-city travel as an alternative to air travel over distances of 400–600 km. The expectation of wider economic effects has grown and spread, along with the growth of the high-speed network itself. After intermediate stations were built on most of the lines, the high-speed railway became interesting for providing services on even shorter distances of up to 200 km. New high-speed rail stations in many smaller towns have thus been used as a catalyst for urban renewal and moreover regional development. [3].

By taking a supply oriented empirical analysis, study of the impact of HSR on air service frequencies and seats offered by airlines in large European countries was made. It emphasized the distinction between routes with and without a hub airport

as an endpoint and it also examined the influence of the location of the HSR station. It found direct competition between HSR and airlines, but it also provided some evidence that HSR can provide feeding services to long haul air services in hub airports, particularly in hub airports with HSR stations [2].
But let us return to the initial question how strong HSR alternative to well established air travel is really. The question that remains is how many people choose to travel by train instead of by plane, when and where. What are the factors that influence the decision and are decisions geographically conditioned? Most authors have defined the nature of the decision-making process on the choice of transport modalities as a discrete choice analysis [4]. This insight is based on economic theories of random utility assuming that the traveller chooses the mode with the greatest utility for him. Since then, discrete choice analysis has been used in various studies on this field worldwide [5].

Many previous studies have shown that the operation of HSR could negatively affect passenger demand for air travel. It also became clear that this choice is influenced by several varied factors, including the purpose of the trip [6]. Income, the ratio between travel costs and income, as well as travel time per kilometre and travel costs per kilometre were found to be the most important variables influencing the choice of travel method of passengers. The authors conclude that lower travel costs per kilometre for a certain mode of transport will increase the demand. In addition, they found that the service quality of the mode of transport is also one of the key elements of choice, regardless of the modality [7].

However, regardless of the method of selection and the criteria that are considered, the length of the trip seems to be one of the strongest factors in the selection. But the distance at which the decision changes in favour of one or the other modality (referred to in the literature as a breakeven distance)) is not always the same. We assume that it depends on many factors and is geographically conditioned. But in general, the literature claims, that the length of journeys between 150 and 775 km is the segment in which high-speed rail has a general time advantage over air transport. For distances over 800 km, air transport is usually more suitable. However, if high-speed rail services were not available, air transport would also be suitable for shorter distances of down to 350 km [8].

The competition between high-speed rail and air transport has been researched for many years. In most cases, the authors investigate how potential passengers decide on the type of transport on one route, where two lines are competing, one by rail and the other by air. Over the past few decades, a whole plethora of papers have been published on this topic.

Published research mostly focuses on competition between individual air or rail transport lines between major cities or international hubs. Most often, authors use LOGIT or other Discrete Choice methods for modelling. These methods describe the situation well, but when we consider a larger geographical area, for example, the whole of Europe, the power of these models drops to a minimum. Very few papers deal with how to build a model that would show the distribution of decisions across a selected geographic area, as it obviously depends on several factors. For example, the spread and level of infrastructure development, GDP and purchasing power of the population, etc.

EXPERIMENTAL

In the research, we used ArcGIS Pro 3.1.3 with the Network Analyst extension, as well as Microsoft Excel, a data analysis program. In ArcGIS Pro, we initially created a layer of European countries. In addition to EU countries, we included Great Britain, Switzerland, Norway, and smaller non-EU state countries. We excluded islands due to their inaccessibility by train. In ArcGIS Pro, we created a point layer based on a 10 x 10 km grid, representing the starting or ending points as locations, processed in our study. We limited these points to the selected area. We got 60.830 of these points. We further excluded points located in areas of major continental bodies of water in Europe since they would not sensibly represent the beginning or the end of journeys. We then created two data layers, one for airports and one for high-speed train stations. In the airport layer, we included 299 airports in selected countries, and in the high-speed train station layer, we included 171 stations. To determine high-speed train stations, we used data from the Eurail Association about high-speed trains in Europe [9]. We considered criteria for determining high-speed rail connections of the EU [10].

We then used the Near tool to determine the nearest train station and airport for each of the 60.830 points. We selected the Geodesic option for the Method, considering the curvature of the Earth's surface. We ran the Near tool twice, separately for airports and train stations. If we had input both at the same time, the Near analysis would have only determined the nearest location, either an airport or a station. However, since we are comparing, we needed distances separately for each layer. The generated table contained data of the nearest train station for high-speed trains or the nearest airport in the NEAR_FID column and the distance between a point and a train station or airport in the NEAR_DIST column. In this column, Euclidean distances were provided, representing the shortest distances between locations [11]. For calculations, we multiplied the Euclidean distances by a factor of 1.3 to approximate to actual distances. We assumed a driving speed of 60 km/h. This allowed us to determine the required time for traveling to the nearest train station or airport.

Figure 1: Part of the map, prepared in ArcGIS Pro, with added airports, train stations and points grid

We exported this data as Excel spreadsheets for further editing. We then compiled a list of high-speed train and airline connections in selected countries, based on train and flight schedules. We included airline connections up to 1000 km and airports with more than 30 airline connections were our departure airports. For each connection, we obtained travel duration and check-in time. Check-in times for train connections in Spain, France, and Italy were 30 minutes, and for Eurostar connections, they were 90 minutes. Check-in times for high-speed trains in other countries were 0 minutes. For airline connections, we considered a uniform 120-minute check-in time. We used the Flight Connections portal for information on airline connections [12] and the Omio portal for train connections [13]. Times were provided in minutes. To obtain the total travel time, we added the check-in time to the flight time or train journey time. Total travel time was used for comparison.

In the Excel spreadsheet, we then combined the list of high-speed train stations, the list of train connections, the list of points, nearest to train stations, the list of airports, the list of airline connections, and the list of points, nearest to airports. The connections between worksheets were facilitated by the Object ID data generated in ArcGIS Pro. In Microsoft Excel, we implement our model and, based on data processing, obtain key information for each point on our grid to determine whether it is worthwhile to travel by train or by plane. We import this information back into ArcGIS Pro to graphically illustrate the operation of our model.

Our model is based on the following conceptual algorithm: step 1: in ArcGIS Pro, load the relevant layers (road network, airports, high-speed train stations, airline connections, high-speed train connections), step 2: load a 10 x 10 km grid of points, step 3: choose an arbitrary point on the grid. This serves as the starting point for further analysis, step 4: determine all points on the grid that are within 100 km from the starting point. This selection of points becomes a new layer of data for analysis, step 5: calculate the fastest route between the starting point and any other arbitrary point within this data layer.

Repeat this process until you have determined all routes between the starting point and all other points within the selection, step 6: based on the mode of travel between the selected points (by road, by train, by air or any combination), determine the fastest mode of travel within a 100 km radius of the starting point. For the selected set of points, sum the number of different modes for the fastest route between two points within the set of points. Based on the mode with the highest count, declare the selected point as the one where the fastest mode of travel within a 100 km radius is by road, by train, or by air, step 7: move on to the next point. Repeat steps 3, 4, 5, and 6, step 8: after completing the analysis for all points within a 100 km radius of the starting point, increase the radius to 200 km. Repeat steps 3, 4, 5, and 6, step 9: continue this process for radius from 100 km up to 1000 km.

We used the following code:

$P - set\ of\ equidistant\ geolocations$
$P_o - origin\ point\ \in$ P
$P_d - destination\ point\ \in$ P
$A_o - airport\ nearest\ to\ P_o$
$R_o - train\ station\ nearest\ to\ P_o$
$A_d - airport\ nearest\ to\ P_d$
$R_d - train\ station\ nearest\ to\ P_d$
$t_{ac} - 2h\ airport\ arrial\&check - in\ time$
$t_{au} - 0.5h\ airport\ bagage\ claim\ and\ exit$

$$T_r(P_o, P_d) = t(P_o, R_o) + t(R_o, R_d) + t(R_d, P_d)$$
$$T_a(P_o, P_d) = t(P_o, A_o) + t_{ac} + t(A_o, A_d) + t_{au} + t(A_d, P_d)$$

for r = 100 km **to** 1000 km
    r1 = r
    r2 = r + 100 km
    foreach P_o **in** P do
        foreach P_d **in** P where $r1 < distance(P_o, P_d) < r2$
            if $T_a(P_o.P_d) < T_r$ **then**
                $P_o[r].preference = airport$
            else if $T_a(P_o.P_d) > T_r$
                $P_o[r].preference = railroad$
            else
                $P_o[r].preference = equal$
        end
    end
    r = r + 100 km
end

RESULTS

We have determined travel times for 222 train connections and 1.758 airline connections. The average travel time by plane was 208,95 minutes, while the average travel time by train was 124,17 minutes. If we subtract the check-in time, the average flight duration is 88,95 minutes, and the train travel time is 133,49 minutes on average. The average distance to the nearest train station is 330,85 km, and the average distance to the nearest airport is 88,29 km. For each point on our grid, we know whether it is more time-effective to travel by plane or by train. This allows us to determine the fastest mode of transportation between randomly selected points at a specific distance.

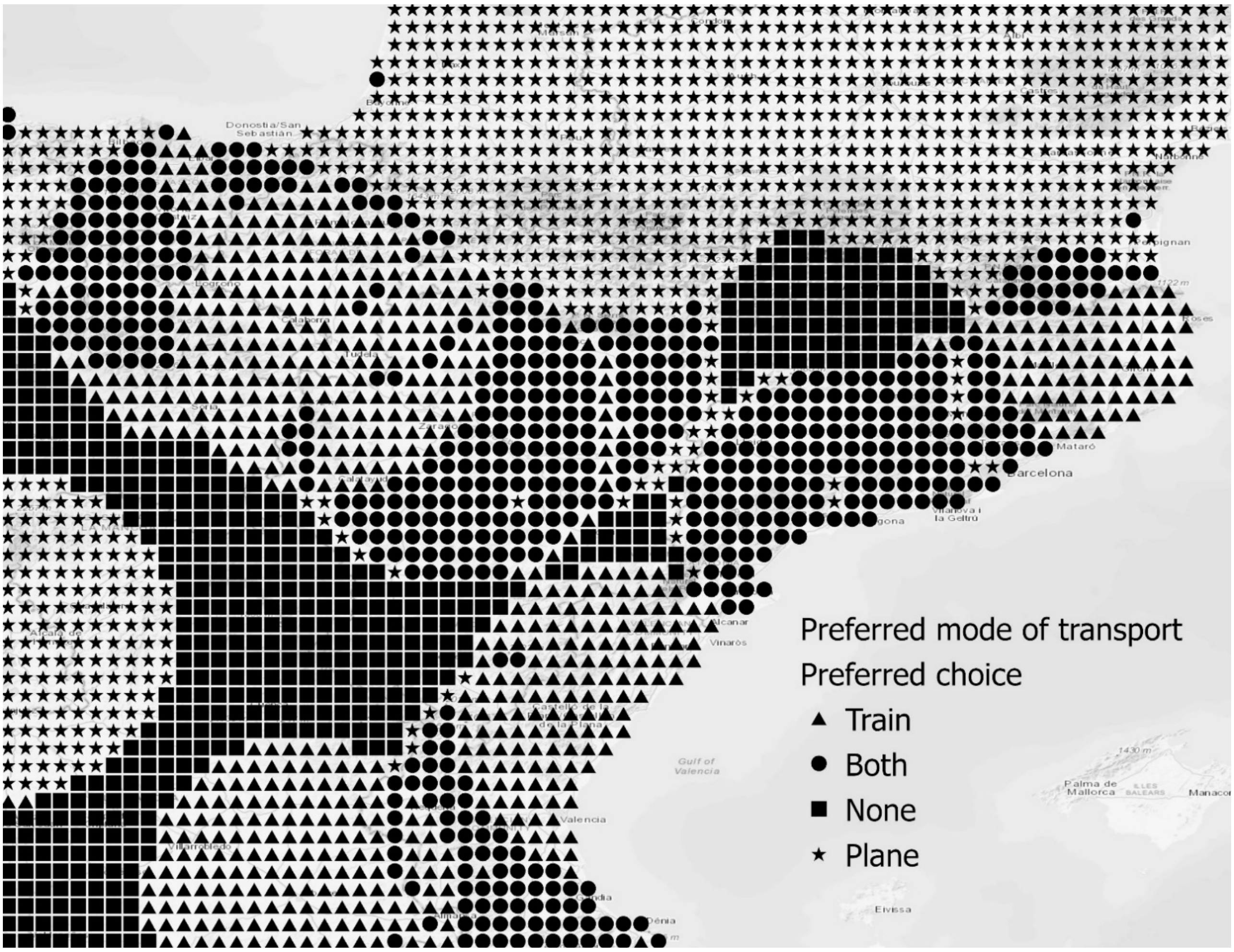

Figure 2: Expected solution, presented with ArcGIS Pro

DISCUSSION

Looking at the statistical data from our research, we can observe that airports are closer to users than high-speed train stations. This can be attributed to the fact that the network of airports in Europe is much more extensive than the network of high-speed train stations. During our research, we found that there are areas in Europe where there is no high-speed rail, and therefore, airplanes are the only feasible option for users to cover longer distances within a reasonable time. A greater number of air connections provide users with more options for covering distances, which gives airplanes an advantage over high-speed trains. If users do not have the option to use high-speed train transportation, it is also not reasonable to expect that users will shift to high-speed trains, and airplanes will continue to be the more attractive solution for them. We can also assess the current infrastructure capacities of specific areas. Based on the point representation on the grid, we can visually highlight areas that are underdeveloped in terms of infrastructure and check what plans are in place for these areas to upgrade the transportation network, thus providing users with alternative transportation capacities. For example, Spain and France, with their efficient high-speed rail systems, offer users a greater range of transportation options compared to countries like Poland or Romania, where air travel currently dominates due to inadequate railway infrastructure. High-speed rail is more concentrated in Western, Central, and Northern Europe, where there is already a well-established high-speed rail system or progress towards achieving that goal is underway.

CONCLUSIONS

The model will allow us to unequivocally determine the breakeven distance between rail and air transport and to determine how it changes geographically depending on the level of development and branching of the transport infrastructure and the offer of different transport options. It provides us with the ability to answer questions related to the choice of transportation between specific locations. In our research, we used a time-based perspective, which can be replaced with a cost-based perspective or a user comfort perspective for transportation services. It allows us to address questions that are relevant or will arise during the transformation of transportation into sustainable transportation. We see exceptional value in the adaptability of the model, as it allows us to implement it in various aspects that influence the choice of transportation means. Such analyses can help us identify where new transportation infrastructure is needed to provide users with the option to choose the mode of transportation for travel at different distances.

Further research using this model should be directed toward addressing current transportation-related issues. The presentation of code and an explanation of the algorithm's idea can provide readers with assistance in building new algorithms or implementing this algorithm to solve problems in this or other domains. This enables the continued development of the model, which can contribute to its utility and reliability in addressing societal issues. Future research should also focus on check-in times. Currently, check-in times for trains are significantly shorter than at airports. It would be interesting to explore how extending check-in times for trains or reducing current check-in times at airports would impact users' transportation choices and how the breakeven point would change. Additionally, the introduction of faster and more cost-effective intermodal transportation connections could influence the changing of the breakeven point. This kind of research could be valuable for optimizing transportation systems and improving the overall travel experience for users.

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