Modelling 15-Minute City Work and Education Amenities Using Surveys and Simulations

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Abstract

Modern cities, against global plans promoting sustainability, are still being designed and built with a primary focus on the needs of drivers. Planning concepts, such as a 15-minute city, aim to minimise car usage by assuring quick access to vital urban functions within walking distance. However, their application needs information about achievability and viability. This work presents a model that combines qualitative and quantitative studies on travel duration from home to school and work. The survey data are a base for a model that calculates connections between the actual locations visited by the respondents and calculates travel parameters. The study performed among parents from three primary schools showed that over 56% of travel to schools can be covered by public transport in less than 15 minutes and that the benefits of using a car on longer travel to work are limited.

Keywords: behaviour modelling, survey analytics, transport simulation, 15-minute city.

1. Introduction

In Europe, the *European Green Deal* action plan has been created as an answer for the Global North countries issues such as excess cars [24], congestion [1], noise [2], and climate change with environmental degradation [23] with a primary focus on the needs of car drivers. Traffic and vehicles on city streets increase [19]. The idea of travelling in one's car is being passed on to the next generation. Therefore, the proportion of children being driven in cars increases [13], and the number of child-related car journeys contribute significantly to road congestion [20].

Cities introduce strategies for car usage limitations. That includes policies such as charges for cars and price reductions for public transport, access restrictions, car sharing, or travel planning support [14]. Among these solutions is a 15-minute city concept.

The 15-minute city is a planning concept that aims to minimise car usage by assuring access to critical urban functions within walking distance of 15 minutes. The fulfilment of the concept assumptions requires the coexistence of several factors, such as diverse urban spaces nearby, routes enabling short commuting, and room for creating walkways or bicycle lanes. However, introducing the planning concept into existing urban tissue is challenging and costly. Without knowing the current state of development, achievability, and the possibility of reaching benefits, such a transformation should not be started, especially without consultation with citizens.

Therefore, it is necessary to model the naturalistic citizen behaviours and analyse transport, sociological, and economic factors of their mobility choices. It can be done by combining social research to understand better stakeholders and computer science to collect objective data, which can be further analysed using methodology from both disciplines.

Our work aims to check how mobility choices affect daily travel in the context of a 15-minute city. The simulations based on survey data collected among parents of primary school pupils estimates how the 15-minute city concept is already present in the citizens' behaviour. Travels from the declared home address to the workplace and children's school are planned using a spatial data analysis platform supported with OpenStreetMap data and public transport timetables. The results allow us to compare the differences in travel between two destinations, school and work. A workplace can be distant when a school is mainly localised near home.

The rest of this paper is structured as follows. Section 2 summarises related works. Section 3 presents transformation from surveys into trips and their processing. Section 4 describes the used data and obtained results. Section 5 presents conclusions and possible further research.

2. Related works

2.1. Transport habits

Social research on transport habits has mainly used quantitative methods, focusing infrastructural data and rational behaviour [6],[8]. However, qualitative research, i.e. [4],[10],[11], conducted on smaller samples and focused on explaining the causes of observed and not always rational behaviour, and triangulation research [17], in which both methodologies are combined, are also emerging in this area [4],[8],[10]. Triangulation research was applied in our work. We assumed that the citizens are selective in choosing the given type's destination and may prefer destinations that are not rational in the aspect of minimalisation of travel duration or distance.

2.2. 15-minute city

Changes in the behaviour of inhabitants of urban areas, reflected in interactions with the surrounding environment and infrastructure are noticed frequently as the solution to social, economic, and environmental issues. Positive changes, i.e. reduction of vehicular emissions, may be supported by creating possibilities for acting differently. Dumbaugh et al. [7] proposed a response to the changing nature of urban transportation's social and financial context, encouraging cities to focus increasingly on two urban development objectives: value capture and livability.

The 15-minute city is a planning concept based on the idea that 15 minutes of walking proximity of key functional areas constitutes a complete human neighbourhood and minimises the necessity to travel further [16]. The key functions include residential, work, commerce, healthcare, education and entertainment, and the closeness of the functions in walking, cycling or by transit (public transport in any form including buses, trams, subway and local trains) reach can be regarded as motivation to abandon a car transport [7].

Although the concept strictly referred to the time of 15 minutes of walking, Ferrer et al. [9] emphasised that the trend of chrono-urbanism is expanding without strict periods or means of transportation. In our work, we discussed the approach to study 15-minute accessibility to two essential functions, work and education, based on actual data, where the place of residence, work and education, and travel between them are known. This allows us to assess actual travelling needs and evaluate whether functional areas nearby translate into real travelling choices.

2.3. Urban data processing

The 15-minute city concept can be examined by exploitation of transportation patterns due to survey data. Rasca et al. [18] proved that travelling time and distance influence commuters' transportation preferences. Bautista-Hernandez [3] showed that transportation mode choice relates to spatial, social, and economic aspects. Yang et al. [25] utilised survey data and simulations to model transport habits and to investigate features' impact on travel behaviour changes.

Spadon et al. [21] proposed a distance-based toolset and related algorithms to track inconsistencies in access to places like police stations, hospitals, and public schools. The analysed graph of the city infrastructure was taken from OpenStreetMap, which was also used in our solution.

Our work discusses car and transit travel (buses, trams, suburban trains, and metro). Zhuge et al. [27] simulated travel, refuelling and parking behaviour, the associated vehicular energy consumption, and emissions based on multi-agent simulation. Curado et al. [5] – based on car mobility data (Rome) – represented mobility data coupled with urban public transport networks, augmenting the network nodes with data on commercial, economic, service and tourist activity in the city. Su et al. [22] proposed a passenger model to measure the effect of different public transport vehicle layouts on the required time for boarding and alighting.

3. Methods

3.1. Social surveys

An empirical social survey was designed to investigate the perspectives of parents of school children on their transport choices and preferences, particularly regarding travelling to school.

First, a qualitative methodology was used, and eight focus group interviews were conducted with parents of children attending primary schools. The qualitative interview covered the following issues: What do parents consider children's safety on the road? How do the place of residence and weather conditions affect the willingness to use specific means of transport? How do respondents estimate the costs of owning and using a car? What is their need for a car and their attitude towards alternative means of transport?

Understanding the complexity of travel behaviour requires a deep knowledge of people's perceptions, attitudes, and behaviours. In particular, it shows how emotional feelings, sometimes even rather than rational and economic calculations, influence the final transport decisions of the city's inhabitants. Qualitative methods are a powerful tool for exploring this complexity, allowing us to capture people's explanations of their behaviour and attitudes [26]. Combining this with an accurate and precise mathematical model will give us a broader and more detailed picture of the issue.

Supported by the previous results, a quantitative questionnaire was created and addressed to parents of children studying in Warsaw primary school. The questionnaire was made available to the respondents using the Computer Assisted Web Interview method [12]. Each respondent selected data from a cafeteria of answers displayed on a computer screen. These were single and multiple-choice questions. The questionnaire was accompanied by a *travel diary*, filled with declarations of specific transport behaviours from one of the last days preceding the survey. Only the middle days of a working week – from Tuesday to Thursday – were considered.

3.2. Routing trips from home

Let us assume that survey $\mathbf{S}$ consist of two parts. The first part P_i describes ith respondent. The second part $\mathbf{T_i}$ is a set of respondents' trips. Thus, the entire survey is given by pair $(P_i, \mathbf{T_i})$. Each $t \in \mathbf{T_i}$ describes the trip's origin $O(t)$, destination $D(t)$, and starting time. $O(t)$ and $D(t)$ are TripPoints consisting of coordinates and a type. The type belongs to one of the values from the closed list containing such values as $HOME$, $WORK$, $SHOP$, $SCHOOL$, and others.

P_i contains information about the respondent's home $H(P_i)$ and a declared starting point. The starting point, denoted as $S(P_i)$, usually is the respondent's home $S(P_i) = H(P_i)$. Therefore, its type is mostly $HOME$, but it can be set as $WORK$ or another type in rare cases.

All collected trips are transferred to simulate trips from home to other TripPoints. The starting point is set as the origin of the first trip. Each next trip t_j has its origin $O(t_j)$ in destination of previous one $D(t_{j-1})$. The algorithm checks the $O(t_j)$ and $D(t_j)$ to fix them to the trip-from-home schema. If the respondent is already travelling from home, the trip is added to $\mathbf{H}$. If the trip ends at home, it is reversed, and $O(t)$ is switched with $D(t)$ (their coordinates and types are replaced) and added to $\mathbf{H}$. If the trip is not attached to the $HOME$ POI at an end, a new trip is routed with origin $O(t)$ set as home address $H(P)$. The new trip is routed from the home address to the destination of the original trip and added to $\mathbf{H}$.

Set $\mathbf{H}$ is cleared from any duplicates, and duration and distances are calculated for each trip covered by various transport choices, including transit (public transport) and individual transport (car). At this moment, the calculated duration does not consider traffic congestion.

3.3. Calculating duration and distance

The survey data with modified trips are processed using the Use4IoT platform [15]. A calculation of trip parameters is possible using a multimodal trip planning module OpenTripPlanner[1] (OTP) supported by OpenStreetMap[2] (OSM). OSM provides information on street networks and public transport stop positions.

OTP calculates a door-to-door trip for a private car without considering parking issues and the walking time necessary to reach the destination from a parking lot. While the module takes into account traffic regulations and road obstacles, it does not consider traffic congestion, which results in a biased estimation of car travel duration. Real travelling time should also include parking time and any delays caused by traffic density. At this moment, this issue has been noted but not solved.

The transit routes are calculated using schedules in the General Transit Feed Specification (GFTS) format. The current schedules are taken from local authorities' public transport resources. GTFS files are generated from regular schedules or emulated from run frequency. The prepared GTFS files are stored in the Apache Hadoop Cluster for batch analysis.

Routes are calculated between public transport stops. The total travel duration is extended by waiting and walking times. The calculated distance includes walking distance from and to the stops and the distance covered during transfers in multimodal trips.

The OTP calculates a single route for a private car but can find several connections for transit. That depends on the available courses in a 15-minute time window $[t-5, t+10]$ where t is the declared starting travel time. It is an open issue how to aggregate transit results. We discuss the average and the minimal distance and duration, excluding the maximal values as they are unlikely to be chosen by a traveller when alternatives exist.

Finally, information about travel duration and distance is integrated with survey data for further data analysis.

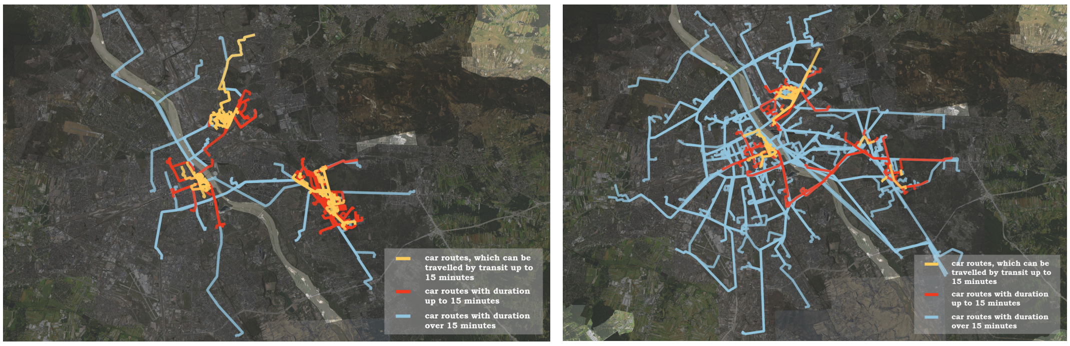
4. Results

4.1. Data

The created questionnaire was presented to 1454 parents of children attending three primary schools. Among them, 523 (parents of 683 children) finished the survey, which gives a response rate of 36%. The collected declarations consist of 1861 reported travels between 2022-03-15 and 2022-04-28. Among the travels, 453 were travels to school, 383 were travels to work, and 631 travels ended at home. Although travel using public transport and private cars was simulated for all respondents, they were also asked about the actual mode of transport. Among 1861 cases, 900 were taken by car (64 as a passenger), 381 by various forms of public transport, and 479 by foot.

The surveys were conducted with parents of pupils studying in three Warsaw primary schools

[1] https://www.opentripplanner.org/
[2] https://www.openstreetmap.org/



(a) education destination **(b)** work destination

Fig. 1. Car routes to work and education destination function with duration distribution

selected according to their location. It was considered that due to the qualitatively different locations, the transport habits and attitudes of both children and their parents, evident in their daily movement around the city, would also differ.

The first primary school (no. 34) is located in the central yet green and relatively prestigious district of Warsaw, Powiśle. The location is close to all service points. However, finding a free parking space is difficult, as a paid parking zone covers the district. Therefore, residents use means of transport other than their car when doing their daily errands, also in the city centre. In this location, 16% of respondents (compared to 7% in school no. 377 and 4% in school no. 218) indicated that they did not own a car at all, and the average was 0.3 cars per household.

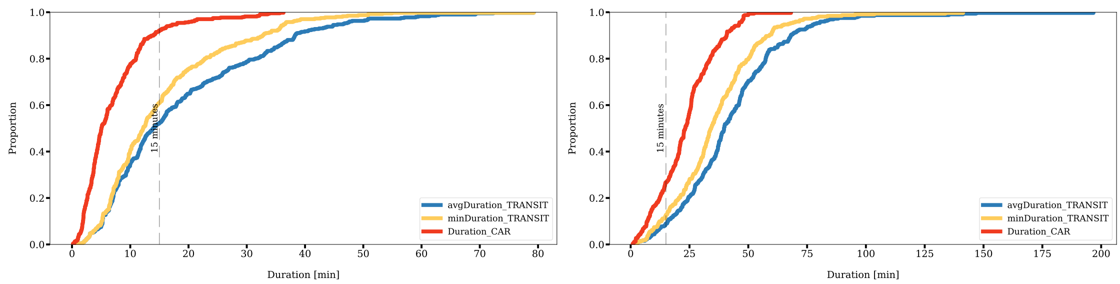
Parents of children enrolled on the second school (no. 377) – near the centre of Warsaw – are further away but still seem connected to it. They often work there, run errands and use the downtown infrastructure. On the one hand, the construction of the metro station (Trocka station) has greatly improved communication with the centre (it takes about 15 minutes to get there by metro). On the other hand, it has caused many people to treat the area as a *transfer* point and to come to the area by car and park their cars on the estate, blocking the pavements and perceptibly increasing traffic (at the time of the survey it was the last station of the second metro line).

In contrast, parents of children attending school no. 218 ('suburban') declared rarely need to commute daily to the city centre. They can do most of their daily business in the neighbourhood and try to do so, and if they are unsuccessful (if only with their place of work), they try to *go and come back*. They declare that living on the outskirts (some consider it already *out of town*) makes it unnecessary for them to visit the centre frequently, even though the distance is not great (about 10 km.) Their children, especially the younger ones, do not come to the centre alone, while the older ones (still studying in the nearby primary school) go there occasionally. This school has the highest ratio of children commuting by car.

4.2. Transit vs individual transport

To compare transit and private car usage, routes from HOME to other points were drawn based on a car itinerary. The trips were then grouped according to the possibility of covering them in 15 minutes by public transport or car. The obtained results were categorized according to the functions of the visited points. Due to the scope of this work, the analysis focuses on two groups: Education and Work.

Car routes to work and education destinations are presented in Fig. 1. Fig. 1a presents travels from HOME to educational institutions, primarily to schools (439), but also to universities (4). The concentration of travel around three centres, as determined by the schools, is visible. The travels are mostly short. Over 56% of them – 244 cases – can be covered in less than 15 minutes using transit or walking in case of closer distances. Other 37% educational destinations – 163



(a) EDUCATION **(b)** WORK

Fig. 2. Cumulative distribution plot of travel time for transit and car

cases – can be reached in up to 15 minutes by car. Only 7% of travels (32 cases) were longer than 15 minutes, even using a car. Travelling to the universities is not statistically meaningful, but it is worth mentioning that only one can be made in less than 15 minutes by transit.

Fig. 1b presents travels from HOME to work. The total number of these travels is 358. The travel network covers nearly the entire city without visible concentration points. The distribution of travel duration differs from travels to educational destinations. The travels are dominated by long trips that cannot be covered in 15 minutes, even by car. Their total number is 269, which accounts for 75% of the cases. The next position – 13% of all travels (48 cases) – takes travels that can be made in 15 minutes but only by car. Only 41 travels (11%) to work can be made in 15 minutes using transit.

Notably, the distribution of short travels varies among schools that respondents' children attend. For school no. 218, in suburbia, only 6 such travels are observed, while for well-communicated school no. 377, near a metro station, 21 such travels were noticed. For school no. 34, which is placed in the centre, 14 short travels were registered.

Fig. 2 presents a cumulative distribution function (CDF) for duration calculated among the travels by car and transit. For transit, the minimal and average duration were considered. Fig. 2a presents CDF for the duration of travels from home to educational destinations. Fig. 2b shows CDF for the duration of travels from home to work.

In some aspects, the results for both types of destinations are similar. Car usage guarantees shorter travel than transit, even assuming the best connection. The difference between the minimal and average transit duration is smaller for shorter than longer travel. It is caused by a lack of alternative connections to short distances rather than by the development of public transport.

However, there are also crucial differences. As shown previously, work travel duration is statistically longer than travel to an educational institution. Interestingly, a characteristic of the CDF plot for car travel duration is more similar to other plots in the case of travels to work. Replacing a car with public transport is statistically less costly in this case.

5. Conclusions

We presented a behaviour mobility model based on survey-described naturalistic citizen behaviours and a simulated transport environment using public transport schedules and road networks for the City of Warsaw.

The results, which benefited from accurate localisation of travel destinations, showed that in 56% of cases, a school could be reached in less than 15 minutes using public transport or on foot. That supports public transport as a real alternative to private cars. Regarding its educational amenities, the 15-minute city concept can be introduced on a large scale if parents are convinced to enrol their children in local schools. This can be achieved by increasing and levelling primary education quality. However, in most cases, the second discussed amenity, work, falls behind the

15-minute criterion. In this case, reducing the number of long travels is challenging. A potential solution lies in technological progress and the possibility of remote work.

The presented analysis provides several arguments for replacing cars with public transport. Travels to educational institutions are mostly short, and schools can often be reached within 15 minutes using transit. On the other hand, the benefits of using a car during much longer travel to work are relatively small, at least in the discussed aspect of the travel duration.

The possible future works are drafted based on the limitations of the actual work. The analysis is limited in time and to three schools. Also, the 15-minute city amenities are limited to two aspects. Extending the analysis, temporarily and spatially, to more respondents with a wider perspective of the destination would allow us to draw more general conclusions. Additionally, the system can bring more realistic results considering the walking distance and congestion in a simulation of individual transport. This can be obtained using a transportation model published by the City of Warsaw.

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References

1. Albalate, D., Fageda, X.: On the relationship between congestion and road safety in cities. Transport Policy **105**(March), 145–152 (2021)
2. Barrigón Morillas, J.M., Rey Gozalo, G., Montes-González, D., Vílchez-Gómez, R., Gómez Escobar, V.: Variability of traffic noise pollution levels as a function of city size variables. Environmental Research **199**(February) (2021). https://doi.org/10.1016/j.envres.2021.111303
3. Bautista-Hernández, D.A.: Mode choice in commuting and the built environment in México City. Is there a chance for non-motorized travel? Journal of Transport Geography **92**, 103024 (2021)
4. Beirão, G., Sarsfield Cabral, J.: Understanding attitudes towards public transport and private car: A qualitative study. Transport Policy **14**(6), 478–489 (2007)
5. Curado, M., Tortosa, L., Vicent, J.F., Yeghikyan, G.: Understanding mobility in rome by means of a multiplex network with data. Journal of Computational Science **51**, 101305 (2021)
6. Czech, A., Gralak, K., Kacprzak, M., Król, A.: Quantitative analysis of sustainable transport development as a support tool for transport system management: Spatial approach. Energies **14**(19) (2021). https://doi.org/10.3390/en14196149
7. Dumbaugh, E., Marshall, W.: Cities and the future of urban transportation: A roadmap for the 21st century. Research in Transportation Business & Management **29**, 4–13 (2018)
8. Emberger, G., Pfaffenbichler, P.: A quantitative analysis of potential impacts of automated vehicles in austria using a dynamic integrated land use and transport interaction model. Transport Policy **98**, 57–67 (2020)
9. Ferrer-Ortiz, C., Marquet, O., Mojica, L., Vich, G.: Barcelona under the 15-minute city lens: Mapping the accessibility and proximity potential based on pedestrian travel times. Smart Cities **5**(1), 146–161 (2022)
10. Flick, U.: Managing quality in qualitative research. Sage Publications (2008)
11. Guido, G., Haghshenas, S.S., Vitale, A., Astarita, V., Geem, Z.W.: A Quantitative and

Qualitative Review of the Role of Intelligent Transportation Systems in Road Safety Studies through Three Decades. Journal of Soft Computing in Civil Engineering **7**(4), 93–109 (2023). https://doi.org/10.22115/SCCE.2023.382320.1597

12. Kagerbauer, M., Manz, W., Zumkeller, D.: Transport survey methods: best practice for decision making, chap. Analysis of PAPI, CATI, and CAWI methods for a multiday household travel survey. Emerald Group Publishing Limited (2013)
13. Kontou, E., McDonald, N.C., Brookshire, K., Pullen-Seufert, N.C., LaJeunesse, S.: U.S. active school travel in 2017: Prevalence and correlates. Preventive Medicine Reports **17**(December 2019), 101024 (2020)
14. Kuss, P., Nicholas, K.A.: A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management. Case Studies on Transport Policy **10**, 1494–1513 (2022)
15. Luckner, M., Grzenda, M., Kunicki, R., Legierski, J.: IoT Architecture for Urban Data-Centric Services and Applications. ACM Transactions on Internet Technology **20**(3) (2020)
16. Moreno, C., Allam, Z., Chabaud, D., Gall, C., Pratlong, F.: Introducing the "15-minute city": Sustainability, resilience and place identity in future post-pandemic cities. Smart Cities **4**(1), 93–111 (2021)
17. Oppermann, M.: Triangulation — a methodological discussion. International Journal of Tourism Research **2**(2), 141–145 (2000)
18. Rasca, S., Saeed, N.: Exploring the factors influencing the use of public transport by commuters living in networks of small cities and towns. Travel Behaviour and Society **28**, 249–263 (2022)
19. Schmale, J., von Schneidemesser, E., Dörrie, A.: An integrated assessment method for sustainable transport system planning in a middle sized German city. Sustainability (Switzerland) **7**(2), 1329–1354 (2015)
20. Singh, N., Vasudevan, V.: Understanding school trip mode choice – The case of Kanpur (India). Journal of Transport Geography **66**(January), 283–290 (2018)
21. Spadon, G., Brandoli, B., Eler, D.M., Rodrigues-Jr, J.F.: Detecting multi-scale distance-based inconsistencies in cities through complex-networks. Journal of Computational Science **30**, 209–222 (2019)
22. Su, B., Andelfinger, P., Kwak, J., Eckhoff, D., Cornet, H., Marinkovic, G., Cai, W., Knoll, A.: A passenger model for simulating boarding and alighting in spatially confined transportation scenarios. Journal of Computational Science **45**, 101173 (2020)
23. Tammekivi, T., Kaasik, M., Hamer, P., Santos, G.S., Šteinberga, I.: Air pollution situation in small towns, including winter resorts: a comparative study of three cases in northern europe. Air Quality, Atmosphere & Health **16**(5), 945–961 (2023)
24. Wadud, Z., Adeel, M., Anable, J., Lucas, K.: A disaggregate analysis of 'excess' car travel and its role in decarbonisation. Transportation Research Part D: Transport and Environment **109**(July), 103377 (2022)
25. Yang, Y., Wang, C., Liu, W., Zhou, P.: Understanding the determinants of travel mode choice of residents and its carbon mitigation potential. Energy Policy **115**, 486–493 (2018)
26. Zawieska, J., Archanowicz-Kudelska, K.: Challenges behind sustainable schools commutes: qualitative approach in the urban environment of XXIst century. Transportation Research Procedia **72**, 2189–2196 (2023), tRA Lisbon 2022 Conference Proceedings Transport Research Arena,14th-17th November 2022, Lisboa, Portugal
27. Zhuge, C., Shao, C., Yang, X.: Agent- and activity-based large-scale simulation of enroute travel, enroute refuelling and parking behaviours in beijing, china. Journal of Computational Science **38**, 101046 (2019)