ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

TEZE K DISERTAČNÍ PRÁCI

České vysoké učení technické v Praze

Fakulta architektury

Ústav modelového projektování MOLAB

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Mobile-Based Sensing – Smartphone Application for Long-term Urban Lifestyle and Mobility Sensing

Doktorský studijní program: Architektura, teorie a tvorba

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S disertací je možno se seznámit na děkanátě Fakulty architektury ČVUT v Praze, na oddělení pro vědeckou a výzkumnou činnost, Thákurova 9, Praha 6.

předseda komise pro obhajobu disertační práce
ve studijním oboru Architektura a urbanismus
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CONTENT

1. STATE OF THE ART

Approaches to city development have changed significantly during the last century [1]. Functional cities with strictly divided zones for work, housing and leisure time, defined by Athens charter in the 1940s [2], were questioned by Jane Jacobs in the early 1970s [3]. She started to introduce sociological concepts such as "eyes on the street" and "social capital" to urban development. This shifted the focus of urban planners from the machine functionality of the city to the human level – on pedestrians and their movement. The ability of places for public life is the requirement of contemporary society.

From around 2000, research on the integration of pedestrians has become increasingly important with the rapidly growing volume of motorised traffic. The aim of architects and urban planners is to balance the cycle, pedestrian and motorised traffic to provide decent conditions for all kinds of participating individuals. This indisputable measurement in the field of public life studies can serve as convincing argument for public space renewal projects.

The theoretical framework of methods for monitoring public spaces and their public life are described by the nestors of public life studies Jan Gehl & Birgitte Svare in the book How to study public life as analogue [1], but it is apparent that some of mentioned method of observation can be mediated also by smartphone chips. The above mentioned eyes on the streets could be replaced by smartphone chips on the streets, who are already present there. The data could be gained from a large number of individuals, without the need for human resources on a daily basis.

The possibility of technological solutions is also developed in the methodology. The mediation of the individuals' activities require observational neutrality and a systematical approach [4], which are the basic properties of technological solutions. The observers should not be a part of the activities. The work of the observer in its sensitivity is so far indispensable. In the manual, Gehl admits the employment of tracking devices but emphasises the role of human registration and common sense for understanding the ongoing situation. The monitoring of individuals' movement via smartphone offers one more benefit: to obtain data over a long period of time.

Gehl compares the study of public life to biological research of animal species: the observation focused on its activities, velocity and manner of movement. We count its occurrence in varied places. For lifestyle monitoring in a settlement structure, three factors seem to be traceable through a smartphone:

- How many people are using the monitored area in certain space?
- Who are the people, what do we know about them?
- Where are they and what are they doing?

The interaction between life and space is an ephemeral phenomenon. That's why Gehl considers it useful to ask repetitively the basic questions about the pedestrian flow and stationary activity.

The quantitative question in the larger scale can be answered by analysing the residual data of mobile operators, but the quality criteria (who are the people and what they do) is easier to follow through smartphone applications. Smartphone applications can collect data more efficiently and with more precise temporal information than traditional observation methods. However, the data can be captured only for some observation tools. Using a smartphone is a regular daily activity and thus does not disturb the users (respondents) in any way [5].

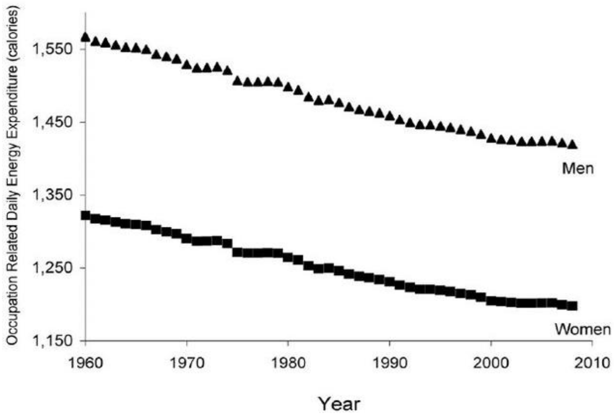


Figure 1 - The mean occupational daily energy expenditure in men and women since 1960 (source T. S. Church et.al, 2011).

Research shows that the physical activity of (not only) the Czech population has been following a decreasing trend (see Fig.1) [6] [7] [8]. WHO refers to a pandemic of inactivity [9] [10]. Architects and urban planners can influence the shape of the physical environment of the city to encourage walking and other modes of physically active movement. Creating an urban environment that is friendly to active modes of transport (i.e., that not only enables but also encourages them) will have an impact that is extends beyond public health. Increasing the share of active modes of transport at the expense of private car transport also has environmental and economic implications. In order to evaluate these consequences and monitor the state of active movement in the Czech population, it is necessary to obtain data on the physical activity of the population, especially in terms of walking.
Smartphones are widely penetrated in the Czech population [11]. Through acceleration sensors and location functions, time-spatial data and the information about traffic modes can be obtained non-invasively of the phone, and hence of the user [12] [13] [14]. Detection of the movement mode is achieved by analysing the acceleration graph, where each transport mode has its own typical curve[15] [16] [17]. The determination of the transport mode can be refined by comparing the trajectory over time with data from public transport timetables[18]. GPS location has high battery requirements, which is inconvenient for the user, but it can be replaced by network based sensing[15] [17].

The commercial offer includes types of applications that already provide geolocation information supplemented by activity monitoring. However, GDPR does not allow the data of these applications to be used without the explicit consent of the user [19]. In this dissertation, I therefore propose a novel mobile application, through which it would be possible to collect data on users' active mobility over a long duration, as an important indicator of city liveability.

2. SUMMARY OF THE RESEARCH QUESTION

Cities continuously produce large amounts of information [13]. The validity of some of the information is only very short. However, by using this volatile information, we can monitor and document the processes which are going on in a city. By combining these fragile and unstable "maps" and city plans, as we know them today, we can achieve a more comprehensive imaging and modelling of a city.

Information about ongoing events and processes in the city is easier to obtain, but the full potential of the data from mobile technologies for spatial planning and crisis management has not yet been fully recognised in the field of city management.

The data can be gained automatically by many different sensors [14], which are a part of the public space and its facilities, or the data can be produced by the users of the city – its inhabitants [12].

72,6% of the population in the Czech Republic have a smartphone. In the age group of 16-24 years the share is 97,9% [11]. An average user of a smartphone has 80 apps installed on their phone and uses almost 40 of them each month [20]. The big data of mobile network operators is not a publicly available source – the data is provided by the companies on a commercial basis which makes their availability for research difficult [21]. The smartphone application is an alternative for massive and long-term data acquisition.

The mobility of people can be monitored using a simple smartphone application that maps their movement. Sensors in smartphones are a low-cost source of information that can be interpreted and used as a dynamic indicator of urban life. We can gain access to data by offering attractive and gripping benefits. Using this widespread and accessible tool, we can collect data about the lifestyle in urban structures. However, it is necessary to develop an appropriate marketing strategy for the successful acquisition of the data.

The design of the application contains also the backend development – the database structure in which the application will store data. The database of the application, that aggregates the users’ data in the longer term can become the data lake for further research on the fields of urban planning, urban design and city development. The interpretation of the collected dataset can provide useful information for decision making or become a measure for urban and mobility strategies.

The proposed smartphone application collects the mobility data of its users. By establishing the data lake of the mobility data the strong and long-term data source for further urban research is created. This thesis presents possibilities of data sample processing and shows the ways to work with the specific data focusing on urban planning and urban design.

The proceedings of the proposed data analysis aims to be incorporated into the design decision-making process. The feasibility of the proposed data analysis methods is validated by the case study: the selected data sample processing provides data on pedestrian activity of Prague residents, who commute to work and back daily by walking or by a combination of public transport use and walking.

This case study is based on the dataset of daily activity schedules of 89 948 urban citizens / agents extracted from agent-based simulation model of multimodal mobility in Prague [22]. The schedules contain the exact routes, transport modes and durations of all trips made by public transport users. For all individuals, the walking distance and the distance of the routine route (to and from work) are measured. The case study examines the pedestrian activity of Prague residents with the above described transport behaviour. It examines the total amount of walking per day and monitors the number of people in the population who can be classified as active individuals based on their daily walking totals. In the study we also observe the balance of routine and non-routine routes. The case study observes daily walking activity in terms of influential factors: age, gender, highest educational attainment, family status and income group.

3. METOD OF THE RESEARCH

The goal of the research is the design of a tool for mobility data aggregation via smartphone. This thesis proves the ability of the outcoming dataset to become a source of information for urban planning and management, heading towards healthier and social responsible cities.

The research comprised four main phases:

- State of the art – Urban lifestyle studies
- Design of the data source
- Defining the possibilities for the use of the data obtained from the designed application
- Case study

The bases for the design of the research was formed by the book by Jan Gehl – How to study public life [1]. The book describes the method of observing public spaces to indicate the weak points and potentials of the locality before the strategy for the urban planning and design is set. From the, methods described in the book, I looked for those where the physical observation of the place can be replaced by sensor data provided by the smartphone chips. Therefore, the research focuses on the key issue of urban life studies and human movement around the city.

After studying the previous works in the field of smartphone sensor applications, the UrbanFit application was designed. The UrbanFit application collects user data into a database for further research. An application programming manual has been developed, including a graphical user interface designed in Auxure Pro. The proposal was preceded by a search of the mobile applications market. The aim was the uniqueness of the application in the Czech environment, and thus also gaining motivation for users. The application market turned out to be volatile and dynamic, not just in the content of the applications, but also in development of legal conditions.

In the available literature, I searched for research in which data with the same or very similar categories as the proposed application database were used. However, these data were obtained in another way (crowdsourcing, questionnaire survey, respondent reported). The output is an overview of ways of processing the dataset from the mobile application.

To confirm the hypothesis, the case study of the mobility and their influencing factors of the Prague population was chosen. The smartphone application remained in the manual stage, so I used alternative data from the agent model of multimodal mobility in Prague for analysis. Data were extracted from the model and subsequently processed in Excel and R + programmes using standard statistical methods.

The above-mentioned research of English-language scientific literature was performed primarily by searching Web of Science, Scopus, Elsevier, IEEE, Google Scholar and ResearchGate. The search was limited to items published between 1975 and January 2022 and the keywords included “smartphone”, “fitness”, “lifestyle”, “physical activity”, “walkability”, “mobility”, “biking”, “urban”, “smart city”. We searched the results for articles related to the topic of this study. We then selected studies that could be repeated or conducted by using smartphone application data.

The bibliographies of the selected articles were examined for further relevant articles. Links found on websites where these articles were published were also searched for pertinent information.

Based on the literature review, thematically specific categories of data use in the urban sphere were created. Furthermore, the necessary input data for these individual categories were determined.

3.1. Workflow

First step of the work was development of the application for smartphone for data acquisition of mobility habits of their users. Subsequently – after the mining will aggregate sufficient amount of data – one case study (the test of usage of the data in urban context) should be done.

However, successful entry into the competitive market of mobile applications includes, in addition to the coding part, also application marketing. The full version of the application and the further PR work to aggregate bigger amount of data turned out to be more expensive than was originally expected. For the case study has been replaced the smartphone applications data has been replaced by the data from agent-based model of multimodal mobility of Prague, developed by a scientific team from Department of Computer Science, FEL, CTU.

The data from the agent-based model has been organised to be of a similar structure to the proposed database. The system of the work with the agent-based model data can also be used for the work with the data aggregated by smartphone application.

3.2. Application programming

The biggest problem turned out to be the coding and maintenance of the application. This is an interdisciplinary project and although DCGI FEL CTU, represented by the team of Ing. Miroslav Macík, Ph.D., participated in the acquisition of the graphics and structure of the application, I was unable to run in its full version. The private commercial sector was also approached for cooperation, but the estimated expenditure proved to be unrealistic. Two SGS grant applications were submitted for application processing, and although compliance with the long-term focus of the Faculty and interdisciplinary cooperation was stated, the project was not granted due to a lack of financial resources.

The purchase and operation is interdisciplinary work on the edge of IT and architecture. The programming part is beyond the scope of an architect. A development of professional software requires hiring professional programmers to the team. The dissertation contains a manual for the application developers, including the design of the UI[1] and UX[2]. Coding was, from the beginning of the work, considered to be an outsourced service.
The placing of the application was consulted with Adikt mobile s. r.o..mThe amount required by the commercial company Adikt mobile s. r.o. for this step is about 300 000 CZK, VAT not included.[3]

3.3. Database replacement

The result of the programming part required finding an alternative data source. At this point it was necessary to find an alternative data source, which provides a database with properties which are similar to the dataset from Urbanfit.
In 2018, The General Data Protection Regulation entered into legal force [19], the comprehensive set of data protection rules for collecting or processing the personal data of Europeans. This precluded the possibility of cooperation in the field of data acquisition with another private sport-tester application.
Following this, we established a cooperation with the team from the Department of Computer Science of the Faculty of Electrical Engineering, led by RNDr. Michal Čertický, PhD. They were recently working on the agent-

[1] *User Interface*
[2] *User Experience*
[3] *price offer was issued in 2016*

based model of multimodal mobility in Prague. Through this cooperation we extracted from the model-space the dataset similar to the requested one. The model provides a representation of mobility during one average day in Prague in 2017. As such, the possibility of observing the development of the city over time was lost.

During the cooperation with the Department of Computer Science we also cooperated with the Prague Institute of Planning and Development, where we implemented the report from the agent-based model to the process of design decision-making in two case studies – projects for the reconstruction of the public space on the streets Revoluční and Klárov [23]. From this experiment, the need for mediation between the computer scientist and urban designers in the field of content and format of the purchased information became evident.

3.4. Case study acquisition

Active mobility and its influencing factors were analysed using data from the agent-based model [22]. We deliberately chose a narrower segment of the population to demonstrate that the data can be manipulated at different levels. For example, respondents with a specific mobility pattern can be selected from the data lake. The analysis provided data on pedestrian movement in Prague that was previously unavailable from other sources. This data work demonstrated that a database acquired through an app will provide valid and unique information about urban lifestyle.

4. OUTPUTS

This section has 2 chapters. Chapter 4.1 consists of the design of the smartphone application, its operating principle and marketing strategy for the local market. In this chapter, a wireframe of the application is developed and a database structure is proposed. The database would start to emerge and expand once the application is extended. Chapter 4.2 focuses on processing data from a database; a confirmation of the hypothesis. The research outcomes measure and evaluate the length of the walking trajectory of the Prague population with specific traffic behaviour and examine its influencing factors. Thus, it demonstrates that the dataset obtained through the application can be used as background information for mobility studies and the implementation of urban design concepts.

4.1 UrbanFit application design

The UrbanFit smartphone app was designed. UrbanFit provides its users a daily report of their routes and caloric expenditure in a simple graphical environment, as well as an overview of the time and route taken by the user in each movement mode over a longer timeframe in calendar mode. The application collects time-spatial stamps and accelerometer logs into its database at regular intervals. The combination of these data layers allows the detection of individual modes of movement based on the acceleration progression curve: walking, running, cycling, driving, train or public transport. It also monitors the resting phase. UrbanFit also uses data entered by the user and associated with their ID to calculate calorie expenditure: age, weight, height and gender (see Fig.2).

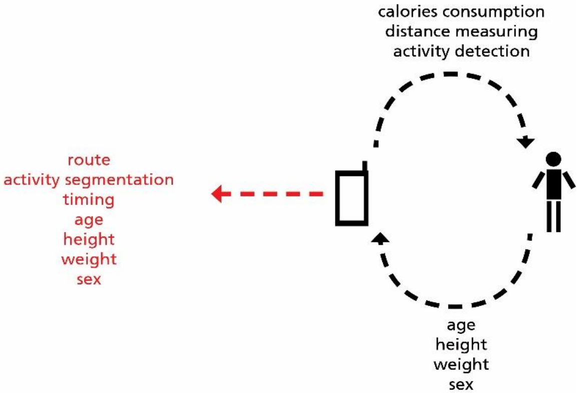


Figure 2 - Applications benefits

A wireframe structure, UI and UX of the app, a method for detecting the mode of movement, as well as a marketing strategy were designed for UrbanFit (see Fig. 3, Fig. 4). The data processed by the app is being stored with the users' consent in its raw form in a database that will be preserved for research purposes in the fields of architecture and urbanism.

Data acquisition through the smartphone application is highly non-obstructive to the respondent/user. On the contrary, it provides a benefit to users in the form of information about their daily physical activity and caloric expenditure. Users are also motivated to participate in the research by personal gain, so we assume that we will be able to obtain data from a longer timeframe than would be the case with standard traffic surveys.

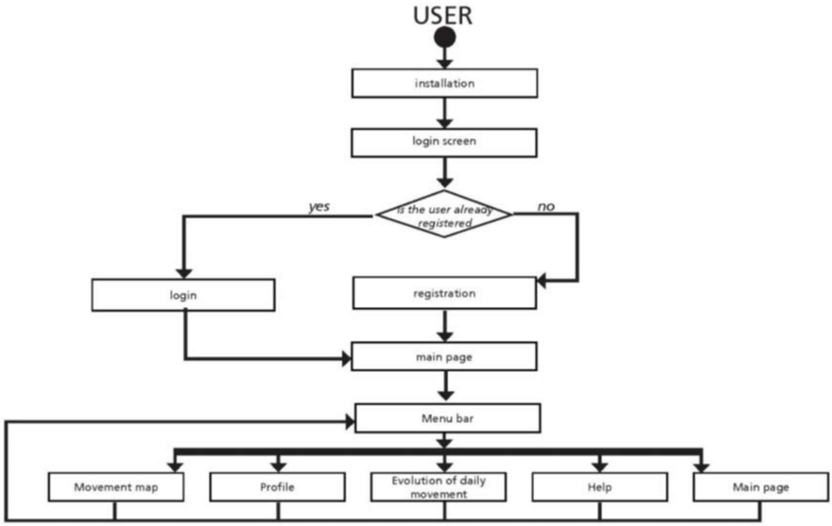
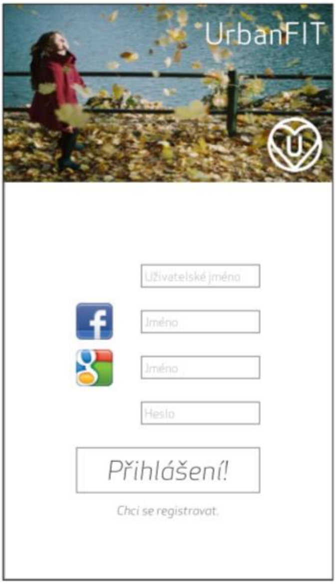


Figure 3 - Scheme of the application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Uživatelské jméno
Jméno
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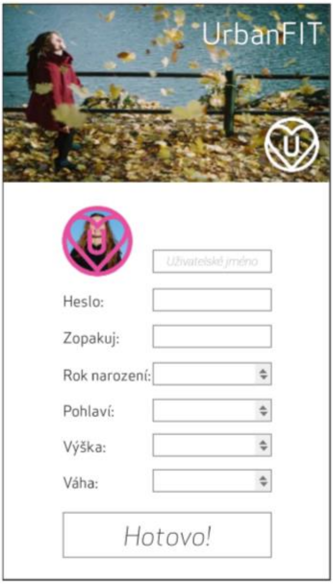
Přihlášení!
Chci se registrovat.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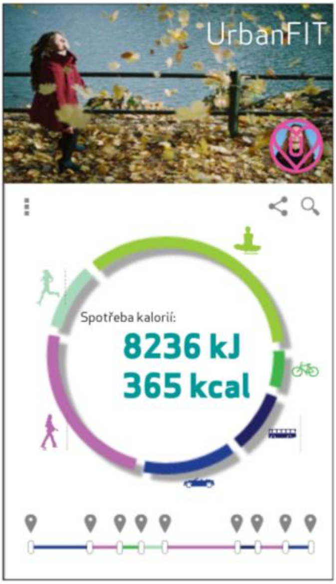
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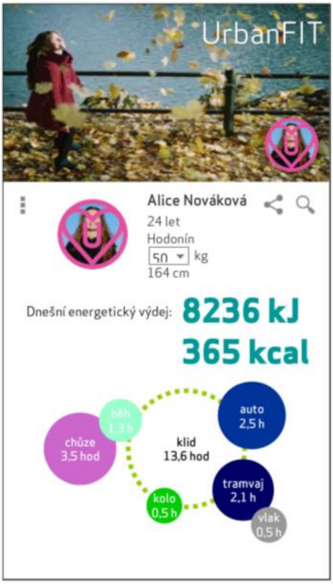
UrbanFIT
Alice Nováková
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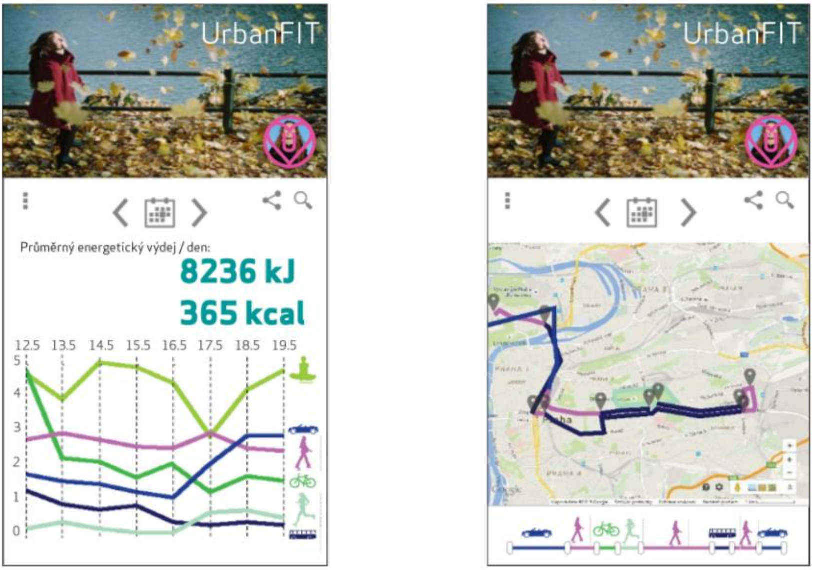

Figure 4 - Screens of the application

Sensing the transportation mode via the UrbanFit app also has its limits:

- Engaging users according to interest

The app is likely to be used primarily by individuals who are interested in a healthy lifestyle and active movement. Information about their caloric expenditure and small amount of active movement may motivate them to change their typical mobility mode [5].

- Data density

The smartphone application will be freely available for download on the web. The data is unlikely to have the same density in space. On the contrary, a higher data density in larger cities can be predicted. The assumption is that the spread of the app will replicate the spread of smartphone ownership in the population. A sufficient number of respondents/users moving in the addressed area will need to be checked before the data can be used. We do not expect to be able to use this data to address small units (streets, squares) where we will probably not achieve the desired density.

- The data will be subject to GDPR

The database and related data will be for internal use only: they will be stored in a special mode and password protected [19].

The use of the aggregated data will be possible in the fields of architecture and urban planning. The main potential for using the data in upcoming research are in the branches of:

- Walkability research [24] [25].
- Physical activity research [26] [27].
- A comparison of the spatial dependence of Body Mass Index [28] [29].
- Economic assessment of walking [30] [31].

The possibilities of using the data for public health and related urban planning purposes is demonstrated in the case study. The programming aspect of the smartphone application was not part of this dissertation as financial funding was unfortunately not available. As such, the application could not be launched and the data could not be realistically collected. Therefore, the validation of this thesis on the use of data from the smartphone app was carried out on a replacement dataset with similar characteristics.

4.2. Urban mobility and influence factors - Case study Prague

The case study provides insight into the movement and transport habits of the population of Prague and the Central Bohemian region. The study focuses on a segment of active mobility: walking and its influencing factors. Walking has been chosen as a key factor of urban life, the positive impact of which on social interaction, the local economy, environment and public health has been demonstrated by previous research.
In the case study, the unavailable data from the smartphone app was replaced with data from an agent-based multimodal mobility model of Prague and the Central Bohemian Region, which have similar structure and categories.
For the analysis, a demographic segment with a specific mobility pattern was selected from the model: agents who walk to and from the workplace daily or use public transport in combination with walking.

A sample of 88 547 agents aged 21-65 years was selected. For each agent, the routes associated with routine movement (i.e., the walking route from home to workplace and back) were extracted from the model, and the total walking distance per day was measured. The dataset from the agent-based model contained extra categories compared to the dataset from the app: the financial income of the agent, as well as their marital status and highest achieved education degree. Conversely, the model dataset lacked the weight and height categories that are required to determine BMI.
The average walking activity of Prague residents, represented in the model by agents with the above transport routine, is 3 106 m, which corresponds to 47% of the daily recommended walking activity according to WHO (see Fig.5).

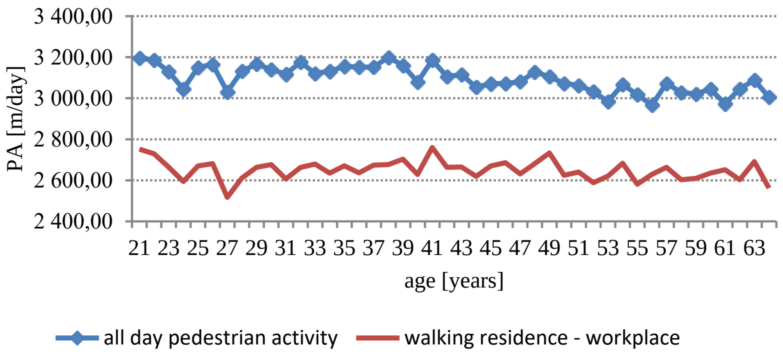

Figure 5 - Average daily PA according age

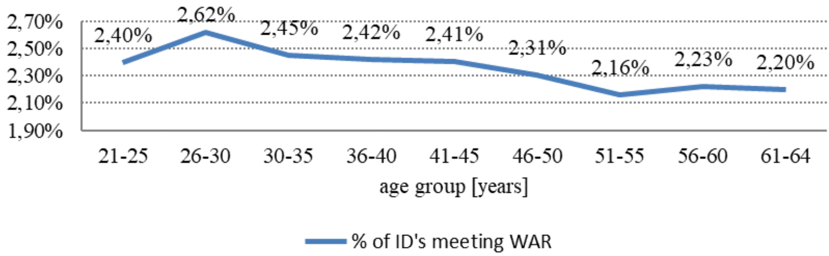

Figure 6 - Active population according to age

This distance decreases by 4 m per year of age for the population over 40 years of age. Only 2.16 - 2.62% of Prague residents, depending on age group, complete the recommended daily walking distance (see Fig. 6). Of the total daily walking route, 85.4% is comprised of routine trajectories — from home to work and back. Only 14.6% of the walking distance is associated with non-routine activities. It is both likely and cautionary that the segment of the population that drives to work daily and/or has a home office is missing out on a significant amount of daily walking activity.

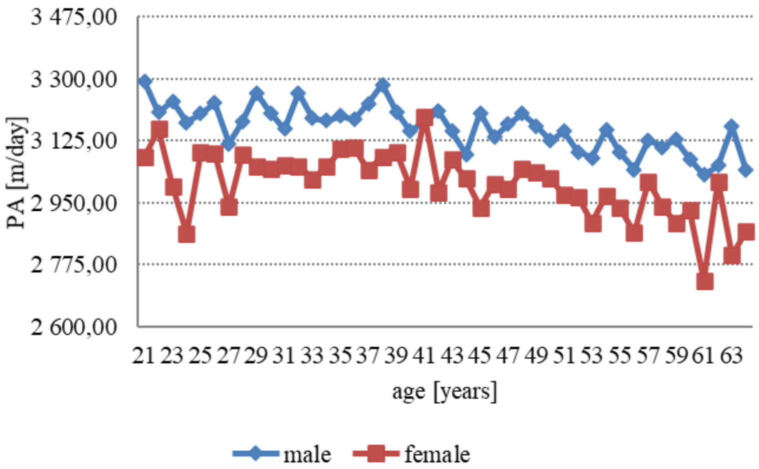

Figure 7 - PA according gender and age

Research has indicated differences in walking activity by gender, with the walking trajectory of women being 4.8% shorter than the average daily walking summary for men. Only 2% of women meet the WHO daily walking recommendations. Among men, the number of active individuals is higher — 2.7%. A difference was noted in the decrease in daily average walking activity — for men over 40 years of age it decreases by 3.87 m/year of age, for women by 4.7m/year of age (see Fig.7).

The case study also processed data from other categories that could not be obtained from the proposed UrbanFit application: financial income of the household member, the marital status of the agent and highest achieved education degree (see Fig. 8, Fig.9).
No association was found between income group and walking activity, although the differences between groups were statistically significant. The highest income group with an income of 1720 EUR or more per household member reported the highest walking activity, while the second highest income group with an income per household member of 1340 EUR - 1720 EUR showed the lowest walking activity. Similarly, the highest number of persons meeting WAR requirements was among the highest income group and the lowest number of physically active persons was in the second highest group.

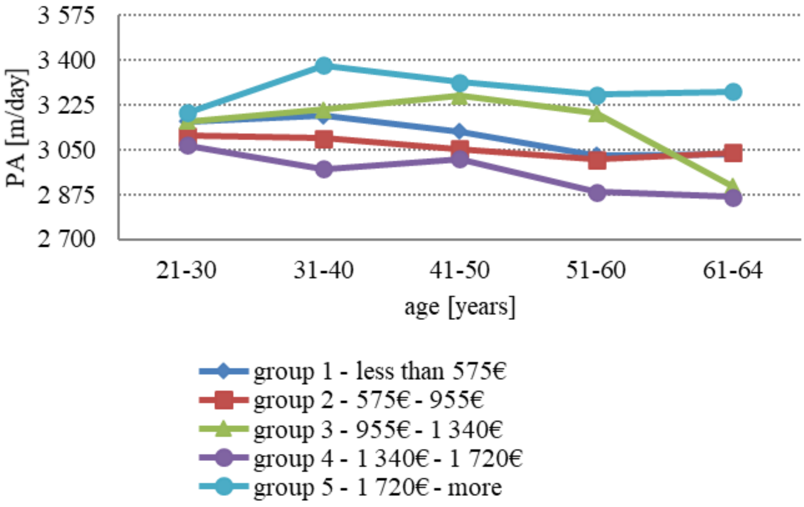

Figure 8 - PA according income group and age

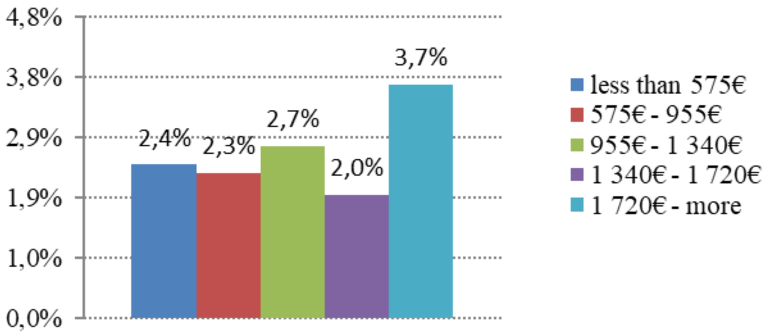

Figure 9 - percentage of WAR fulfilling agents according income group

Differences in walking activity between agents with different marital status are minimal, although statistically significant due to the sample size. Analysis was performed in the following groups: single, married, divorced, widowed. There were no statistically significant differences between groups when looking at the number of individuals meeting WAR.

Educational attainment has an effect on the walking activity of respondents. Higher education has been shown to be associated with lower walking activity. In looking for groups that cause the overall difference, we concluded that there are three groups of education levels. The first is made up of subjects with no high school diploma and those with primary education, the second is made up of only subjects with high school diploma and the third cluster is made up of the remaining groups of senior professionals and university graduates. The clusters differ significantly from one another, but the groups within a cluster do not differ.

5. CONCLUSION

Active movement is the blood in the veins of the physical city. Understanding urban life through the prism of the architect and urbanist, as defined by Jan Gehl, means observing the movement and actions of humans and understanding their motivations and goals.

Urban lifestyle is a multidisciplinary conceptual framework, which contains environmental quality, quality of life and human well-being [32]. Physical activity and active forms of population transport run like a thread throughout all these concepts. Physical activity is closely related to health, which is a major variable in quality of life, and is also central to well-being. Health and liveability are defined as two separate dimensions of quality of life. The liveability of places is also tightly connected with active modes of transportation. Whether the concept of safety or the socio-cultural environment, which are also mentioned in the literature as indicators of quality of life, cannot be created without pedestrians (i.e., people in active transport mode) [33].

Collecting data on active mobility, which forms an important foundation for social connection, local economy, is emission-free, environmentally friendly, and is also a key factor for public health in the prevention of lifestyle diseases, is of interest to municipal and state institutions as well as organisations dealing with urbanism, public space or public health. Based on this measured 'hard data', the impact of sustainable mobility projects can be assessed.

This work focuses on monitoring the pedestrian movement of the population. The movement activity of an individual, through the prevalence of smartphones and the ubiquity of internet connectivity, can be monitored through a simple smartphone application called UrbanFit. Traditional methods of collecting population mobility data, such as traffic surveys, are being replaced by digital measurements.
The dissertation proposes the structure, the way of functioning and the graphic design of the UrbanFit application. I also present a marketing method through which the application could be disseminated to users. The UrbanFit application is tailored to collect data with a specific structure. This dataset would then provide data for research in the field of urban planning and architecture.

From the dataset obtained through the UrbanFit smartphone app, not only time-spatial information can be extracted, but also data about the user's person — age, gender, height and weight, making it qualitatively more valuable than, for example, data taken from sensors installed in the city. The data from smartphone apps aims to be more accurate than information obtained through standard ways (i.e., through questionnaires answered by respondents, who often work with their own estimates). They represent a full-fledged alternative in quantitative research, which are respondent friendly (In this case the user of the application).

The dataset from UrbanFit can be combined further with available data layers to provide the basis for strategic decisions in the field of urban mobility and/or public health. They can also serve as a basis for the economic evaluation of urban projects. The data are collected by the smartphone application over a longer durational horizon and therefore provide an overview of the development of the monitored issue over time. They can also be used to compare the situation before and after the implementation of various scenarios.

I demonstrate the possibilities of working with these data through a case study of urban mobility in Prague and its influencing factors. Data from a multimodal agent-based model of urban mobility in Prague and the Central Bohemia Region are used for demonstration. Data from the agent-based model replaces the data collected from a smartphone application, the programming of which was outside the scope of the research.

The case study using data from the agent-based multimodal urban mobility model of Prague and the Central Bohemia Region focuses on the determinants that influence the pedestrian movement of residents. The study showed low pedestrian physical activity of Prague residents. For a selected segment of individuals between 21-65 years of age who commute daily to work by walking or by public transport, the average daily walking distance was found to be 3 106 m[4]. Of this, 85.4% consists of routine routes - i.e., from home to work and back. Only 14.7% of daily walking activity is linked to non-routine activities. There are gender differences in the walking activity of Prague residents - women's walking activity is 4.8% lower than the daily cumulative walking activity of men. Only 2% of women meet the WHO daily recommendations for walking activity. For men, the number of active

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individuals is higher - 2.7%. With each year over the age of 40, the average daily walking activity decreases by 3.87m for men and 4.7m for women.

Data from the agent-based model provides more categories than the data from the smartphone app. The analysis of the effect on walking activity was also done for the categories "marital status", "highest education attained", "financial income per household member", which could not be obtained through the app. On the other hand, it was not possible to conduct an analysis of the effect of BMI on the walking activity of the population using the data from the agent-based model.

Conducting the case study confirmed the hypothesis that smartphone data can be a powerful tool for urban planning and management. The evolution of pedestrian activity is an important indicator for a city, as its change brings with it consequences within other disciplines. From the data available to us fresh off the pandemic [34], it seems that physical movement and the motivation for it will be a big challenge for the next decade. Institutions responsible for planning the urban environment should reflect this data and tailor public spaces to promote a physical movement.

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SUMMARY

The increasing demand for data and smart solutions is one of the fastest growing sectors of human development. This trend is also noticeable in the fields of architecture and urban planning. Data on city processes are necessary indicators for the precise assessment of their current state and can be identifiers for evaluating changes.
Cities and the people living in them are constantly producing large amounts of data through sensors. Combining these data layers can reveal much about the way we use cities and how cities affect their inhabitants.

The mobility of individuals can be mapped through a simple mobile application that records the movement of users. The sensors contained in smartphones are a low-cost yet long-term source of information that, if properly interpreted, can be a dynamic indicator of city life.
I propose the structure and user interface of a smartphone application that uses the fundamental sensors of smartphones to capture data on the mobility of the application's users. The sensors in a simple sport-tester trace the time, type and route of movement around the city, which they report to a database. Based on additional data that users are willing to provide through the application, a stable source of information about users' lifestyles is established. The app for calculating users' caloric expenditure requires information about their age, height, weight and gender. The collected data can be used for developing a long-term understanding of urban life. This dissertation presents practical applications of this particular dataset that are potentially capable of providing data-driven arguments for strategic decision-making on urban and settlement development. This theoretical part of the thesis can then be applied to other datasets of a similar structure.

I demonstrate the possibilities of working with these data through a case study of urban mobility in Prague and its influencing factors. Data from a multimodal agent-based model of urban mobility in Prague and the Central Bohemia Region are used for demonstration. Data from the agent-based model replaces the data collected from a smartphone application, the programming of which was outside the scope of the research.
The case study using data from the agent-based multimodal urban mobility model of Prague and the Central Bohemia Region focuses on the determinants that influence the pedestrian movement of residents. The study showed low pedestrian physical activity of Prague residents. For a selected segment of individuals between 21-65 years of age who commute daily to work by

walking or by public transport, the average daily walking distance was found to be 3 106 m[5]. Of this, 85.4% consists of routine routes - i.e., from home to work and back. Only 14.7% of daily walking activity is linked to non-routine activities. There are gender differences in the walking activity of Prague residents - women's walking activity is 4.8% lower than the daily cumulative walking activity of men. Only 2% of women meet the WHO daily recommendations for walking activity. For men, the number of active individuals is higher - 2.7%. With each year over the age of 40, the average daily walking activity decreases by 3.87m for men and 4.7m for women.

Data from the agent-based model provides more categories than the data from the smartphone app. The analysis of the effect on walking activity was also done for the categories "marital status", "highest education attained", "financial income per household member", which could not be obtained through the app. On the other hand, it was not possible to conduct an analysis of the effect of BMI on the walking activity of the population using the data from the agent-based model.
Unlike the data provided by the users of the app, the agent model data only provides insight into one typical day. Therefore, it is not possible to read from them the long-term evolution of the walking phenomenon and the influence of the urban fabric, which could be tracked through the dataset from the smartphone app.

Through this case study, it was achieved to confirm the thesis that indicates the smartphone app data as a source of information needed for projects and strategies for the development of healthy cities with a high quality of social life.

Keywords: *physical activity, walking, smartphone, app application, data acquisition, active mobility, smart cities*

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[5] *World Health Organization recommends walking aktivity of 10 000 steps a day (aproximately 6,6 km).*

RESUMÉ

Zvyšující se poptávka po datech a chytrých řešeních je jedním z nejrychleji rostoucích odvětví vývoje lidské činnosti. Tato tendence je znatelná také v oblasti architektury a městského plánování. Data o procesech ve městě jsou potřebným ukazatelem pro přesné hodnocení jejich stávajícího stavu a dokáží být identifikátorem pro hodnocení změn.
Města a lidé v nich produkují prostřednictvím sensorů neustále velké množství dat. Kombinací těchto datových vrstev můžeme odhalit mnohé o způsobu, jakým města využíváme a jak města na své obyvatele působí.

Mobilitu jednotlivců je možné mapovat prostřednictvím jednoduché mobilní aplikace, která zaznamenává pohyb uživatelů. Sensory obsažené ve smartphonech jsou nízkonákladovým a zároveň dlouhodobým zdrojem informací, které při správné interpretaci mohou být dynamickým indikátorem života ve městě.
Navrhuji strukturu a uživatelské rozhraní aplikace pro smartphony, která využívá základní sensory smartphonů k získávání dat o mobilitě uživatelů aplikace. Sensory v jednoduchém sport-testeru mapují čas, způsob a trasu pohybu po městě, kterou zaznamenávají do databáze. Na základě dalších údajů, které uživatel je prostřednictvím aplikace ochoten poskytnout, vzniká stabilní zdroj informací o životním stylu uživatelů. Aplikace pro výpočet kalorické spotřeby od uživatele vyžaduje informace o jeho věku, výšce, váze a genderu. Získaná data lze využít pro dlouhodobé poznávání městského života. Práce prezentuje praktické možnosti využití této konkrétní datové sady, které jsou schopny poskytovat daty podložené argumenty pro strategická rozhodování o rozvoji měst a sídel. Tato teoretická část práce může být následně aplikována na další sady dat o stejné struktuře.

Možnosti práce s daty demonstrujeme na případové studii městské mobility v Praze a jejích vlivových faktorů. Pro demonstraci jsou použita data z multimodálního agentového modelu městské mobility v Praze a Středočeském kraji. Data z agentového modelu nahrazují masivně získávaná data ze smartphone aplikace, jejíž programovací část není součástí výzkumu.
Případová studie za použití dat z agentového modelu multimodální mobility Prahy a Středočeského kraje se zaměřuje na vlivové faktory, které ovlivňují pěší pohyb obyvatel. Studie prokázala nízkou pěší fyzickou aktivitu Pražanů. U vybraného segmentu jedinců mezi 21-65 lety, kteří denně dojíždějí do práce městskou hromadnou dopravou, bylo zjištěno průměrné denní penzum chůze 3

106 m[6]. Z toho 85,4% tvoří trasy rutinní – tedy z domova do místa výkonu práce a zpět. Jen 14,7% denní pěší aktivity je svázáno s aktivitami nerutinními. V pěší aktivitě Pražanů se projevily také genderové rozdíly – pěší aktivita žen je 4,8% nižší, než denní souhrn chůze mužů. Jen 2% žen splňuje denní doporučení WHO stran pěší aktivity. U mužů je počet aktivních jedinců vyšší – 2,7%. S věkem se od 40-ti let se s každým rokem snižuje denní průměrná pěší aktivita u mužů o 3,87 m, u žen o 4,7m.

Data z agentového modelu poskytují vice kategorií, než data ze smartphone aplikace. Analýza vlivu na pěší aktivitu byla provedena i u kategorií "rodinný stav", "nejvyšší dosažené vzdělání", "finanční příjem na člena domácnosti", které by prostřednictvím aplikace nebylo možné získat. Naopak na datech z agentového modelu nebylo možné provést analýzu vlivu BMI na pěší aktivitu obyvatelstva.
Na rozdíl od dat, poskytovaných uživateli aplikace, data z agentového modelu poskytují vhled jen do jednoho typického dne. Není z nich tedy možné vyčíst dlouhodobý vývoj fenoménu chůze a vlivu městské struktury, který by bylo možno sledovat prostřednictvím datasetu ze smartphone aplikace.

Prostřednictvím případové studie se podařilo potvrdit tezi, která indikuje data ze smartphone aplikace jako zdroj informací, potřebných k projektům a strategiím pro rozvoj zdravých měst s vysokou kvalitou společenského života.

Klíčová slova: *fyzická aktivita, chůze, smartphone, aplikace, získávání dat, aktivní mobilita, chytrá města*.

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[6] *World Health Organization doporučuje denní pěší pohybovou aktivitu 10 000 kroků, tedy cca. 6,6 km.*