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Modelling of the suburbanisation process
in the Poznań metropolitan area
using artificial neural networks
and cellular automata
– summary of PhD thesis

Modelowanie procesu suburbanizacji
w aglomeracji poznańskiej z wykorzystaniem
sztucznych sieci neuronowych
i automatów komórkowych

Dissertation written under the direction of
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PhD thesis goals

The new social and economic environment created in Poland after 1989 has contributed to significant transformations of Polish cities. Two trends have prevailed in this process: closing the gap which emerged during the communist regime and Polish cities joining globalisation which process has been gathering momentum since late 20th century. Mass suburbanisation is a phenomenon new to Polish cities. While in the United States and Western Europe research of migration to the suburbs has been a very important issue discussed by representatives of various fields of science, Polish researchers tend to discuss the subject relatively infrequently. What is more, domestic publications on cities' spatial expansion only revolve around its description rather than provide explanation of the related mechanisms. Non-existent research on spatial transformation of Polish metropolitan areas has been the chief goal for tackling the subject.

This thesis' main goal is to survey the usefulness of cellular automata and artificial neural networks in modelling the process of suburbanization of the Poznań metropolitan area. This goal is of empirical, theoretical and application-related nature. In the theoretical aspect, this dissertation aims at constructing a hybrid model combining automata and artificial neural networks to analyze the issues of suburbanization in Poland's social and economic conditions.

The dissertation's empirical aspect is related to identifying suburbanization-conditioning factor: the reasons why people abandon Poznań and the preference in selecting place of residence (push and pull factors). This is accompanied by an analysis of the influence of changing place of residence on transport behaviour patterns.

The application aspect refers to the construction of the hybrid model's algorithm of universal nature to be employed for modelling any given metropolitan area growth. The analyses included in this dissertation: computer simulation, field studies and questionnaires, have also been aimed at reinforcing the theoretical and empirical fundamentals of Poznań metropolitan area's spatial planning. Moreover, with this dissertation in mind, a computer software "PozSym" was originated for cellular automata simulations; the software's architecture allows for applying other metropolitan areas in growth modelling.

The spatial range of the Ph.D. thesis includes the Poznań metropolitan area defined as the city of Poznań and Poznań county between 1990 and 2005.

Poznań suburbanization characteristics

The Poznań metropolitan area has been witnessing a self-sustaining suburbanization process. The identified features characteristic of suburbanization processes include a drop in the central city's (Poznań) number of inhabitants accompanied by a growing number of people within the whole metropolitan area, a negative migration balance in the central city accompanied by a positive migration balance in administrative units located around the city and a dynamic growth of housing development outside the city limits. More and more frequently, Poznań suburbs have been witnessing the characteristic features of urban sprawl. Some new estates are established on areas where a connection with the existing settlement network structure is non-existent. These estates are devoid of services while providing a public transport system in the future will be very difficult or quite impossible due to the location and the existing road system. The spatial separation of the functions refers also to shops and public utility enterprises. The metropolitan area attracts a growing number of single-function facilities, e.g. a shopping centre in Swadzim and Adam Mickiewicz University campus "Morasko". The car is the only means of transport ensuring efficient and rapid transfer between these facilities.

The time under scrutiny (1990-2005) could be divided into three characteristic time intervals of suburbanization. The first (mid-1990s) consisted in the inhabitants' translocation resulting from completing large investments in multi-family housing development commenced back in the 1980s with the chief investment locations including Czerwonak commune and the towns of Murowana Goślina and Swarzędz. The second interval occurred in the mid-1990s when the housing market witnessed a downturn: the number of flats for sale dropped by 50% against 1990, hitting in 1995 the lowest level in the period in question. The housing development slowdown triggered off a weaker population growth in Poznań communes. The slow population growth held true for all Poznań communes and the slow rate persisted until 2000. Since the turn of the centuries, the number of inhabitants in the satellite towns has been growing rapidly. The preferred locations are in the west of the city and include communes bordering with the city of Poznań. In the time under survey, Poznań's population would decrease, primarily in the city centre. The growth in housing facilities in the time in question was more rapid than the growth in the metropolitan area's population. In general, this results in a drop in the number of individuals per a single flat. The decline in the number of inhabitants per one flat in Poznań has continued since 1990. In the Poznań communes the

phenomenon has persisted since the turn of the centuries.

The assumption's theoretical model and the results

In forecasting the development of Poznań's suburbs in the 2020 time perspective, the hybrid model has been employed, combining cellular automata and artificial neural network. Figure 1 presents the model's operating algorithm.

Employment of the hybrid model in the research process was broken down into two stages. Stage one consisted in an analysis of factors affecting the attractiveness of settling within the Poznań metropolitan area, followed by a simulation with artificial neural networks. The settlement-related attractiveness was established by means of artificial neural networks for each main area (each cell) into which the Poznań metropolitan area was divided. Among over thirty analysed factors affecting settlement attractiveness, the proximity of railway stations and the soil valuation class proved of greatest importance. The attractiveness analysis further revealed the significance of the proximity of water and protected areas. The prevailing factors discouraging settlement included the proximity of airports and military training areas. After 2000 a single, strongly discouraging factor was the proximity of the existing development.

The cell automat whose rules were developed by means of artificial neural networks with reference to observations of spatial changes in population density in 1990, 1995, 2000 and 2005 was applied in forecasting simulations for 2010, 2015 and 2020. Despite the initial reservations about the selection of the parameters of the function of transition of the cell automat through an artificial neural network, the simulations indicated a significant drop in population density in the centre of Poznań city as well as in towns located in the vicinity of Poznań and a further growth in the number of people living around Poznań although the growth was weaker than indicated by the Chief Statistical Office (GUS). This growth took place mainly in rural areas of the adjacent communes. In successive simulations relying on Poznań data from 2000 and 2005 and broken down into community councils for 2010, 2015 and 2015, the cell automat revealed a definitely bigger decline in the number of inhabitants in the city centre. This decline tended to be very diversified in the city centre, unlike in the former research exercise. It was also proved this way that population translocation will be more intense in suburbs within the Poznań city limits in comparison with the first simulation. Both simulations indicate a growing rate of suburbanization.

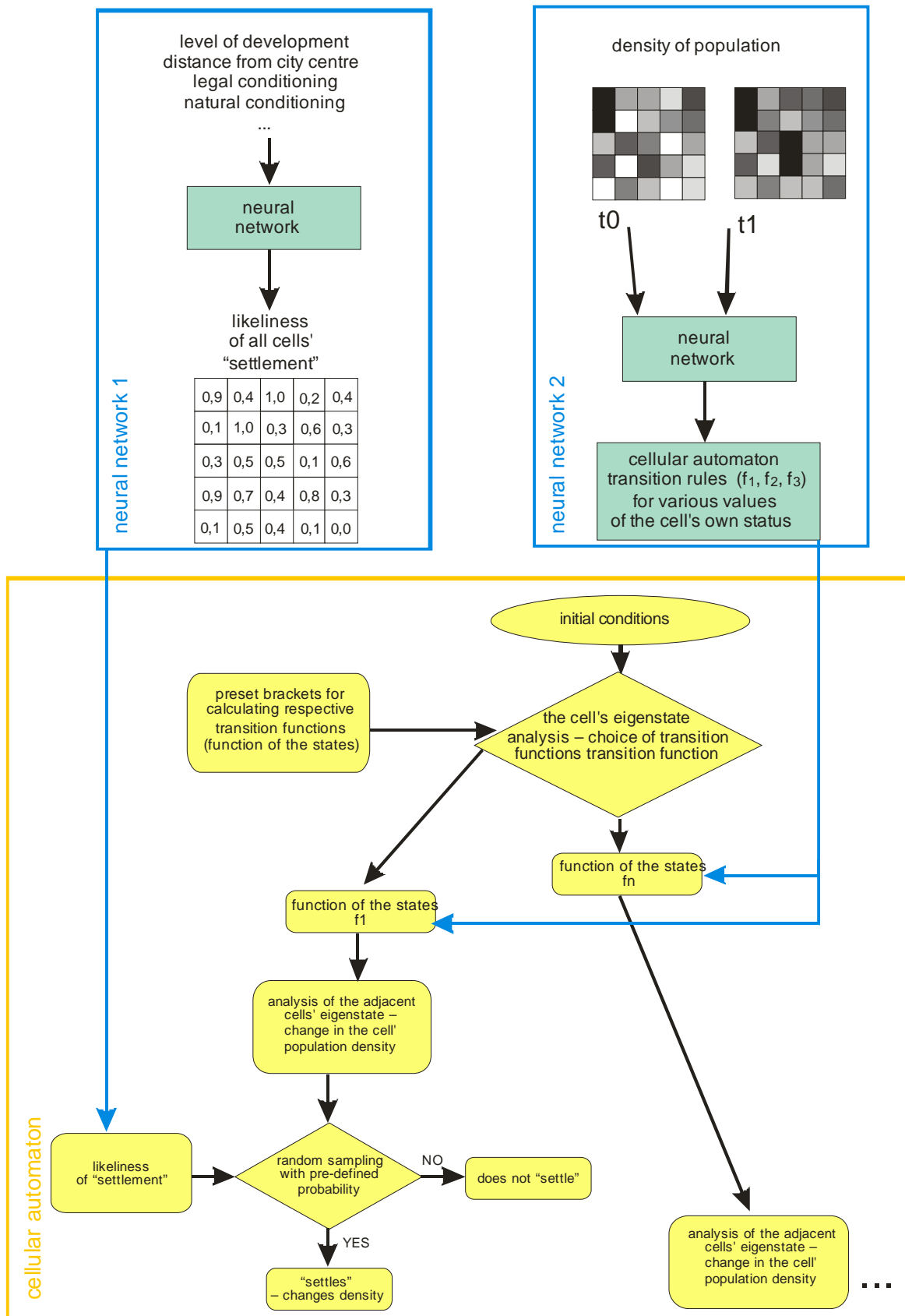


Figure 1
The hybrid model's operating algorithm

Source: own compilation

Statistical survey results

The research was conducted in the other half of 2006 and embraced nearly 600 persons. A total of 562 correctly filled questionnaires were obtained from people who had changed their residence in the years 1989-2006 and now live in the suburbs defined as communes making up Poznań county. There was one questionnaire per household. The biggest group included new inhabitants of the suburbs who had lived in the city before moving - 397 respondents (70.6%), followed by those who had already lived in one of the communes of Poznań county - 85 respondents (15.1%). The remaining group embraced people who had lived outside the Poznań metropolitan area, including abroad. A decided majority of the respondents (79.8%) moved to the suburbs after 1999. The aim of the research was to identify reasons for the migration to the suburbs and the resultant changes in transport behaviour patterns.

Most of the respondents (55.3%) were females. One in five was aged 30-34, 14.6% were aged 25-29, 13.3% were aged either 35-39 or 40-44, while one in ten respondents was aged 18-24 or 35-49. Respondents 50-54 years of age accounted for 9.1%, and those older than 54 represented 8.7%. While a definite majority (55.2%) had tertiary education, among those that had first lived in the county (42.9%) the greatest proportion had secondary education. On the other hand, among those who had migrated from the city, 59.6% had tertiary education and 35.3% had secondary schooling. Working individuals made up three-fourths of the respondents. One in ten respondents was a student. Pensioners and housewives accounted for 6.7% each, and the unemployed for 1.4%. Worth emphasising is the fact that 4.1% of individuals who gave their status as 'worker' also ticked 'student'.

The average household of the new suburban residents consisted of 3.28 persons, slightly below the average for Poznań county. Four- (35.5%) and three-member (30.9%) households predominated, with nearly half of them devoid of individuals aged under 18. One in four households had a monthly per capita income of 1,001-1,500 PLN, and there was a similar proportion of those with 501-1,000 PLN (EUR 127.80 - 255.10)¹. Another group (19.8%) included households with per capita income of 1,501-2,000 PLN (382.91 - 510.20 EUR), followed by 15.6% of those with per capita income of over 2,500 PLN (637.76 EUR). Not only was the real income level comparatively high, but so was the subjective assessment of

¹ The mean exchange rate in August-October 2006 was 1 EUR = 3.92 PLN

one's material situation. There were 7.6% of respondents who regarded their position very good and 43.9% who claimed it was good. 42.3% of them described their level of affluence as average, 5.2% as low, and only 0.5% as very low.

Among the new suburban residents the motorisation rate amounted to 454.8 cars per 1,000 persons, markedly higher than Poznań county's average (402.0 cars/1,000 population) and Poznań city's average (403.4 cars/1,000 population).

These characteristics show that migrants leaving cities are primarily affluent, economically active people in their prime. The demographic situation of the families (e.g. the number of children) does not depart significantly from the general national tendencies.

The chief reason for migrating to Poznań suburbs was inadequate housing space. A large majority of the respondents referred to it as too small. The decision about moving out was further affected by a high noise level in the former place of residence as well as an improved financial situation. A change in place of residence also resulted from a high cost of living and air pollution in Poznań as well as a change in family situation. Relations with neighbours and safety in the former place of residence were of little importance.

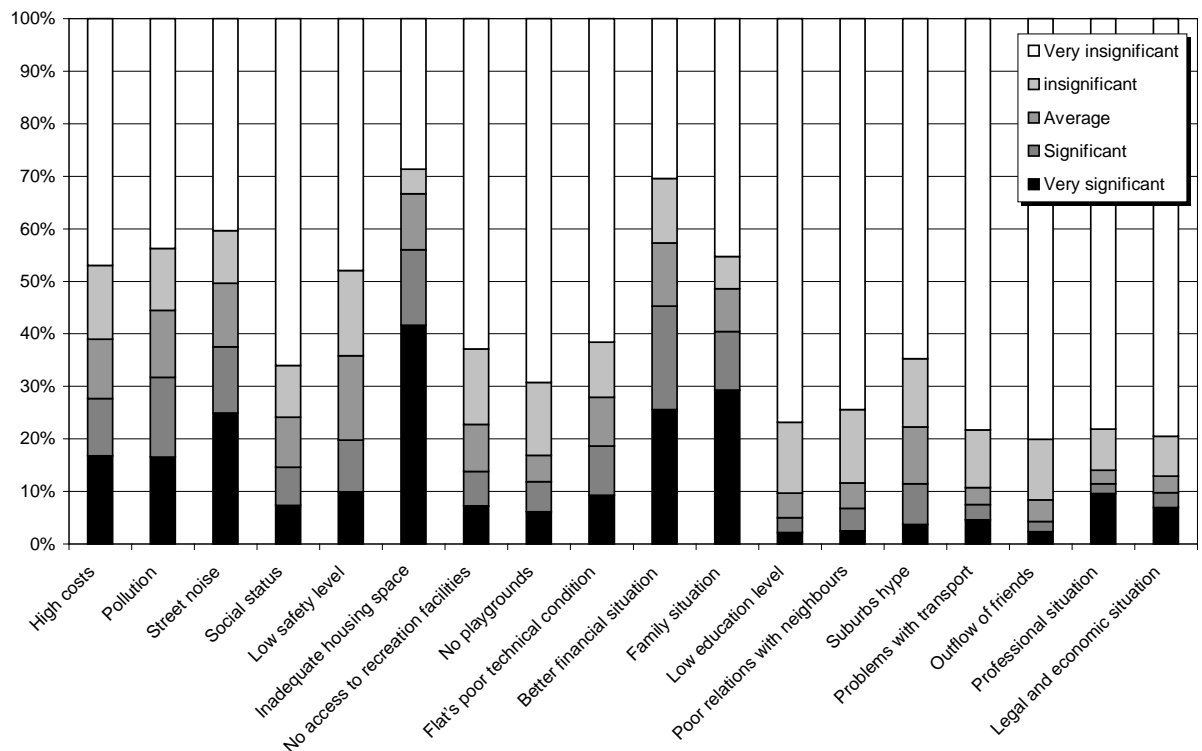


Figure 2
Reasons why respondents moved out from their previous place of residence; respondents in total.

Source: own compilation

When choosing a new place of residence, Poznań dwellers would consider first and foremost the natural environment values. The most appreciated benefits included silence, clean air, proximity of green areas and interesting surrounds. These factors tended to be more important than financial issues. Easy access to Poznań city centre by car proved more significant than the price of purchasing or building a house while public transport solutions proved of less importance. Poznań inhabitants claimed that when choosing their new place of residence, they were not susceptible to the developers' marketing activity or their family members or friends formerly migrating to suburbs.

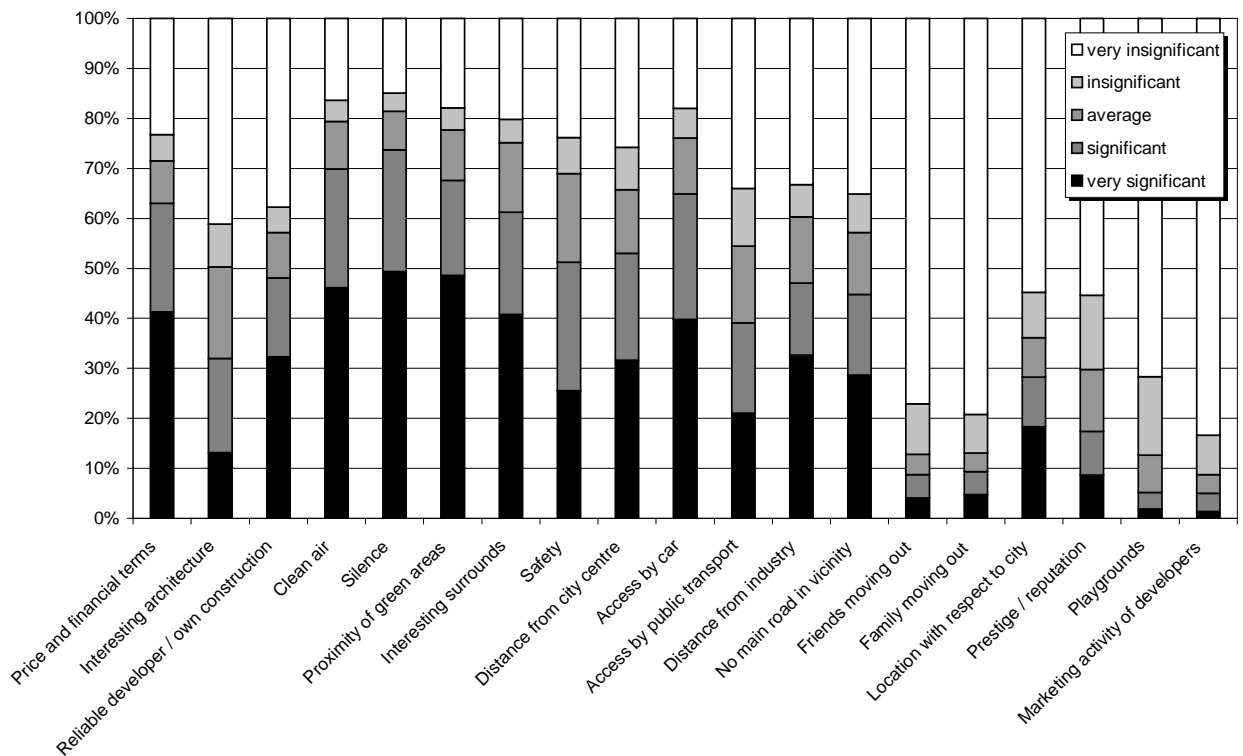


Figure 3
The influence of factors on choosing a specific location for a new place of residence; respondents totally.

Source: own compilation

Nearly all individuals who had moved out of Poznań claimed that they were satisfied with the decision. The biggest benefit of living in the suburbs was improvement of living conditions. The state of the environment around the place of residence also tended to enhance dramatically, and so did access to green areas. Moving out adversely affected access to cultural, educational institutions, shops and healthcare facilities.

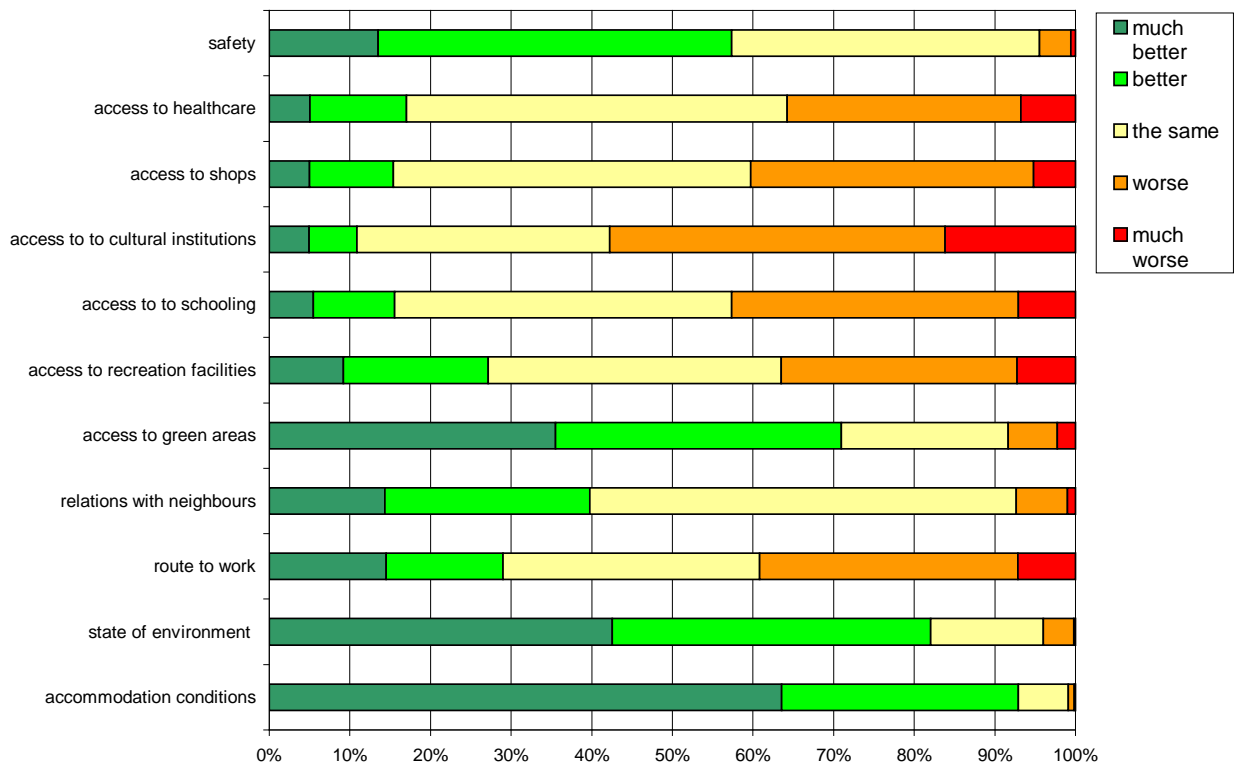


Figure 4
Change in living conditions in comparison with the former place of residence; respondents in total.

Source: own compilation

The influence of suburbanization on the change to transport behaviour patterns.

The decision to change one's place of residence triggers off changes to public transport solutions. The new suburbanites tend to be much more reliant on their cars than when they lived in Poznań. While not all of them became regular drivers, moving out of the city nearly always involves declining the Poznań Municipal Transport Company's services (MPK). Suburbanites seem to be forced to resort to their cars. The number of car commuters is larger than suburbanites willing to drive their vehicles if given a choice of means of transport. Non-existent attractive offer of public transport contributes to the car's growing share in transport tasks division which, in turn, contributes to deteriorating living conditions in central Poznań. This is one of the reasons for migrating to suburbs.

Table 1.
Transport behaviour before and after change of residence and the preferred mode of locomotion if given a choice of means of transport.

Means of transport	Before removal	After removal	Preferred commuting vehicle
Persons coming from Poznań			
Car	46.00%	69.20%	64.90%
Suburbs bus service	2.50%	2.80%	7.10%
Rail	0.00%	1.00%	1.80%
MPK Poznań	26.00%	3.40%	13.40%
Bicycle	1.30%	1.60%	8.70%
On foot	6.80%	1.60%	4.10%
Several means of transport	17.40%	20.50%	not applicable
Persons living in suburbs also formerly			
Car	38.10%	53.40%	63.70%
Suburbs bus service	10.10%	4.85%	7.70%
Rail	9.50%	8.45%	5.50%
MPK Poznań	2.40%	1.80%	3.30%
Bicycle	3.00%	1.80%	11.00%
On foot	16.70%	7.25%	8.80%
Several means of transport	20.30%	22.45%	not applicable

Source: own compilation

The conceptual model

The most important impulse for urban development has been the socio-economic change that took place after 1989, including liberalisation of building regulations and making the purchase of a car a much more readily available possibility. Still, the number of persons moving to the suburbs was not very high until the early 1990s. It was then that the number of cars started to rise, thus contributing to mounting transport problems and the ensuing deterioration of environmental conditions. This, in turn, has been the direct cause for many Poznań residents to migrate to the suburbs. The change of place of residence results in a higher proportion of persons using the car as the means of transport. The growing number of journeys by car has been topped with longer commuting routes after migrating to the suburbs. All this leads to a growing automobile congestion in the city and the surrounding communes. This, in turn, contributes to further deterioration of the state of the environment, especially in the city centre which induces more individuals to change their place of

residence. This triggers off a change in their transport behaviour patterns... The city becomes increasingly sprawled. A model of this process is presented in Figure 5.

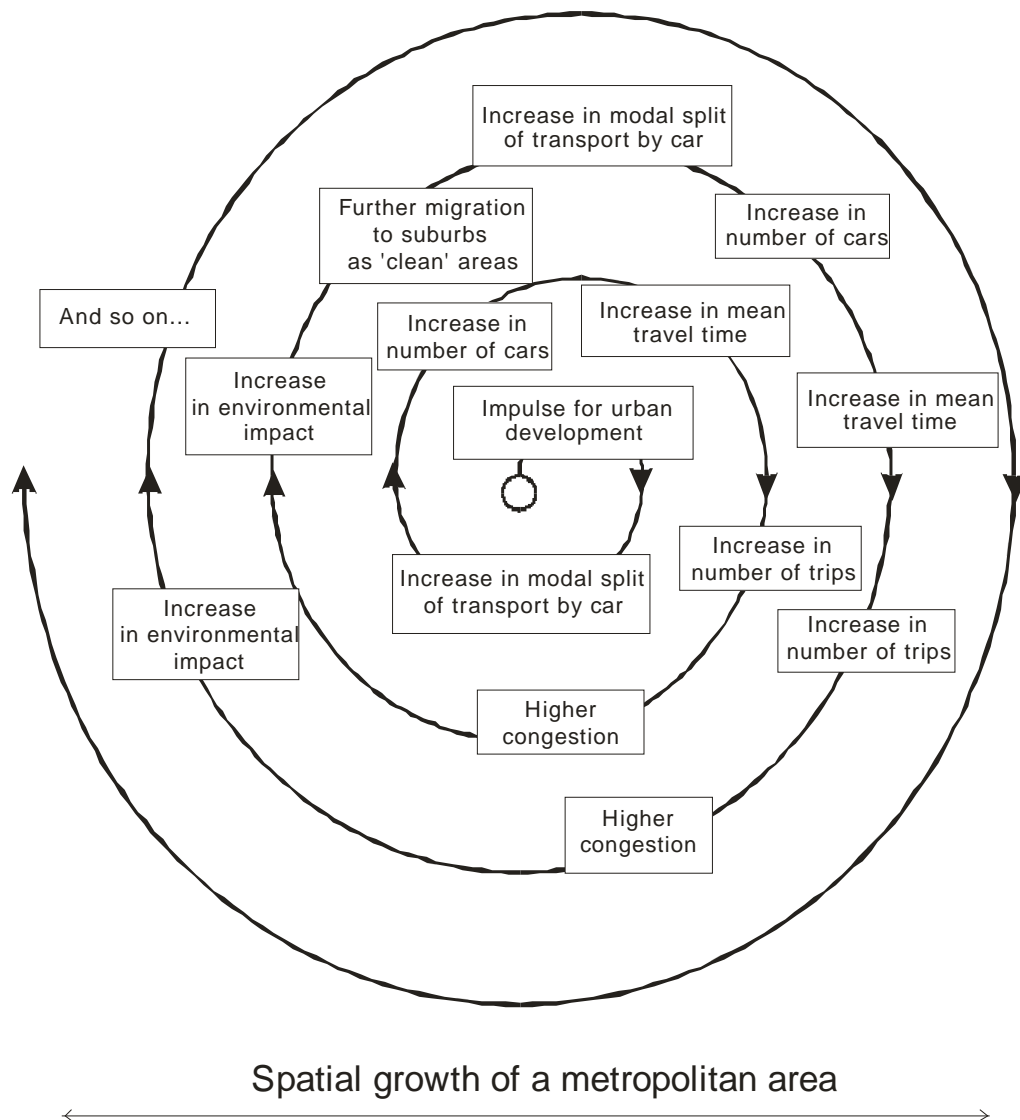


Figure 5
Connection between the development of suburbs and growing traffic congestion
Source: own compilation

The de-concentration has transport and environment-related dimensions as shown in the reflections above and many more: social, cultural and economic. The latter seems to be the most important: on the one hand, spatial development of the suburbs boosts commuting costs, and thus the costs of living; on the other, the depopulating tenement houses or blocks of flats lead to ever worsening living conditions and increasing costs of rent. The owners, unable to meet operating costs or find new tenants, often raise the rent for the remaining lodgers, thus forcing another group of people to move, usually to the suburbs. As a result, the old districts are settled by groups of short-term occupiers (e.g. students). They are not interested in

improving the quality of the flats and houses as it leads to rising rent costs. They are trapped in a vicious circle. The growing costs of living in the city centre offsets the effects that the rising costs of suburban living, e.g. travel costs, could have for curbing the development of the suburbs (see: Figure 6).

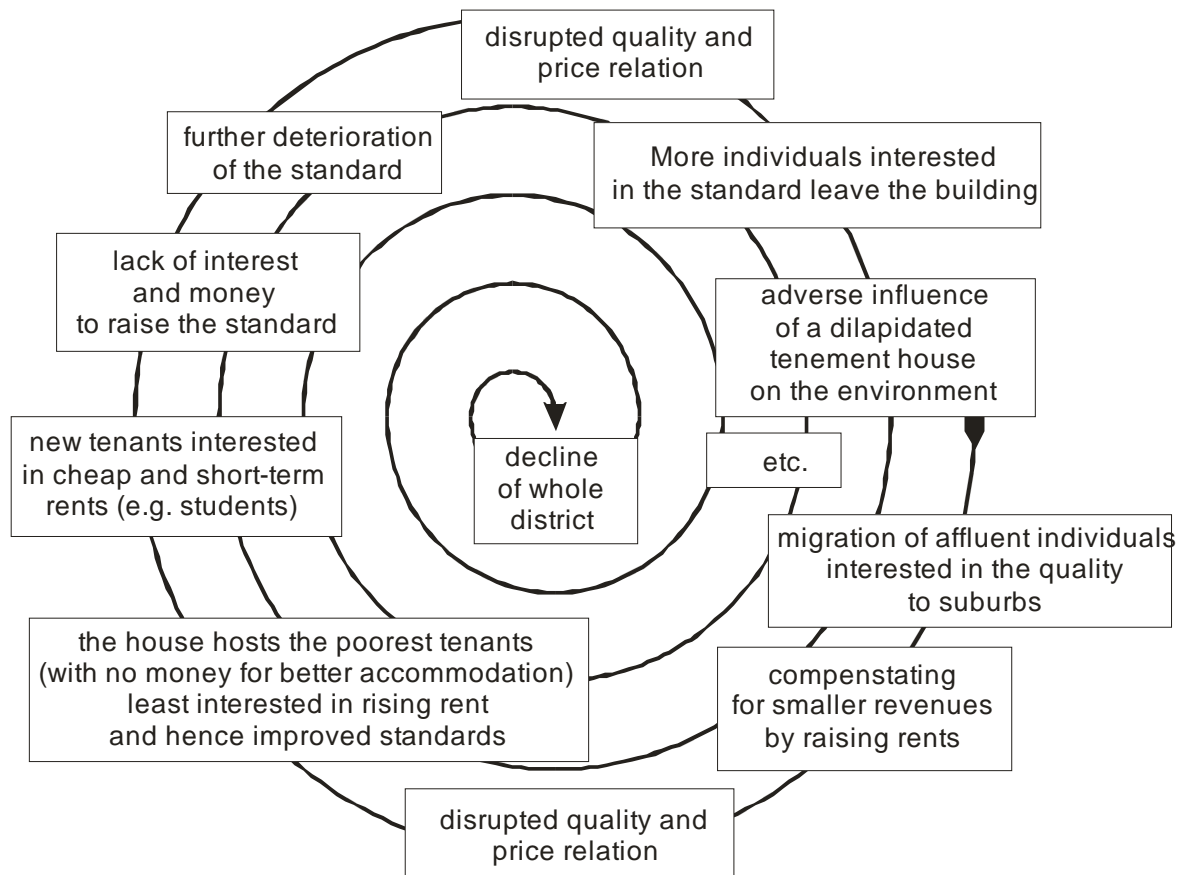


Figure 6
The relation between the more affluent social groups' migration to suburbs and decline of a district.

Source: own compilation

Summary

The Poznań agglomeration has witnessed the phenomenon of suburbanization. The chief reasons for moving out of the city include inadequate housing conditions in the initial place of residence and low quality of the city centre environment. In the suburbs the inhabitants look primarily for silence and peace.

Since the turn of the centuries, migration to the suburbs has intensified. The spatial forms of suburb development raise special concern as they are remote from Western Europe's

best practice and contribute to the suburbanites' dependence on their cars. These processes pose a serious threat to the Poznań agglomeration's sustainable development.

The research results confirm the hybrid model's high potential in the suburbanization process simulations not only in the Poznań metropolitan area. This work leads to the conclusion that with properly analysed factors and parameters, the model may prove a useful tool in analyzing and forecasting the development of other Polish and global metropolitan areas. However, it will take many experiments to make the model a more detailed one.