CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FACULTY OF ENVIRONMENTAL SCIENCES

MASTER THESIS

Transportation: A Leading Driver of Urban Sprawl in Villages Outside Prague, Czech Republic

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Prague 2014

Declaration:

I hereby declare that I am the sole author of the thesis entitled: "Transportation: A leading driver of urban sprawl in the villages surrounding Prague, Czech Republic." I marked all quotations and any literature used is stated in the attached list of references.

In Prague on 23.4.2014

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Acknowledgements

I would hereby like to thank my supervisor Ing. Kateřina Zímová for her wise, everlasting and reliable support. Ing. Zímová is beyond intelligent, kind and accommodating that without her supervision this thesis wouldn't be as is. I would also like to thank the rest of my supervising team, Ing. Vratislava Janovská and Elizabeth Brabec for their time, effort and inputs that were fundamental to this project's success. Also to the generous Vojtěch Barták for his timely assistance and brilliant contributions.

Lastly I would like to thank my family, friends, and significant other for their endless support that was truly essential to this thesis' completion.

In Prague on 23.4.2014

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Abstract

Urban sprawl is a phenomenon that has been changing the face of cities globally for decades. However, in the Czech Republic urban sprawl has been hindered for a number of years due to a vast history under authoritative rule. Trends of substantial suburbanization only trace back to the mid 1990s in the Czech Republic; where as in the United States they go back to post World War II years. For this reason, urban sprawl in the Czech Republic has developed with a substantial different nature than that of the United States'. One significant difference is the pattern in which sprawl has developed. In the Czech Republic, sprawl has taken a spotted configuration, with new developments growing from existing villages.

Another outstanding difference of Czech urban sprawl, and the main focus of this thesis study, is the influence of public transportation networks on urban expansion. This again can be traced to the later time period of suburbanization trends. The Prague area already had a substantial, well-planned and extensive public transportation system in place in the late 1990s and early 2000, when urban sprawl began to accelerate. Transit buses and trains aided the feasibility of living further from the city. The data from this study seeks to prove the influence of public transportation on urban sprawl in villages within a 50-kilometer buffer surrounding Prague.

Keywords: Urban Sprawl, Urban Expansion, Suburbanization, Prague, Czech Republic, Public Transportation

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1. Introduction

In the Czech Republic urban sprawl has become a major phenomenon that is changing its major cities and re-forming the border communities. In year 2000, the capital city, Prague, dropped by approximately 6,000 inhabitants. Of this 6,000 figure, ultimately a third were residents leaving the city (Buff, 2003). This is the beginning of urban sprawl for the Czech Republic.

Urban sprawl in the Czech Republic has been a more modern trend, with most developments being realized after the fall of communism. In 2002, the Prague area housing stock increased by 53.4 percent, as the Czech Republic continued a stable population. In 2001, of all buildings under construction, only 3.2 percent were non-residential (Buff, 2003). As the Czech News Agency and interviewer in the Czech weekly news magazine, Respekt, state, "Since the collapse of the communist regime in 1989, thousands and thousands of Czechs have fulfilled their dream [of owning their] own cozy house outside the urban tumult in the wild that is yet close to the 'civilization,'" (ČTK, 2008). Respekt touches upon the *Czech dream* and preference for suburban life, of which can be said partially stimulated urban expansion in the countryside areas surrounding Prague.

With the vast amount of sprawl commencing post millennium, Czech urban expansion has had a presumably short growth period. Regardless of its minimal timeline, Czech sprawl has nonetheless had a rapid growth rate. For example, in one village just south of Prague, Dolni Brezany, the population increased from approximately 1,000 inhabitants originally, to about 15,000 in 2008 (ČTK, 2008).

According to the Czech News Agency, "In the past ten years, 100,000 family houses have been built in the 10-million Czech Republic, mainly in former fields on the outskirts of big towns," (ČTK, 2008). This illustration of mass new developments on former agriculture parcels is exactly the case for majority of modern sprawl developments built outside of Prague.

Developments have focused on agriculture land that is abutting existing villages. This has caused numerous problems beyond the obvious environmental toll. A large

environmental burden is created as fields and forests are replaced with built-up land use (Buff, 2003). There are also social problems as newer, younger, and generally more educated people populate historic villages with inhabitants of substantially different backgrounds and social structures (Ouředníček, 2005). Impacts of urban sprawl are countless and at times unforeseen in regards to the future. It is important to understand what the drivers behind sprawl are, in order to inform and guide further development.

Many authors have attempted to narrow down the principle causes of sprawl. Authors Habibi and Asadi nicely characterize common popular drivers of urban sprawl into five simple categories: economic, inner city problems, transportation, demographic housing, and other (Habibi and Asadi, 2011).

There are, for one, economic factors, such as economic growth, increased income, price of land, and subsidies. The next category entails perceived problems of the inner city such as crime, pollution, small apartments, high levels of taxation, lack of green space, damaged infrastructures and such. Next, transportation factors are a large source of urban sprawl globally; these include individual car use, improvement to transportation systems, availability of roads, and low cost of commuting. Demographic housing factors involve, "population growth, more space per person, and diversity of choice," (Habibi and Asadi, page 138). The last category, other, is comprised of, "technological innovation[s], public facilities, and infrastructures," (Habibi and Asadi, page 138).

All of these factors together have largely been responsible for the spread of new housing developments throughout the adjacent countryside that circularly surrounds Prague. One of these factors that have played a particularly interesting and influential role in Czech urban sprawl is transportation. Access to large motorways, as well as availability of public transportation networks, give such localities a large advantage. These areas have by and large seen higher rates of new housing developments.

This thesis is in correlation with a concurrent PhD study being conducted at the Česká zemědělská univerzita v Praze (ČZU), or similarly known, Czech University of Life Sciences, Prague.

2. Aims of Diploma Thesis

The main objective of this paper is to prove village access to public transportation networks is a leading driver of urban sprawl in localities that are within a 50-kilometer buffer zone around Prague, Czech Republic. Other aims in regards to this topic include:

1) Create a well understanding of current literature on urban sprawl in both the Czech Republic and the United States.
2) Introduce the key drivers of urban sprawl expansion presented by other authors.
3) Prove that access to public transportation networks has caused some villages outside of Prague to flourish with suburbanization more than those areas that are not within close vicinity to a public bus, train, or tram.
4) Produce statistic results that show the relationship between public transportation and urban sprawl expansion.
5) Conclusions on Czech Republic's public transportation network and relationship to urban sprawl.

3. Review of Literature

3.1 What is Urban Sprawl?

Many diverse authors have various different ways to define urban sprawl. With many definitions in existence, there is currently no general consensus on just one. A simple portrayal is provided by Brueckner (2006), who explores the thought that *urban sprawl* can simply be defined as, "excessive spatial growth of cities," (Brueckner, 2006). This is one of the simplest definitions possible, which can be

seen as lacking in sufficient amount of description. In such basic example, not a single process or pattern of sprawl is discussed at the least. Under thus simple definition, some rural growth could technically be characterized as urban sprawl. This could create discrepancies when classifying, analyzing and studying urban sprawl.

The European Environmental Agency (EEA) generally outlines urban sprawl as the, "physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas," (Habibi & Asadi, 2011). This definition certainly seeks to entail more defining characteristics of sprawl than the first author's example, by Brueckner, does. However, the EEA still does not distinguish a possible physical pattern that the urban sprawl would resemble. A primary example of an author that does use physical patterns in order to define sprawl is Ewing (2002). Ewing indicates a few specific distinguishing characteristic features:

> *(1) Poor accessibility [is] the common denominator of sprawl — with the following patterns most often identified… scattered or leapfrog development, commercial strip development, uniform low-density development or single-use development (with different land uses segregated from one other, as in bedroom communities)* (Ewing, Pendall, Chen, & America, 2002).

Other authors use their definition as an outlet to exploit unfavorable tendencies that are often cultivated by urban sprawl. Author Peiser (2001) particularly stresses the inefficient use of land and negative expansion patterns that sprawling developments tend to produce:

> *(2) The term is used variously to mean the gluttonous use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient use of land* (Peiser, 2001).

Peiser further demonstrates his opinion through cynical vocabulary like, "gluttonous," that surely seeks to stimulate a pessimistic feel. Similar to the previous definition, authors Carruthers and Ulfarsson describe sprawl while

entailing a slight negative undertone. Carruthers and Ulfarsson's explanation is similar to Ewing's and Peiser's in that they all use characteristic patterns and processes in order to help distinguish urban sprawl:

> (3) *Unplanned, uncontrolled and uncoordinated single-use development that does not provide for a functional mix of uses and/or is not functionally related to surrounding land uses, and which variously appears as low-density, ribbon or strip, scattered, leapfrog or isolated development* (Carruthers & Ulfarsson, 2002).

From the above three authors, Ewing, Peiser, and Caruthers and Ulfarsson, one can see there are clear similarities between a bulk of existing definitions. As is common, the three definitions alike use physical appearance (patterns), density, and often an underlying opposition is implied. There are infinite ways to describe and define urban sprawl. To date, there is no universal or generic definition for global use. Solely because there is no agreed definition, does not mean one cannot seek to understand what the most important drivers of urban expansion are (Christiansen & Loftsgarden, 2011).

3.2 History of Sprawl in the Czech Republic

3.2.1 Restricted ownership

Throughout the totalitarian and authoritative rule of the then Czechoslovakia, ownership was restricted on many levels. After World War II, "the Communist government introduced policies that imposed central planning and state control," author Cvrcek states. Some of these policies included the, "collectivization of agriculture, gradual nationalization of the retail sector, severe restrictions on import and currency convertibility and currency reform," (Cvrcek, 2006). These policies made every day aspects of life, as in food and retail, government mandated and rationed.

As for the housing market in the socialist Czech nation, residents were required to obtain a permit in order to relocate to large cities. This permit was hard to earn and

was granted sparingly (Andrusz, 2001). Beyond the difficulty of relocation, there was also a high preference to live in the center of metropolitan areas. Urban areas were favored because of the inherent heightened employment opportunities and close allocation of services. Many people hence decided to live on the periphery of large cities in anticipation that one day, they could find access to urban living (Ouředníček, 2005).

Ownership during Communism was restricted in whole. This restriction of ownership consequently fueled a neglected expansion of urban sprawl. It was not until the mid 1990s that the public gained purchasing power. Accordingly, residential suburbanization was only marginal until about this time (Sýkora and Ouředníček, 2007).

3.2.2 Short period of time

Suburbanization has only taken place as a primary process, seriously impacting the face of Czech metropolitan areas, since the second half of the 1990s. This is majorly due to the fact that the Czech Republic was under a strict authoritative regime until this time. During those times, there was restricted ownership, as was previously discussed. Beyond the fact of state ownership, investments and developments focused on the ever-important central urban core framework (Sýkora and Ouředníček, 2007).

Historically, investments toward city outskirts were low because the peripheral areas were regarded as places for people of lower socioeconomic status, and higher industrial activity. Beyond the lack of monetary investments, these social perceptions of suburban areas deterred relocation to areas outside the city. Hence, urban sprawl was not a mainstream development process for the Czech Republic until recently (Sýkora and Ouředníček, 2007).

Also corresponding to the short time period of urban sprawl growth, auto ownership has seen a relatively recent spike in the Czech Republic. Between the years of 1988 and 1998, there was a rise in per-capita car ownership by 63 percent. Particularly more striking in relevance to this paper's research, there was a significantly higher

increase of 93 percent in auto ownership in the Prague area (Pucher, 1999). A recent substantial growth in automobile ownership corresponds nicely with contemporary patterns of migration from the inner city to further outlying suburban communities.

3.3 Drivers of Urban Sprawl

3.3.1 Preference: (Czech dream, increased prosperity, rich bigger homes, green open space)

3.3.1.1 Individual preference, Czech Dream

Individual preferences have been recognized by many authors as one of the leading drivers of urban sprawl. Just as there is the ever infamous, "American Dream," there is quite similarly the, "Czech dream," (Ouředníček, 2005). During times of socialism and communism, many people living within Czech cities aspired to have their own, detached house with a private garden. Czechs dreamed of cul-de-sac developments, backyard swimming pools, and the suburban life as they pictured Americans having (Špačková and Ouředníček, 2011).

Figure 1. A typical Czech urban sprawling development with fenced-in yard and pool in Tuklaty. There is a noticeable lack of large trees; roadside trees are deliberately planted with low growth trees. This can be attributed to the Czech Dream and perceptions of American sprawl communities, in which they wish to be alike (Google Earth image, 2013).

However, this may only be a provisional increase in the preference for suburban development housing. The, "Czech dream," may fade from being a leading driver of

sprawl as decades pass and preferences are less affected by communism, however the perceived benefits of suburban life will continue to make individual preferences a liable force that drives suburban sprawl. Some of these perceived advantages could be, for say, better environmental quality, smaller settlements, larger plots, individual car use, safer living, a quieter environment, and benefits of the like (Ouředníček, 2005).

Though the, "Czech Dream," has been affected by the totalitarian and oppressive ruling regimes of the past, growing numbers of Europeans are nonetheless gaining a preference for suburban residential life. As the European Environmental Agency points out in their EEA Report, "More and more people in Europe regard a new house, ideally a semi-detached or detached house in the suburban/rural areas outside the city, as the prime investment to be made in their lifetimes," (European Environmental Agency, 2006). Europeans in general are starting to gravitate to suburban life, even countries un-effected by socialist ruling regimes. The fact that Europeans are increasingly starting to prefer detached, rural, housing will continue preference as a leading driver of urban sprawl beyond recent trends (that are following the fall of communism).

3.3.1.2 Increased prosperity

Side by side with preference, an appreciation in the public's affluence has also been a leading driver of urban sprawl in the villages surrounding Prague. With funds readily available, preference for larger homes and private access to a garden becomes attainable *along with* the purchasing power. With just preference, and no monetary wealth, the preference could be of no significance whatsoever (Ouředníček, 2005).

Following the fall of communism, there was an increase in wealth for a large portion of the population in the Czech Republic. There was no longer a mandate of social equality, so for once there could be people of higher monetary wealth than others. Properties were reinstituted to their original owners, or a family member, and sale of these properties also brought money to individuals. With a higher amount of

wealthy people, suburbanization becomes exceedingly more realizable (Ouředníček, 2005).

As author Ouředníček states quite effectively, "when [a] society is rich and the proportion of young, childbearing families [are] high, there is a high probability of dominance of suburbanization. On the other hand, when [a] society is poor, even these families prefer to economic attractiveness of big cities at the expense of a lower standard of living," (Ouředníček, page 3). Wealthier communities can support living further from an economic hub, and oppositely, less affluent populations demand it.

With more monetary funds, families are suddenly able to support the financial burden of a longer commute, and higher monthly heating cost that is necessary with a larger home. Longer commuters require either paying daily for public transportation, or ownership and maintenance of a private vehicle. By vehicle, longer commutes demand higher gas prices and more frequent vehicle maintenances, adding yet another expense to moving from the ever-essential economic center. With an increase in wealth, individuals are readily able and have the *choice* to sacrifice these economic advantages of the inner city for a greener, countryside life (Sýkora & Ouředníček, 2007).

Less affluent populations benefit from positioning themselves in close proximity to an economic center in order to prosper economically. By situating themselves in a city, less affluent people do not require a car, and are surrounded by employment opportunities. They also have an availability of common commodities, services, and needs necessitated by every day life. The less affluent *must* trade off open green spaces and larger homes in return for the centralization of economic opportunities and everyday needs. Increased affluence, and as mentioned, together with preference, is one of the leading drivers triggering the flux of residential suburban growth surrounding Prague (Sýkora & Ouředníček, 2007).

Suddenly, and otherwise impossible during the communist era, newly prosperous individuals are able to show-off their wealth by building larger housing in less dense, outer-city limits. Correspondingly, there is also a somewhat lack of larger

housing in the densely packed city center, and higher price per square meter. The scarcity of bigger homes thus drives the price higher for the limited existing larger units (Christiansen and Loftsgarden, 2011).

Generally, people in suburban-type communities buffering the Prague area are commuting to inner city jobs on a weekly basis. They must rely on owning a private automobile or being able to access and afford public transportation. This new possibility to display wealth and obtain desired suburban homes came upon in the Czech Republic after the Velvet Revolution. This was the time period following the mid 1990s and on, which correlates with the beginning of major urban sprawl patterns around Prague (Ouředníček, 2005).

Currently, as was touched upon, the number of affluent people in the Czech Republic has been increasing for some time and thus, there is greater population base that can afford a decentralized type of life (Ouředníček, 2005). On top of an increase in wealth, there has also been reasonably cheap land available that neighbors Prague and other Czech large cities. This can partially be attributed to a decrease in protection of agricultural lands (Hirt, 2013). Farmers are selling pieces of agricultural plots because in turn they make more money by selling the land for residential real estate than they can by cultivating it, as will be discussed further in the section "Market Failure," (3.3.2.2).

3.3.1.3 Preference for "safer," green neighborhood

Gardens are favored by families with children, as are bigger homes for large and young families. Suburban areas are perceived as safer than inner city housing, which is especially appealing for families with young children. For example, there are quieter streets with less traffic, cleaner air, better environmental conditions, and very importantly, there is a perception of less crime (Christiansen and Loftsgarden, 2011).

Whether true or not, most individuals associate city life with more crime than counter suburban areas. American Authors Ellen and O'Regan coined the term "flight from blight," which describes the trajectory pattern of people moving from

a city to suburbs in the fear of crime. In the United States, there were high rates of this "flight from blight" after World War II due to elevated crime rates within cities. Many middle class, mostly white, households moved away from cities and fueled growth of suburban skirt communities (Ellen and O'Regan, 2010). All of these perceived incentives of suburban housing (less crime, cleaner environment, open space) are very attractive for families, and in particularly younger families with children.

3.3.2 Affordability (new young families) and market failure

3.3.2.1 Affordability for young families

Almost oppositely, affordability can also be a significant driver leading the residential pull from a city center to more peripheral areas. The cost of housing can be lower outside the urban core of Prague, and likewise for most cities. Prague currently is experiencing a market failure, with scarce affordable housing available within it's city limits. This has almost *forced* many young families in their 30s to move to more affordable, fringe communities. This is quite different from wealthy families who are moving to suburban areas to access large development lots for constructing mansion-like residencies. By moving to city hinterlands, families with less wealth can still gain access to the ever-important economic city center, while also providing a larger home with a private garden. In this case, is it especially beneficial to striving young families for the suburban locality to have sufficient access to an adequate public transportation network (Christiansen & Loftsgarden, 2011).

In summary, cities within Central Eastern Europe (CEE) can corroborate that land market, or affordability, has pushed urban sprawl in a couple different ways. The first, as discussed, is due to the high price of centrally located city housing. Unaffordable city housing is driving inhabitants further and further away from the bustling central city framework. Simultaneously, the low cost of suburban housing becomes particularly alluring during such a market failure (Christiansen & Loftsgarden, 2011).

Also affecting the affordability is the expansion of office and retail enterprises into city centers. New commercial development within CEE cities has taken away from residential opportunities in the same areas (Bertaud, 2005). After the fall of communism, there were new possibilities for retail businesses in Prague and similarly for other CEE cities that had previously been restricted. Logically, gaining space for a bulk of new enterprises in an already dense city will cost the existing residential housing stock.

3.3.2.2 Market failure

The present affordability of the urban border communities ultimately represents a market failure in the Czech Republic. For one, farmers sell agricultural land for development purposes because the farmer makes more money by marketing his land than he can from cultivating it. The farmer usually does not sell his whole land, but a portion of it. New laws on land protection essentially fueled this turn over of land from agriculture to residential land use. These new laws made sale of agriculture lands easier, and plots suddenly could be sold for 100 times their price per hectare (ČTK, 2008).

Recreational and open space areas have long been studied for their positive impact on the wellbeing of mankind. Green spaces are therefore incredibly valuable to neighboring and corresponding populations. This same principle very well applies to agriculture land as well, (Nutsford, Pearson, Kingham, 2013). Large, open, agricultural spaces are the characteristic look to Prague's countryside. Therefore, agricultural open spaces are a part of Czech's cultural heritage and represent an extremely important non-monetary value. Many economists focus on giving a monetary value to such nature goods in the practice termed, environmental accounting. Social values are left out of the market price when selling agricultural land, and this thus makes the suburban residential price deceivingly and artificially lower. This is the first market failure that can be observed in the market value of Czech Republic's new suburban real-estate developments (Christiansen and Loftsgarden, 2011).

Further more, increased road congestion and traffic are by-products of urban sprawl and represent a cost imposed onto each individual on that roadway. Reduced speed signifies a longer commute for all automobile travelers involved. Time is a very difficult entity to assign a monetary value to, and thus this cost is missing from the price of suburban homes. In addition to time, a longer commute amplifies the fuel costs as well. People do not entirely understand the full cost of commuting, and hence leads to individuals inhabiting regions further and further from their occupations. This is ultimately the second market failure in Czech Republic land and housing prices (Bruckner, 2000).

3.3.3 Introduction of mortgages supported by state subsidy

The introduction of state subsidized mortgages came at the turn of the 21st century for the Czech Republic. This aided a more diverse and dynamic growth of suburban residential housing (Sýkora and Ouředníček, 2007). Following a 1989 recession, particular towns received large state loans to fund the development of new housing and apartment complexes. For an example, the town of Smržovka, a northern community close to the Poland border, was given a 200 million Czech koruna (converted to about seven million U.S. dollars), to finance the construction of 70 new houses and 40 new apartment units. Thus, state subsidy loans increased the feasibility of suburban expansion by providing new, attractive and readily available real estate options (Leeds, 1996).

The mortgage market in Czech Republic has only begun to develop. This is largely because the long-term credit market is still in its formative years. Lending money can be a risky endeavor without a concrete and generic system to evaluate each individual's ability to pay money back. This is where a long-term credit system generally plays its role, providing an unbiased and concrete approach to evaluate each individual's logistical monetary responsibility. The state ownership, and "people's republic," that existed during Stalinism restricts the present amount of accessible records available for the public's monetary endeavors (Leeds, 1996). Logically, until the Czech Republic has decades of records to form a solid base that will define each individual's economic history, lending programs will still be in formative stages.

3.3.4 Transportation

Connection to a city center gives radial communities many advantages. First, and possibly the most important advantage that was already discussed, is the source of employment opportunities that the city comprises. Secondly, the city holds ample services, commodities, everyday goods, entertainment, communities (people) and such. Therefore, urban sprawl magnetizes itself to places with good transportation connections and access to the urban core. Transportation factors that can feed urban sprawl are:

- Sufficient public transport infrastructure and connections
- Transportation system improvement
- Availability of road and highway networks
- Low costs

  (Habibi and Asadi, 2011)

3.3.4.1 Public transportation

Public transportation systems are frequently leading drivers of urban sprawl in European cities. They provide a reliable, and often fast, connection to the urban center (Habibi and Asadi, 2011). This allows families without access to an automobile the opportunity to live further from the urban core.

3.3.4.2 Highways – development along D1

A widespread and common cause of urban sprawl is frequently the, "availability of roads," (Habibi and Asadi, page 138). The Czech Republic is not independent from this case, and one prime example is the expansion that has taken place along the D1 highway (Sýkora and Ouředníček, 2007). Being within close proximity to a decent road network makes living outside a city more realizable. In the Czech Republic, a motorway network is especially appealing as it brings together the array of villages that are spotted across the countryside, sometimes referred to as "satellite" towns (ČTK, 2008). In turn, this creates a more attractive suburban life in such sprawling village localities.

The D1 highway is the oldest of six major motorways in the Czech Republic. The motorway construction started in 1967, and its goal was to link major Czech cities Prague and Brno. The first section was in operation by July of 1971, with a length of 21 kilometers (just over 13 miles). The D1 motorway was completed and successfully in operation between Prague and Brno by 1980 (ŘSD, 2012).

Along with providing ease of automobile transport between Prague and Brno, the D1 highway has caused large amounts of de-concentration from these cities. The motorway has sprouted major patterns of ribbon development along it. The D1 is flanked by a collection of establishments including retail, hypermarkets, warehousing, entertainment, and suburban developments. The large array of businesses along the D1 has affected employment and economic de-concentration from the city, which has brought residential development along with it (Sýkora & Ouředníček, 2007).

One specific example of economic de-concentration can be demonstrated with the Labe-Vltava Press printing house. The Labe-Vltava Press moved from its central urban location on Wenceslas Square, right in the heart of Prague's central city. The press relocated to Uhříněves – an inner suburban locality on the Southeast edge of the city, and not too far from the D1 highway. It is economically efficient for the press to move to a cheaper real-estate area, with ease of transportation of products and raw material. The press also likely gained monetary wealth from the sale its previous downtown location. Thus industrial relocation, and the D1 motorway, has caused economic de-concentration and an increase in sprawl in general (Sýkora and Ouředníček, 2007).

3.3.4.3 Reduced transportation cost

Low transportation costs can be a significant macro driver of urban sprawl in a couple different spheres. One example would be the low cost of fuel. Cheaper fuel prices can make automobile ownership and operation more viable to a wider range of people. Consequently, cheaper fuel prices can be an essential driver of suburbanization by increasing the economic feasibility of living further from the city (Brody, 2013).

In another sector, low fuel prices can keep public transportation fees from increasing. It is important for public transportation expenses to remain low so that suburban expansion can be accessible to a larger portion of the society. Whether it is low transportation cost for individual automobile use or public transit, affordability is fundamental for urban sprawl to thrive. Without people to flock from the city to hinterlands, growth in urban sprawl would be minimal. By marketing to a wider range of populations, suburbanization is ignited more rapidly (Habibi & Asadi, 2011).

Reduced transportation costs can also fuel non-residential sprawl. Businesses can situate themselves in more isolated locations as long as fuel prices are not too costly. Businesses need raw materials, and to transport products or outputs, which together rely heavily on fuel prices for budget calculation. The lower the fuel costs, the further a business can situate themselves from the source of materials and the recipients of the product, goods or services (Habibi & Asadi, 2011).

On the contrary, high fuel costs hinder the expansion from city centers. In the case of high fuel costs, people benefit from living in dense city centers that discourage the use of automobiles.

3.3.5 Drivers of Uneven weight to development

Physical environment and one's preference for a certain aesthetic are principle drivers to an uneven weight of development around a city. Growth is habitually drawn to areas with aesthetically attractive natural environments. In Prague's case, this has been realized in the Southeast region below the city. This region is known for its beauteous hilly and forested terrain. More new developments have been realized in this area than in any other regions surrounding the Czech Republic's capital (see Figure 2 below) (Sýkora and Ouředníček, 2007).

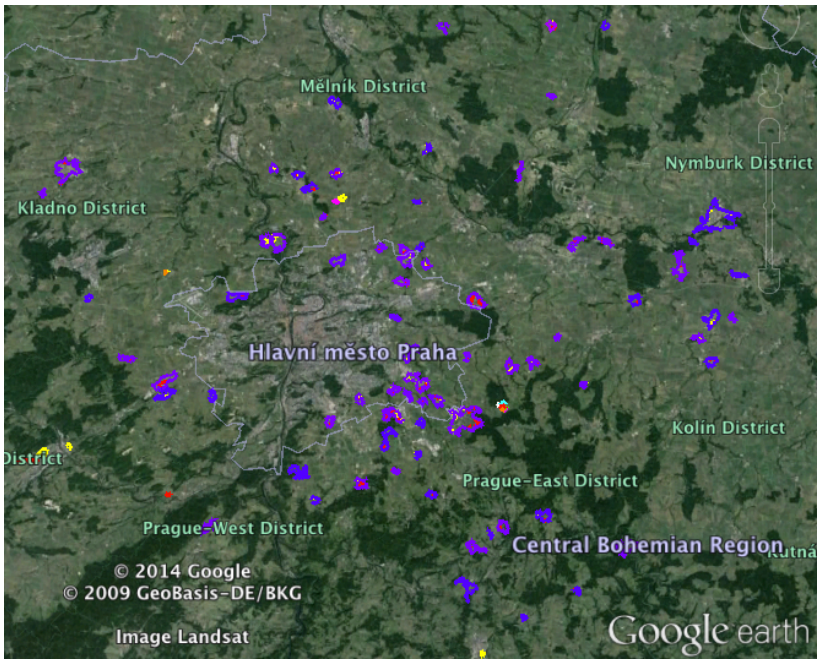


Figure 2. From sample of the total villages, shows a clear uneven weight of villages with new developments. Development shows clear attraction to the southeast region outside of Prague. The map also shows a lot of dark imagery showing the forestry in the area (Google Earth image, 2014).

3.4 Differences between United States and Czech Republic

3.4.1 Automobile dependence

Generally in the United States, sprawling communities depend on automobiles for even the shortest of commutes. Urban sprawl communities in the United States generally fail to mix different land uses in close proximity. Residential areas are separated from commercial ones, and there is no intertwining connectivity that would aid a walkable lifestyle, as urban cities tend to produce. American sprawl also is typically low in density, creating more distance between each house, and necessitates further walking distances to escape these residential deserts (Song and Knaap, 2004). This makes grabbing milk at the store or other small daily errands a process without owning an automobile.

United States sprawl development design does not aid connectivity, but oppositely largely deters it. With the ever-popular cul-de-sac arrangement, residential neighborhoods regularly lead to dead ends and stretch great distances to reach areas of non-residential land uses (Song & Knaap, 2004). A cul-de-sac is a development shaped like a lollipop, with a straight street ending in a dead-end circle. Alongside

the cul-de-sac, most American sprawling communities are comprised of unconnected, intertwining, dead-end subdevelopments, (EMBARQ, n.d.).

Figure 3. Beyond the cul-de-sac, American suburban design largely discourages walking. Getting from point A to B in suburbia (left), is more difficult than in urban settings (right) (EMBARQ, n.d.).

With only residential housing in close walking proximity, American neighborhoods leave little to no employment opportunities within walking distance. A study conducted by Christopher Leinberger found that American families from suburban, car-dependent suburbs are spending 25 percent of their household budget on transport. This is compared to 9 percent of budgets spent on transit for urban households located in walkable areas (Leinberger, 2009).

Typical to European cities, like Prague, there is an extensive public transportation system that allows residents in sprawled villages access to the city without a car. Living in a suburban community outside Prague does not nearly require private automobile ownership to the extent that the United States does. Even though automobile ownership has prompted a recent rise in the Czech Republic's sprawl, the extensive public transportation system has made urban expansion without an automobile more feasible in the Prague area than in most areas surrounding American cities. As authors Song and Knaap point out, the design and pattern of American urban sprawl communities discourage walkability, and ultimately necessitates the use of an automobile (Song and Knaap, 2004).

3.4.2 Non-residential development driving residential

In the United States, residential sprawl has usually preceded any type of commercial development. Following a location's increase in population, commercial endeavors begin to rise; this is the circumstance for most American suburban sprawl. A growth in the residential population simultaneously brings demand for physical goods, alongside a ready source of employees. Residential development has subsequently been creating the sprawl pattern in the United States. The condition is not the same when sprawl is not expanding onto free open land, as it had been in the United State's case (Sýkora and Ouředníček, 2007).

Oppositely, in the Czech Republic, it is commercial developments that often play their own influential role in the urban sprawl pattern. This is essentially a case specific to post-communist cities. Retail and warehousing are both major factors that are de-concentrating developments around Prague (Sýkora & Ouředníček, 2007). Being in close proximity to commercial and retail enterprises is an advantage; one has access to everyday goods and employment opportunities, as was previously discussed.

In a historic and densely developed city like Prague, there is not abundant space to expand new and especially large enterprises. This is why shopping complexes have placed themselves strategically between the densely packed city and growing suburban communities. For example, there are large shopping complex areas at urban border communities Zličín, Černý Most, and Letňany. These examples are at the end of city Metro lines, so can be easily accessed by urban dwellers. The shopping areas are also just bordering the edge of the city, thus inhabitants of nearby suburban communities can reach them without need to enter the city. They also provide ample parking, attracting those who are automobile dependent (Sýkora and Ouředníček, 2007).

3.4.3 Flow of tax revenues

Community fund budgets are formulated partially on the basis of the given locality's population size. In Western civilizations, this is seen as a problem for urban city communities. This is because there is a general outflow of tax revenues, which thus

leaves an insufficient amount of money for inner-city governments (Ouředníček, 2005). Many people are commuting and spending time in the city, but living just outside of it. This creates a skew for the amount of funding needed for the city, since more people are functioning and using the city's services than the budget reflects by basing it off the volume of residents.

In the Czech Republic, there is the opposite problem because many people are left registered to the city even though they have already flocked to hinterlands. Mainly, this is due to the time consuming and pain-staking task of re-registering family members to a new address. Sometimes, due to such troubles, just one family member changes their resident registration and the rest are left registered to the city. Ultimately, in Prague's case, this results in an in-flow of money to the city, and hence monetary outflows are less than they should be. In summary, Czech's cities are receiving a surplus of financing than ultimately envisioned with respect to population size, and suburban communities are not receiving enough (Ouředníček, 2005).

3.4.4 New development attracted to existing built-up areas, Socio-economic impact of incoming populations

In the United States, the canvas for urban sprawl differs substantially to that of the Czech Republic's. Prague's suburban areas are not blank sheets, but hold old, existing villages. Czech sprawl has thus been attracted to places where developments already stand. As author Ouředníček declares, there are only a few cases where small developments of less than a dozen houses were established, "in the middle of a sunflower field," (Ouředníček, page 12). This has caused a stepping-stone type pattern, with blotted patches of suburban sprawl growth. The existing network of settlements has hence significantly influenced sprawl in the Czech Republic, and was not a probable case in the United States during the time of major urban expansion.

The fact that new developments are fixed to existing ones has greatly impacted the social make-up of these now mixed communities. People moving from the city are, in general, younger and have achieved a higher level of education than the

indigenous people. The incomers also have more money than the original villagers, as some come to build new, large, gaudy homes. There is this, "division between the 'old and the poor' and 'the young and the rich,'" (Špačková & Ouředníček, page 345). The result is a more stratified social identity. Potential social problems could rise from different groups living in close vicinity to each other with substantially different backgrounds and lifestyles. Communities that are largest in size around Prague have the highest amount of well-educated people relocating to them (Ouředníček, 2005).

A stratified social division between the educated and uneducated is hardly the persona of United States suburbs. That is because there are not two drastic groups defined by level of education living discordantly together in American suburban communities. The urban sprawl communities of the United States are generally old, and by this point have a developed a fair societal mix for the most part. One of the most famous portrayals of United States sprawl is seen with the post war development in Levittown, Long Island, New York (Powell, 2010).

Levittown is a massive development, comprised of prefabricated, and purposefully inexpensive homes. This period of time following World War II was the peak for urban sprawl in the United States. In 1944, the Veteran Administration (VA), alongside the Federal Housing Association (FHA), extended federal tax and mortgage policies to make sure returning soldiers were able to purchase homes. This meant that buyers only had to put down ten percent of the cost of the house, instead of the previous 50 to 60 percent (Powell, 2010). This was an immense driver of urban sprawl in the United States.

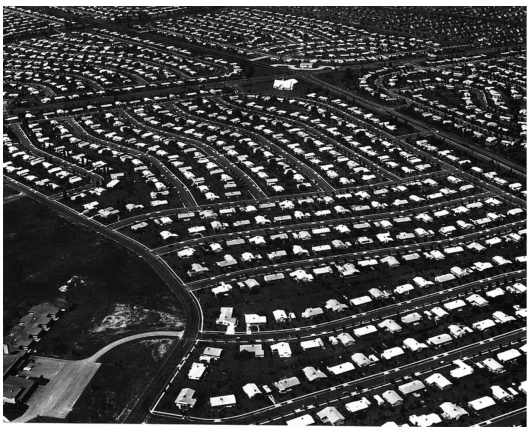


Figure 4. Levittown, NY aerial in 1959. Clearly illustrates the presence of suburbanization in much earlier years than Czech Republic, (University of South Carolina, n.d.).

Levittown perfectly portrays the major time period for the majority of American suburban expansion, taking place post World War II into autonomous open land for the most part. This predates Czech Republic's urban sprawl patterns significantly, which did not start until after the Velvet Revolution, or more specifically the mid 1990s, (Ouředníček, 2005). This later date should so indicate a significant larger amount of development already existing in Czech Republic country lands when urban sprawl began.

4. Methodology

4.1 Data

The collection of different data was crucial for the success of this study. Data that was utilized incudes a point shapefile in ArcGIS comprised of all Czech villages, aerial photographs 2003, 2006, and present from mapy.cz, 1950 cadaster map from http://geoportal.gov.cz/, Google Earth aerial photographs of each locality, and public transportation time tables from website http://jizdnirady.idnes.cz.

4.2 Selection of villages

The national *current* city border was used as the determining line for Prague; no villages were selected that lie within this boundary. It is important that it is noted this study used the current border, as the boundary has been extended over time. From this periphery line, all villages were selected that are within a 50-kilometer radial buffer around the city. Within ArcGIS, the buffer analysis tool was utilized to make a selection from a point shapefile that includes all Czech Republic villages. Input parameters include a shapefile that contains the Prague city borderline, the point shapefile with the villages, and 50-kilometers is delineated in the buffer distance field.

4.3 Collection transportation data

Of the total amount of villages inside the 50-kilometer buffer, a sample was taken in order to retrieve the necessary public transportation data. Of the total 1,217 villages,

the sample included a stochastically selected 225. Data was collected for both villages with and without new developments for a complete comparison. The sample made sure to include any villages that were physically visited, so that these localities could be fully understood and used as prime examples.

From the website, http://jizdnirady.idnes.cz, timetable outputs from the National Information System of Timetables were retrieved. This website is operated under the authority of the Ministry of Transport of the Czech Republic. For the sample villages, this website was used to collect the total number of trains, buses, or trams a day, how long it takes to get from the village to Prague, the average travel time, if there is an existing direct connection or not, the average amount of connections needed to get from the village to Prague (any switches between bus-train, train-train), the first train leaving in the morning from the village to Prague, and the last train in the evening leaving from Prague to the village. Information was taken from a regular, non-holiday, working weekday.

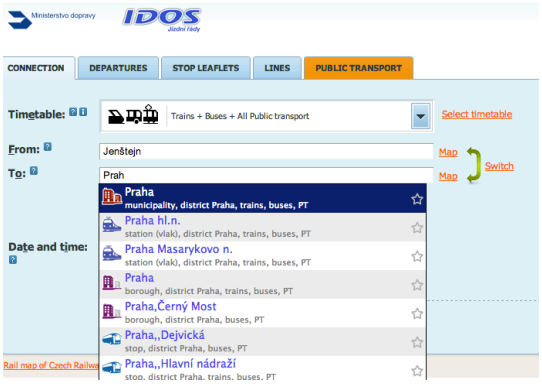


Figure 5. The general municipality of Prague is chosen. Select a weekday and start the time from 00:00 to view the first departing connection from the village to the city. Record the time of the first departure (Image: IDOS website).

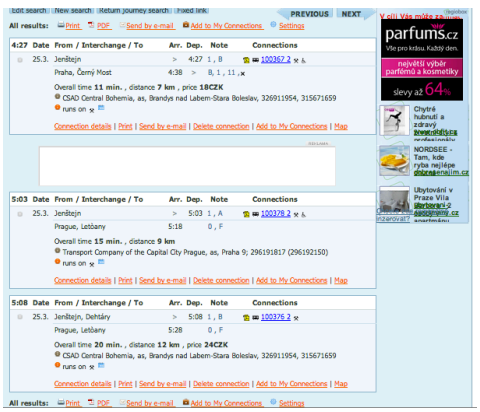


Figure 6. Start counting from the first train or bus in the morning leaving from the village and record how long it takes, how many connections (in this case, no connections are required), and if there is a direct connection (in this case there is).

Count how many times a connection runs from the village to Prague for the complete day. When done, average the time duration it takes and the number of connections (Image: IDOS website).

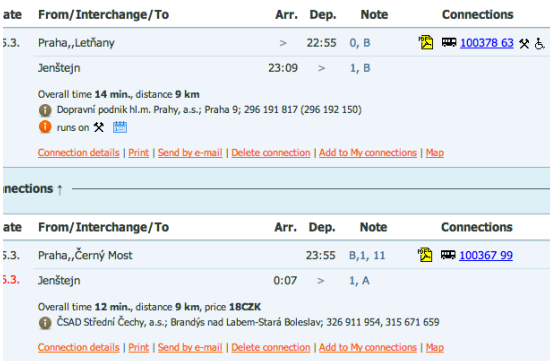


Figure 7. Edit the search, switching to Prague as the departure, and find when the final connection leaves Prague. Record all data into a spreadsheet (Image: IDOS website).

4.4 New developments within villages

The data for new developments was collected visually. A 1993 aerial photograph was used as the bases for comparison. Each selected village that lies within the 50-kilometer buffer was remotely visited and analyzed via mapy.cz. The 1993 photograph was compared to the 2003, 2006, and present on mapy.cz to reveal any new developments that were constructed during this time frame. During this phase of data collection, developments were sought after that particularly did not match the patterns of the historic village.

Figure 8. Czech Village Radonice in 2013, one can see the bottom left corner of development is clearly distinguishable from the older parts of the village, (Google Earth Image, 2013)

4.5 Location in relation to Prague

It is also important to look at where the villages are in relation to Prague. Location could possibly be an important influencing factor, and is essential to compare its influence on urban sprawl. The location to Prague was evaluated on a simple four-

quadrant axis. Two axes were drawn crossing in the center of Prague, creating four quadrants that cover the whole study area. The quadrants were numbered one through four, starting at the northeast square and continuing clockwise. Each village searched and determined the appropriate quadrant number. For example, village Babice was entered, as pictured below, and it would be given the value two since it falls in the second quadrant location from Prague.

Literature suggested that southeast of Prague is a popular area for urban sprawl relocation. This was due to the beauty in this area, which is characterized by forests and rolling hills that attractive to new residents. The quadrant locations were partially included in order to evaluate the influence of this probable influencing factor.

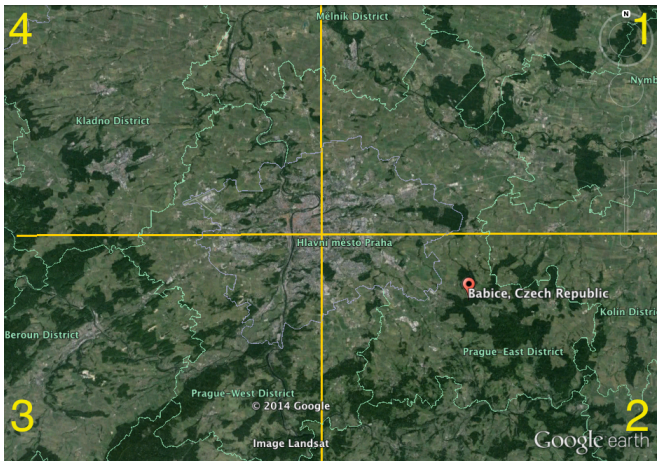


Figure 9. Babice shown with marker as would be during data collection. Babice's quadrant location is then determined to be two, (Google Earth image, 2014).

4.6 Comparing size of new development/original village

Cadaster information was not readily available for each village. In order to compare sizes of new developments with the original villages, this part of the study began by using Google Earth. Within Google Earth, the study began by outlining the new villages, and the original village. Any large commercial endeavors adjacent any village was excluded, such as large plants or solar farms. Commercial developments were omitted because they would skew the residential data that was ultimately being sought after.

After completing outlines for every new development and original village, they were exported as .kmz files. These files were then uploaded as layers into ArcGIS for additional comparison. Here one can compare and see if developments were attracted to larger villages, and how much expansion has taken place in relation to the original village. In ArcGIS, one can also retrieve the total size of new developments in the total study area.

Each year was counted, 2003, 2006, and present, for a total number of residential homes in each new development. This information was received from the Czech website, www.mapy.cz. In order to be arbitrarily inclusive, a house must have had a completed roof in order to be incorporated. If the developments had substantial completion prior to 2003, their 1950s cadaster map was checked on the Czech governmental website, http://geoportal.gov.cz/. From here one can tell if the development was already started by year 1950, or if the construction began sometime between 1950 and 2003. A correct border could then be better interpreted by seeing which developments were pre-existent to 1950. There is such a large gap of 53 years in aerial photographs because imagery between those dates are extremely difficult to get. Aerial images exist for 1993, but are especially expensive to attain for such a large study area.

A cumulative figure was determined that characterizes the total sum of housing parcels in all of the new developments at each locality. This further represented each village's growth better than the number of new developments. The size varies significantly between new developments, so a total number of housing parcels is a better indicator for increase in size and population at each the village.

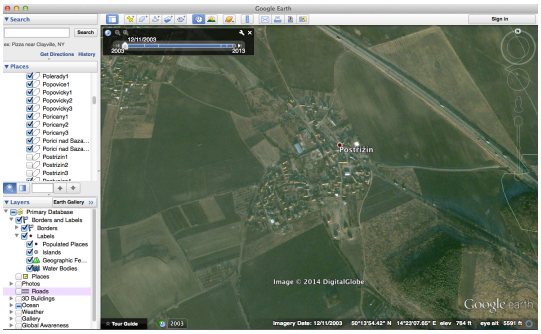
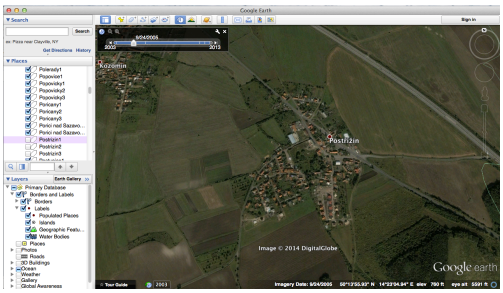


Figure 10. 2003 aerial photo of the PostřižÍn Village. Utilize the time slider to show historical imagery. Continue to change date back and forth to look for new development (Google Earth image, 2003).

Figure 11. 2005 aerial image: some new development protruding from the southern part of the village. Wait to commence outline for a fuller completion of the development (Google Earth image, 2005).



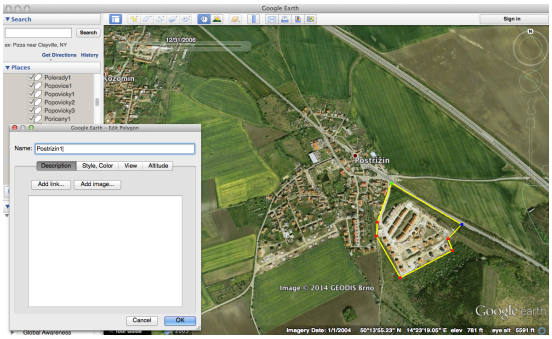


Figure 12. 2006: development continues. Use the 'add polygon' tool, and under 'style, color' choose the setting 'outlined' to visually see the photo while outlining (Google Earth image, 2006).

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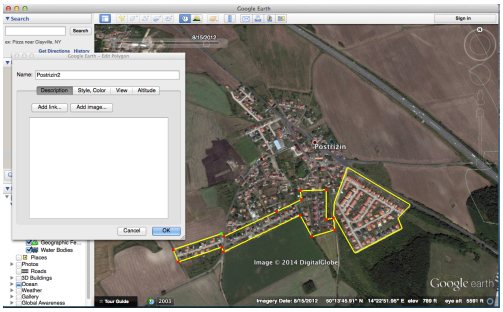
Figure 13. 2012: development advances. Continue to outline, sliding the time scale between before development started and the present in order to decipher borders between the new and old, and to make sure one includes all of the new development. In the photo, additional developments have begun in the north (Google Earth image, 2012).



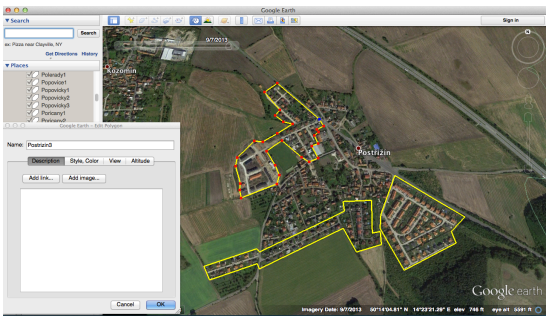
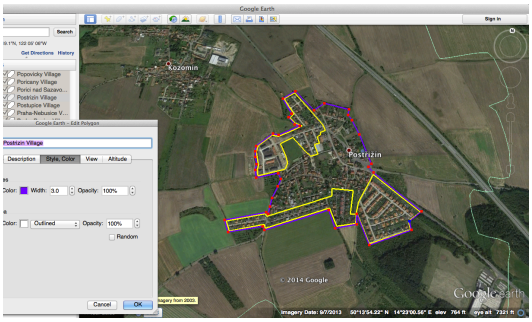


Figure 14. 2013 is the final map provided. The third development is outlined. Some areas do not have as many aerial photographs available on Google Maps. In this case the outlines were based off comparisons to www.mapy.cz aerial photographs (Google Earth image, 2013).

Figure 15. A village outline is then created in purple. This outline comprises all the new developments and the original village. To get the size of the original village, the new developments will be subtracted from the size in ArcGIS at a later step in the process (Google Earth image, 2013).



4.7 Statistics

4.7.1 Research questions

The following points of analysis were all selected to try and reveal what the key drivers of urban sprawl in the Prague area are. More specifically, they seek to disclose the weight of influence public transportation has on urban sprawl and suburbanization in the 50-kilometer buffer around Prague.

These topics of analysis include: the average number of public transit connections departing in a day from the villages that contain new developments. The percent of localities with a direct route that have new developments and percent of villages without a direct route have new developments. The average number of public transits connections departing in a day from villages with and without new developments.

In addition, the mean average public transit time for villages that consist new developments and the mean average public transit time for villages that consist no new developments. Also for both villages with and without new developments, the average first departing time from village to Prague; and the last departure time from Prague back to the village.

4.7.2 Statistical methods

Ing. Vojtěch Barták, a professor at ČZU, performed the statistics from the collected data. The data used in the study is still preliminary, so the results from the statistical analysis are therefore also preliminary. The main research questions tested statistically were:

> Is there an association between the number of transit connections in a day and the number of new developments? For each pair of groups (of number of new developments), is there a significant difference between the numbers of connections? What is the correlation between the average travel time to a locality and the number of new developments? What is the connection between the locality quadrant and number of new developments? What is

the connection between quadrant location and the number of departing connections in a day?

4.7.2.1 Two-sample t-test

A two-sample t-test is used when one wants to know if there is a significant difference between two sets of mean outcomes. A t-statistic is calculated and compared to a standard table of t-values to determine whether a certain level of statistical significance is reached (Columbia University, n.d.).

4.7.2.2. Wilcoxon two-sample test

The Wilcoxon two-sample test is a useful tool when one wants to see whether values of two sample sets differ in size. There are no assumptions and the scale is ordinal. First, "rank order all $N = m + n$ values from both samples (m and n) combined. [Next] sum the ranks of the smallest sample (Wsmallest). This value is used to determine the level of significance. Look up the level of significance in a table using Wsmallest, m and n. Calculating the exact level of significance is based on calculating all possible permutations of ranks over both samples," (Institute of Phonetic Sciences Amsterdam, n.d.).

4.7.2.3 Analysis of variance (ANOVA)

Analysis of variance is a statistical method that is used to test differences between two or means, and their association. By analyzing variance, interpretations about the means are made. Analysis of variance provides a statistical test determining if the means of the different groups are equal or not. This allows a t-test-like analysis for more than two groups. One assumption of ANOVA is that errors are independently and normally distributed, (Lane, n.d.).

A square root transformation is useful to bring about homogeneity or normality when using ANOVA. One takes the square root of each of the raw data scores, then performs analysis of variance on the transformed numbers, (Maddux, n.d.).

4.7.2.4 Tukey's multiple comparison test

Tukey's multiple comparison test is used to determine which means amongst a set differ from the rest. Tukey's test is performed when results from ANOVA indicate that group means do indeed differ. "The test compares the difference between each pair of means with appropriate adjustment for the multiple testing. The results are presented as a matrix showing the result for each pair, either as a P-value or as confidence interval," (Crichton, n.d.).

4.7.2.5 Spearman's rank correlation coefficient

The Spearman's rank correlation coefficient is used when one wants to, "measure the strength of association between two ranked variables," (AERD Statistics, n.d.). In other words, this test looks at the statistical dependency of two different variables. The Spearman's rank correlation was used when searching for the correlation between the number of new houses and number of connections in a day.

4.7.2.6 Chi-squared test

The Chi-squared test, "compares the tallies or counts of categorical responses between two (or more) independent groups," (Eck & Ryan, n.d.). Results are arranged into a table for testing, and applied the chi-squared formula. The formula is based off the numeric positions in a table, as shown below.

Variable 2	Data type 1	Data type 2	Totals
Category 1	a	b	a + b
Category 2	c	d	c + d
Total	a + c	b + d	a + b + c + d = N

Table 1. Chi-squared contingency table (Eck & Ryan, n.d.)

$$\chi^2 = \frac{(ad - bc)^2(a + b + c + d)}{(a + b)(c + d)(b + d)(a + c)}$$

Formula 1. Chi-squared formula (Eck & Ryan, n.d.)

5. Results

5.1 Descriptive statistics

From the total 225 sample villages, 33 have a direct public transit connection to Prague. Of the 33 villages with a direct connection, 17 have new developments. This means that just over 51.5% percent of villages with a direct connection have constructed new residential developments. On the other hand, of the sample villages, there are 192 without a direct transit connection. Of the 192 villages without a direct connection, 80 contain new residential developments. This means that only approximately 41.6% of villages without a direct connection have new developments. Therefore, villages with direct connections have almost exactly a ten percent more likelihood of constructing new residential developments.

The average number of public transit connections leaving from villages with new developments to Prague is approximately 42.7 departures a day. On the other hand, the average number of connections for villages with no new developments is roughly 24.4 departures a day. This gives a well-defined association between the availability of public transportation and the amount of new urban sprawl development that has arisen in villages that lie within 50-kilometers outside of Prague. There is, on average, a greater amount of public transit connections from villages with new developments to Prague compared to those villages without any recent residential developments.

The mean average public transportation time from villages with new developments to Prague is about 54.86 minutes. The mean average time from villages without any new developments is approximately 81.11 minutes. This mean taken from the village averages shows that there is over a half hour difference in transit time between villages with and without new developments.

The average time of first departure by public transportation from selected villages to Prague is 4:35 AM for villages that have new residential development. The collective average first departure time for villages that do not consist any new developments is 4:52 AM. This is almost a full 20 minutes later for villages without any new developments.

In respect to the above, the average last departure time for villages with new developments from Prague is 21:30 (9:30 PM). The average last departing public transit from Prague for villages without any recent residential development is 19:42 (7:42 PM). This is a total of an hour and 48 minutes difference in regards to the last departing public transit connection between villages with and without new developments and Prague.

5.2 Statistic Results

5.2.1 Number of transit connections leaving in a day versus villages with and without new development

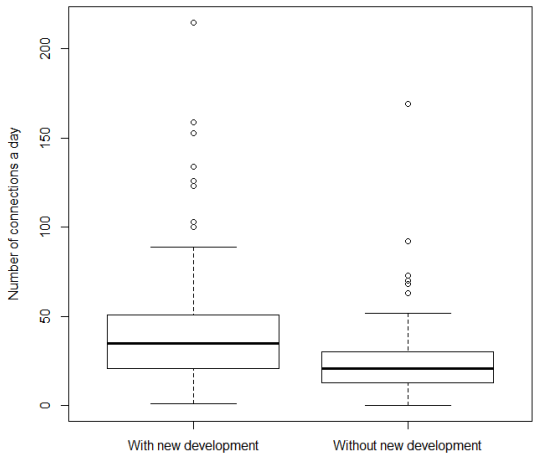


Figure 16. Number of connections a day compared to villages with and without new developments.

The research question is, is there a significant different between the number of public transit connections leaving in a day from the villages with and without new developments to Prague? The two-sample Wilcoxon test was used rather than the two-sample t-test because the distributions of the data are substantially non-normal (see the picture above).

Result: W = 8812.5, **p-value = 7.182e-08**

Therefore, the answer to the research question is villages with new developments have significantly higher number of connections in a day.

5.2.2 Number of transit connections a day versus number of new developments

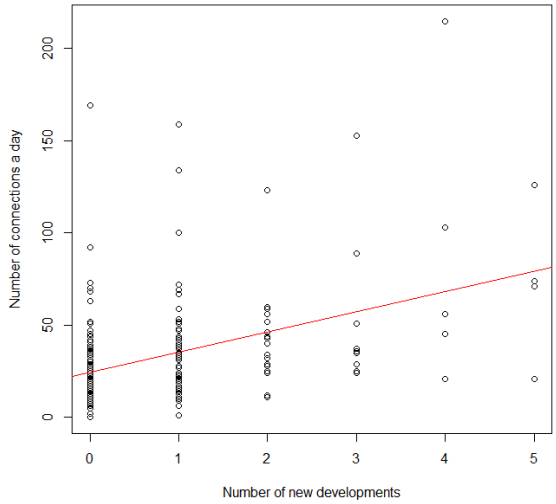


Figure 17. Number of new developments versus number of connections in a day

This looks like a clear trend however it cannot be tested using linear regression or correlation, as the number of developments cannot be treated as a continuous variable. Thus the analysis of variance was used after grouping the last three sets of "number of new developments" into a single group "three or more." This was necessary in order to make the number of observations in each group relatively balanced. The next picture, as follows, was produced after this.

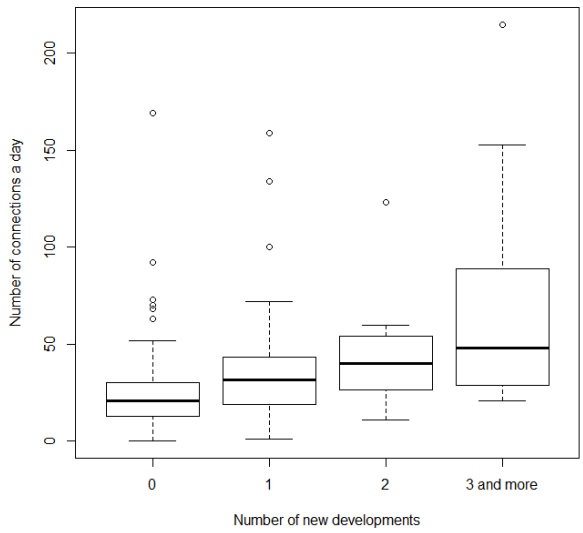


Figure 18. Number of new developments versus number of connections a day, with grouping

The next step uses a square-root transformation of the response variable (i.e. the number of connections) to make the data in each group more normal (this is one of the assumptions in the analysis of variance):

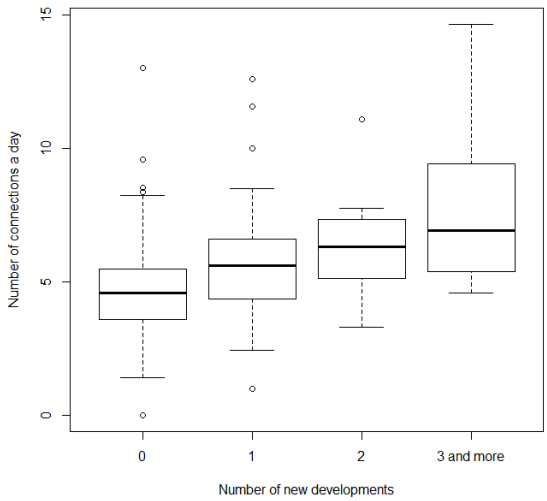


Figure 19. Number of new devlopments versus number of connections a day, with transformation

So now the following can be tested: is there a significant difference between the number of connections in different groups, corresponding to the number of developments? The test used is the analysis of variance, with square-root transformation of the response variable.

Results: F-value = 16.26, Degrees of freedom for residuals = 221,

p-value = 1.39e-09

Answer: Yes, the group means show significant differences.

Next multiple comparisons is performed in order to identify between what pairs the differences are. The question is, for each pair of groups, is there a significant difference between the numbers of connections? The test that is used is Tukey's multiple comparison test.

Group/Group	0	1	2
1	0.9788; **0.0068837**		
2	1.5241; **0.0075740**	0.5453; 0.7011860	
3 and more	3.0531; **0.0000000**	2.0744; **0.0004441**	1.5290; 0.0750213

Table 2. Results (the difference between means and p-value), The groups are number of new developments

Answer: There are significant differences between pairs 0-1, 0-2, 0-3 and more, and 1-3 and more. Unfortunately, the differences between groups 1 and 2, as well as

between 2 and 3-and-more, are not significant. Thus the trend cannot be completely proven. Apart from the results of the previous analysis (comparison between villages with and without development), it can be concluded that villages with three or more developments have a significantly higher amount of public transit connections than those with only one development.

5.2.3 Average time to get to localities with and without new developments

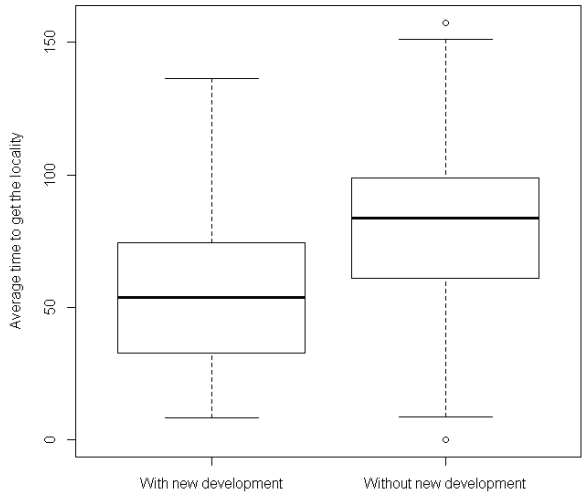


Figure 20. Average time to get to locality compared to villages with and without new developments

The question is, is there a difference in average time to get the locality between the villages without and with new development? The test that was used is the two-sample t-test.

Results:
Means: With new dev. = 54.86031, Without new dev. = 81.11375

t = 6.7199, degrees of freedom = 223, **p-value = 1.498e-10**

So therefore the answer is yes, the average time to get to localities that comprise new developments is significantly lower than villages that do not contain any recent development.

5.2.4 Number of new developments versus average time to get to locality

The same process is applied here as in 5.2.2. First there is the original data together with the least-squared linear regression line:

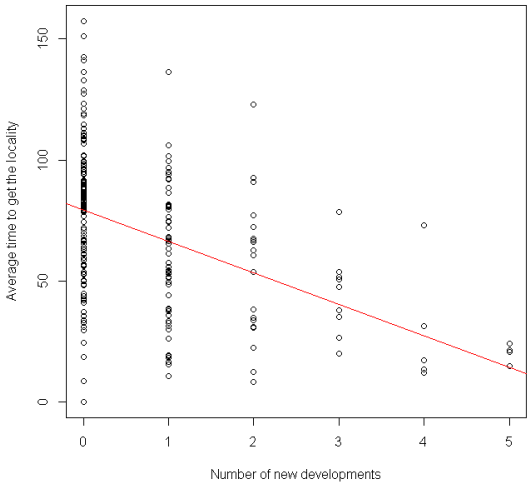


Figure 21. Number of new developments compared to average time to get to locality

Similar to as in 5.2.2, the same data is in the following figure with the number of new developments treated as categories, and the last three categories are grouped together.

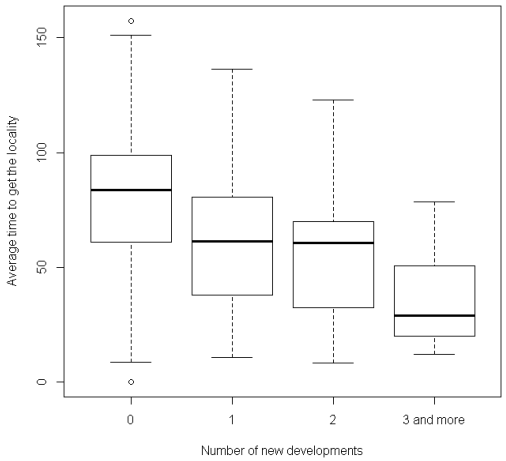


Figure 22. Number of new developments, grouped, compared to average travel time

No transformation is needed because the data looks normally distributed, so the test can begin. The first question is, are there significant differences between the average time to get the locality in different groups? The test that is used is once again the analysis of variance. From the below results, the answer is yes, there are

significant differences in the average travel time between the different groups that are based categorized by number of new developments (no new developments being in group zero).

Result: F = 19.45, **p-value = 3.15e-11**

Next, a multiple comparison is preformed. The question is, what are the pairs of groups with significant difference in average time to get to the locality? The test that is used is Tukey's multiple comparison test. The results, difference between the means and p-value, are as follows in Table 2.

Group/Group	0	1	2
1	-20.3631; **0.0000463**		
2	-26.0901; **0.0013712**	-5.7270; 0.8700621	
3 and more	-46.0604; **0.0000000**	-25.6973; **0.0050008**	-19.9704; 0.1452039

Table 3. Differences between means and p-values for different groups of number of new developments.

The answer is that the structure of significant results (see the bold p-values in the table) is the same as in part 5.2.2 of this report. The negative trend visible in the initial plot (i.e. the red line) cannot be fully confirmed, as there is no difference between the groups 1 and 2, or between groups 2 and 3-and-more. However, there is significant difference between groups 0 and all the other groups, and between groups 1 and 3-and-more.

5.2.5 Number of new houses versus average time to get to locality

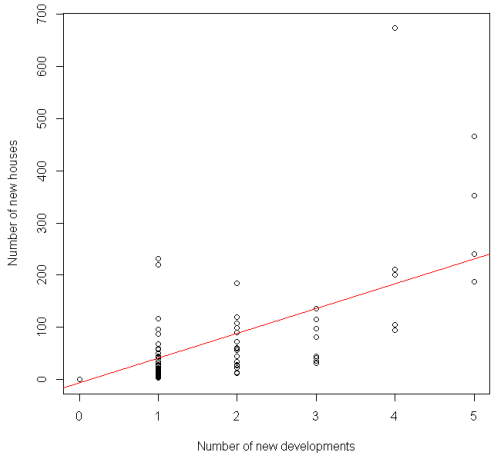


Figure 23. Number of new developments versus number of new houses.

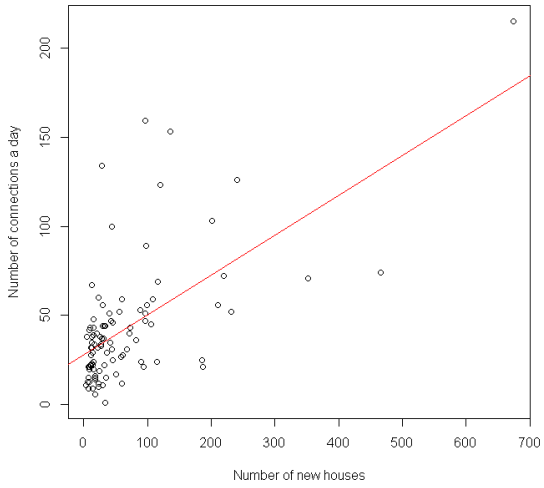


Figure 24. Number of new houses verses number of connections a day for villages with new developments.

The research questions is, is there a correlation between the number of new houses and number of connection in a day? The test performed is the Spearman's rank correlation coefficient.

Result: rho = 0.5279617, **p-value = 2.74e-08**

The answer is thus yes; there is a positive correlation of approximately 0.5. This means that there is a positive connection between the number of actual parcels being built and number of connections. A positive correlation means that both values increase together. Hence, the greater amount of public transit connections available has caused more residential parcels to be constructed in a given locality.

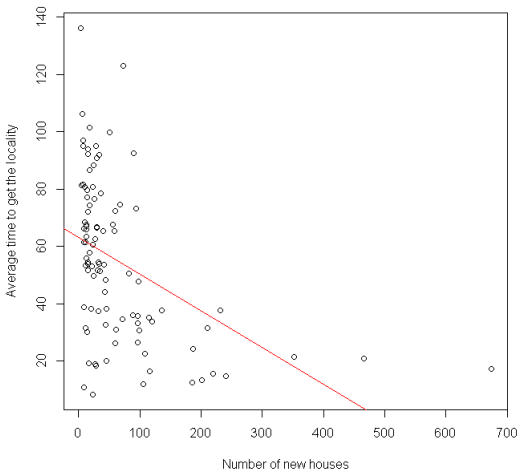


Figure 25. Number of new houses versus average time travel time to locality (for villages with a new development only)

The research question now is, is there a correlation between number of new houses and average time to get the locality? The test is once again the Spearman rank correlation coefficient.

Result: rho = -0.5267339, **p-value = 2.99e-08**

The answer is then yes; there is a negative correlation of approximately -0.5. A negative correlation is such when one variable increased the other decreases. Thus, the number of new houses increases as the travel time decreases.

5.2.6 Presence of a direct train in the villages with and without new developments

The research question is, does the presence of a new developments in a village depend on the presence of a direct train? The test used is a Chi-squared test (in the contingency table). The results are in Table 3.

	With new development	Without new development
With direct train	24 (24.7%)	9 (7.0%)
Without direct train	73 (75.3%)	119 (93.0%)

Table 4. Existence of a direct train compared to the presence of new developments.

Chi-squared = 12.4515, degrees of freedom = 1, **p-value = 0.0004177**

The answer is that the probability is higher that a village with a direct train route will have a new development in comparison to localities without a direct train connection.

5.2.7 Presence of a train in the villages with and without new developments

The next research question looked to see if the presence of a train has any impact on the probability of new development. The thought was that some people may prefer a train, and that those localities might have a higher amount of new development. The initiated test is a Chi-squared test (in the contingency table). Results are in the following table.

	With new development	Without new development
With train	78 (80.4%)	105 (82.0%)
Without train	19 (19.6%)	23 (18.0%)

Table 5. Results showing no dependency of new developments on train accessibility

Chi-squared = 0.0185, degrees of freedom = 1, 0.8919

The answer is no, the presence of a train does not increase the probability of new developments at such localities.

5.2.8 Presence of new developments in different quadrants

From the four quadrants, Northeast, Southeast, Southwest, and Northwest, it was hypothesized that the greatest amount of development would be in quadrant two, the Southeast. It was stated in section 3.3.5 that this is a characteristically aesthetic place and has been a popular destination for people to reside in. As was stated, this Southeast region below Prague is known for is forested area and picturesque rolling hills (Sýkora & Ouředníček, 2007). The research question was, does the presence of a new development depend on the quadrant location? The test used is the Chi-squared test (of the homogeneity of multiple binomial distributions).

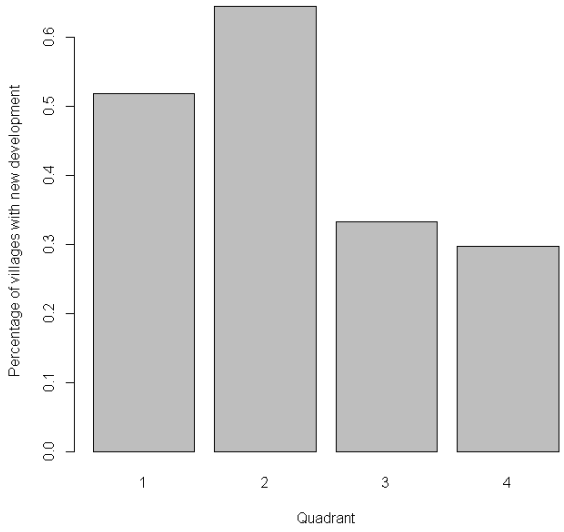


Figure 26. Distribution of new developments according to locational quadrant

	With new development	Without new development
Quadrant 1	29 (51.8%)	27 (48.2%)
Quadrant 2	29 (64.4%)	16 (35.6%)
Quadrant 3	20 (33.3%)	40 (66.7%)
Quadrant 4	19 (29.7%)	45 (70.3%)

Table 6. Number and percentage of villages in each quadrant with and without new development

Result: Chi-squared = 17.1098, degrees of freedom = 3, **p-value = 0.0006709**

The answer is yes; there is a different weight of new developments for each quadrant. The hypothesis was also correct, with the highest amount of new developments being realized in the second quadrant.

5.2.8.1 Multiple comparison test

In a multiple comparison test, the question was examined: between what pairs of quadrants is there a significant difference? The test used is the multiple comparisons for binomial distributions, direct analogy of the Tukey's method for analysis of variance.

Results (p-values):

Quadrant/Quadrant	2	3	4
1	0.5722158	0.18007524	0.062805269
2		**0.00727643**	**0.001457078**
3			0.972101011

Table 7. Comparing between what pairs of quadrants is there a significant difference?

The only proven significant difference is between quadrant two and quadrants three and four. Quadrant two has a noticeably higher probability to suffer from new development. This corresponds nicely with the hypothesis and expected results from related literature.

5.2.9 Number of connections in a day compared to quadrant location

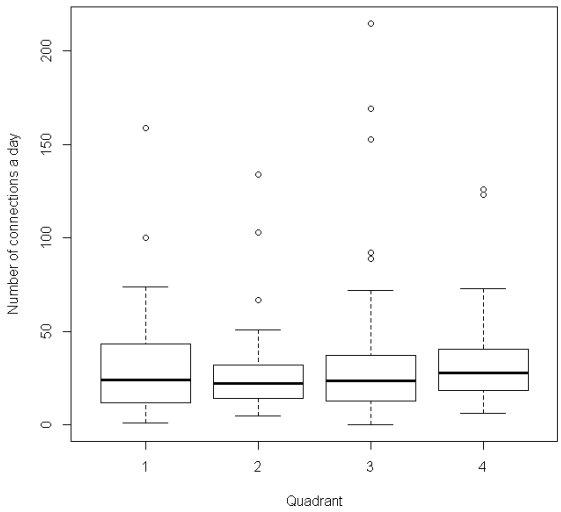
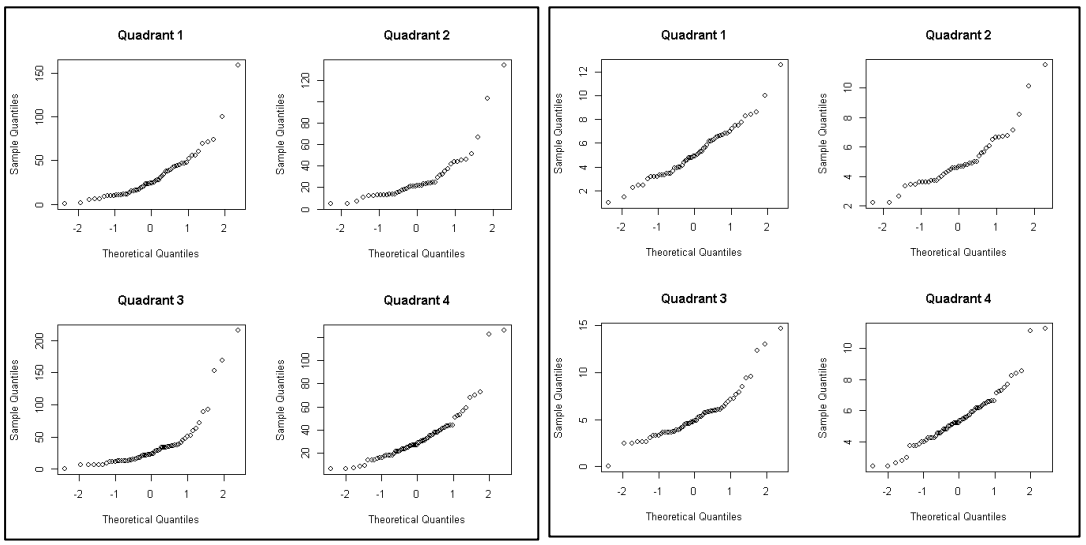


Figure 27. Number of connections a day sorted into quadrant location

For the analysis of variance, a square-root transformation was applied. For demonstration of this need, see the following quantile-quantile plots before and after the transformation. If the data is approximately normally distributed, the dots in the graphs should form a straight diagonal line.



Figures 27 & 28. Figure 27 (left): before transformation. **Figure 28** (right): after square-rooted transformation. The right is more normally distributed since the plots are closer to a straight diagonal line.

After the transformation, the data looks like figure 29. The research question can then be posed, are there significant differences between the number of connections a day in different quadrants? The test that is used is analysis of variance with a square-rooted response variable.

Result: F-value = 0.598, Degrees of freedom for residuals = 221, p-value = 0.617

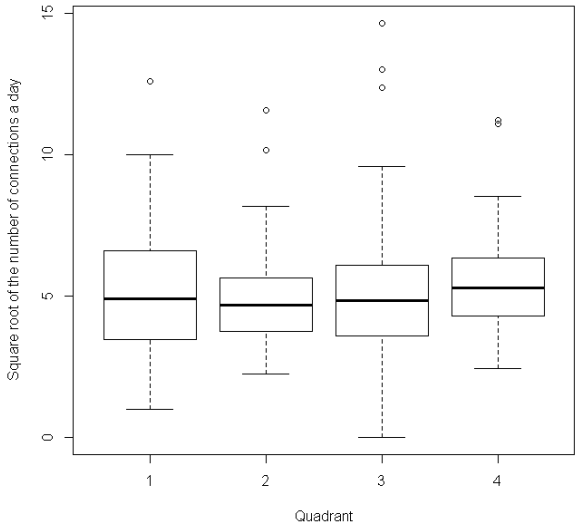


Figure 29. Number of connections in respect to quadrant location

From the above graph, one can tell that the answer is no; there are no significant differences in the number of public transit connections a day and the quadrant location. As seen in the Figure 29, the means for each quadrant are almost level with each other. Thus, it cannot be concluded that there is any relation between the number of public transit connections and geographical quadrant location.

6. Discussion

From the tested data, favorable results were produced in regards to their correspondence with the premise of this thesis and the expected hypotheses. It is hereby clearly proven that there is a strong connection between a village's access to public transportation and the development of new residential housing within a 50-kilometer buffer around Prague.

The first departing connection is an important factor to look at. In order for public transportation to be viable outlet for the regular workday commute it must leave for Prague at an early enough time. The collective average is about 20 minutes later for villages without any new development. This indicates a stronger public transit connection for villages that have sprouted new development.

The urban commuting workforce in sprawling communities will indeed rely on sufficient amount of morning public transit connections. Possibly just as strongly, the commuting workforce will rely on enough connections in the evening. Getting to and from work is an important denominating factor when considering a suburban location for its urban commuting potential. From the results, there is an even stronger difference in evening departure times between villages with and without new developments.

On average, villages with new developments have an hour and 18 minute later departure from Prague. The average last departure time to villages without any new developments is 19:42. In a lot of industries today, 19:42 is just not late enough. Even a lot of retail businesses are open passed this time. If an individual misses their last connection, they are left with no options for public transportation. This could be a determining factor if looking to reside outside the city while still being able to commute on a daily basis.

When examining Figure 16, the results produced are likewise as expected. The mean number of connections from villages with new developments to Prague is higher than the mean number for villages without any new developments. Similarly, in Figure 20, villages with a shorter commuting time to Prague have significantly higher amounts of new development. It can be expected that new developments would be attracted to areas with shorter commutes, making a more attractive commute to incoming residents. It can also be anticipated that development would be drawn to places with ample transit connections in a day. Less planning is required when more transit connections are available. Ample connections leave leeway for residents, with a safety cushion of transit connections flanking one's desired departure times to and from the city.

It would be interesting to look at, in an additional study, if the number of public transit connections were increased after new developments were constructed. In retrospect, perhaps bus lines could have been added after the locality was chosen for development. Possible difficulties with such a study would be to retrieve public transit information for previous years.

The only statistical test that came up with an unanticipated result is the presence of a train compared to villages with and without new developments. The hypothesis was that people prefer trains to buses, and thus perhaps more developments have been realized in areas with train connections. The outcomes produced from a Chi-squared test, section 5.2.10, showed no connection between the availability of a train and the occurrence of new developments. Based off speculation, this could be because of more direct bus routes, longer trips required by train, or the fact that buses may have more destinations within Prague.

Besides this final statistic, all results favor the hypothesis that urban sprawl experiences increased rates of development in villages outside of Prague that have higher public transportation accessibility. Even this final statistic on presence of trains is not necessary in opposition of the theory. The result is not negative; the figures are too close together to define an association. Nonetheless, the theory states that public transportation, not specifically trains, have been a leading driver of urban sprawl. This still stands true based on the overwhelming positive majority of results from this study. For further study, the influence a bus network on urban sprawl could be considered. Buses have potentially become the preferred outlet of public transportation outside of Prague. For the most part, bus transportation is cheaper than train in the Czech Republic.

7. Conclusion

This study clearly identified availability of public transportation networks to be in strong association with the presence of urban sprawl developments in the villages lying within 50-kilometers outside of Czech Republic's capital city, Prague. Results showed a strong connection between residential sprawl development and increased number of connections in a day. It also showed a greater amount of development for villages with direct public transportation routes. In summary, a higher public transit connection from outside villages to Prague has produced noticeably more urban sprawl residential development according to the results from tested data. This accomplished one of the most important aims and goal of this thesis: to prove that access to public transportation networks has caused some

villages outside of Prague to flourish with suburbanization more than those areas that are not within a close vicinity to a public bus, train, or tram.

With such highly conducive results yielded for the tested data, further investigation could likewise produce noteworthy conclusions. In a feasible supplementary study, one could look to determine possible connections between the availability of public transportation networks and the year development started. One could also see if there has been any growth or decline in area of development throughout the years. Additionally, it would be interesting to determine the connection between a range of other factors with the occurrence of new developments. Some of these factors could perhaps be the presence of a town green, ponds or lakes, the number of parks, stores or markets, population size at initiation of development, and so on.

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