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The effect of spatial configuration on propensity for non-motorised journey to work:

Case study of a gridded and a non-gridded American city

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Abstract

The theory of 'natural movement' postulates that configuration of the urban grid is an important generator of aggregate patterns of movement in urban areas (Hillier et al. 1993). Retail and commercial land uses locate themselves at these configurationally hotspot locations to take advantage of the economic opportunities created by movement i.e. passing customers (Hillier 1996). These retail and commercial areas are also work places for a good number of people and will influence the choice of some residential locations. Since journey-distance and journey-time are two very important factors influencing propensity for walking or cycling (Plaut 2005; Wardman et al. 2007; Pucher & Dijkstra 2003; Schwanen & Mokhtarian 2005) we hypothesize that the sites of retail areas as understood by their configurational index, will first affect the choices of residential locations and hence also influence the use of non-motorized transport (NMT) particularly walking and bicycling.

We test this hypothesis in the cities of Pittsburgh and Lubbock (USA) using data collected from American Community Survey and US census bureau. Topological and angular configuration analyses of CAD drawn axial lines and street centrelines derived from GIS maps were performed for both cities. ArcGIS spatial analysis tools were applied to combine land use, socio-economic & demographic, transportation and space syntax variables to the scale of census block-groups that was selected as the study unit. Statistical analyses including stepwise and best-subset regressions were carried out to select relevant and significant variables explaining the use of NMT. The findings indicate that choice of transportation mode is significantly explained by multiple variables in which configuration features prominently. In the paper, we also describe and test our assumptions, comment on the selection of areas instead of axial lines as units of analysis, and postulate on the applicability of this research on creating sustainable communities.

Keywords

Space syntax, mode choice, walking, residential location, GIS.

1. Introduction

Increasing awareness of environmental issues has brought a focus on the choice of transportation modes that people living in large cities make regularly. One example is the increased awareness for air quality decline in metropolitan regions with land development patterns that overwhelmingly favour the automobile (Levine & Frank 2006). Use of cars when not necessary is a matter of concern in the US where 40% of total auto trips are shorter than 2 miles (National Household Travel Survey, 2007). Fifty percent of personal shopping and 22% of work trips are less than 1 mile, and 70% of personal shopping and 39% of work trips less than 2 miles (Moudon et al., 2005). Yet, even for these short trips, driving is the most utilized mode of travel. As policy makers are recognizing the need for an alternative to motorized journey to mitigate environmental impacts and to increase personal and social benefits, research on the factors that affect choice of non-motorized transportation (NMT), mainly walking, and cycling are gaining attention. This exploratory research is an attempt to understand if indeed street configuration plays a role and if so what might be the contribution of space syntax.

2. Research objective

The theory of 'natural movement' postulates that configuration of the urban grid is an important generator of aggregate patterns of movement in urban areas (Hillier et al. 1993). Retail and commercial land uses locate themselves at these configurationally hotspot locations to take advantage of the economic opportunities created by movement i.e. passing customers (Hillier 1996). We realise that these retail and commercial areas are also work places for a good number of people. Since distance of residential location from work is an important factor affecting the choices of transportation mode, we hypothesize that more walkers and bicyclists will live in integrated areas while car users will likely be in segregated areas. Moreover, car commuters will likely to live in their own homes and walkers in rented houses. We base these on the understanding that renters being more mobile can revise location decisions more easily than homeowners who might be constrained by a larger set of non-flexible housing options. The other objective of this study is to examine if indeed space syntax variables have a role in predicting transportation mode choice, especially when compared to those previously identified by transportation researchers; i.e. spatial, social, and economic factors. Finally, we also want to understand the differences that gridded and non-gridded cities offer in the study of transportation mode choice.

In this exploratory research, we investigate the factors for choosing one of four transport modes for going to work. We accept and use the classification done earlier by the US census bureau (US Census Bureau 2015) regarding transport modes, namely: driving, using public transportation, bicycling, and walking.

3. Literature Review

The literature review of transportation choice becomes difficult simply because of its interdisciplinary and cross-disciplinary nature. For example Kockelman, (1997) have explored the association between a number of dimensions and characteristics of urban form and travel behaviour. Land-use balance, mix, and accessibility were found to be more relevant to travel-behaviour prediction. Another research by Cervero & Kockelman (1997) has indicated that density, land-use diversity, and pedestrian-oriented designs are statistically significant for reducing trip-rates and encouraging non-motorised transport (NMT). Robert Carvero (2002) identified three core dimensions of built environments – density, diversity, and design. He asserted that intensities and mixtures of land use are significant in influencing mode choice, particularly decisions to drive-alone, share a ride, or patronize public transit. Additionally, the relationships of different socio-demographic characteristics with travel behaviour have been analysed by several researchers. Generally, the dependent variables for transportation mode choice can be classified in three categories: transportation factors, individual characteristics, and land use attributes.

Transportation variables that affect travel behaviour in urban areas include time for travelling, waiting and parking (Cervero 2002), travel distance, cost, reliability of transport mode, level of comfort, accident risk, etc. (Geurs & van Wee 2004). In some cases where driving takes a long travel time especially during peak hours, individuals might prefer alternative modes that offer a quicker trip. On the other hand, individuals are more likely to walk if they live in an area with a well-connected street network and an accessible train station (Kamruzzaman et al. 2014).

Individual characteristics such as age and motivation are important for transportation mode choice. For instance bicycling is more popular among male and younger adults, and those who are physically active (Moudon et al. 2005). Perception of environmental factors such as the distance to destination and the perceived quality of the route also has a role. If the available routes to be taken are unsafe, unpleasant, or unattractive, there will be reluctance to undertake the trip (Handy 1994). We need to keep in mind that individual characteristics are often tampered by idiosyncrasies. For example, Bhat & Guo's (2007) concern about income is pertinent. They have suggested that this may influence travel behaviour simply because higher income households not only are more likely to own cars; they might own several, and use them more than low-income households no matter where they live. This creates a situation where high-income households are less sensitive to the forces of built environment in their car use patterns compared to their low-income counterparts.

In summary, individual characteristics that affect transportation mode choice are car ownership, age, gender, race, employment status, having a driving license (or not), household structure, income, educational level, physical abilities etc (Greenwald & Boarnet 2001; Cervero 2002; Geurs & van Wee 2004; Bull et al. 2000). Other researchers have included additional factors such as home ownership (Fang 2008; Cao et al. 2009; Handy et al. 2005) and household tenure (Crane & Crepeau 1998).

Other researchers suggest that the observed associations between travel behaviour and neighbourhood characteristics are largely explained by the self-selection of residents with conducive neighbourhoods to their attitudes or lifestyle (Handy & Clifton 2001; Bagley & Mokhtarian 2002) Self-selection is a situation when individuals choose to live in the neighbourhood that is favourable for their desired mode of travel. In such cases, the attributes of the built environment are not a cause for mode choice. Rather, their preference of a certain mode of transport is the cause for selecting a neighbourhood (Handy et al. 2005).

Land use attributes are the most pervasive factors that are applied in transportation planning practices. They include land use density, diversity, job accessibility, labour force accessibility, ratio of sidewalks, distribution of multifamily households (Cervero 2002; Geurs & van Wee 2004), distance to downtown, and percentage of un-built land inside census tract (Crane & Crepeau 1998).

Proponents of the new urbanism and smart growth concepts claim a significant connection between the built environment and travel behaviour (Bhat & Guo 2007). They affirm that neighbourhoods with higher levels of density, land-use mix, transit accessibility, and pedestrian friendliness encourage the residents to drive less than in neighbourhoods with lower levels of these characteristics.

There are general observations that high density areas are characterized by smaller parking spaces, narrower streets and severe traffic (Fang 2008). The conditions of high-density areas generally work in favour of choosing smaller, easier to manoeuvre and more fuel-efficient vehicles. Moreover, they significantly influence mode change to non-motorized or public transport, which positively contribute in the reduction of driving. In contrast, low-density patterns of growth are associated with longer trip distances and greater reliance on the cars (Handy & Clifton 2001; Cao et al. 2009; Crane & Crepeau 1998).

4. Does configuration influence transport mode choice?

In this very important research area space syntax has a promising role to play. Literature review indicates that space syntax has been applied to analyze the effect of configuration on movement (pedestrian, cyclists, and vehicular) in urban environments. For example, the effect of axial lines on potential use of bicycles for home to work trips was examined in the city of Trondheim, Norway (Manum & Nordstrom 2013). Dai & Yu, (2013) have shown a strong correlation between axial integration and cyclist movements (R^2 of 0.77) in Hangzhou, China.

Some studies have combined configuration measures with GIS-based built environment variables and have found statistically significant associations of configuration with the average walking volumes (Lee & Seo 2013). In another study space syntax was used to investigate the walkability of historical urban squares analysing the street configuration and land use compositions to determine their relationship with levels of observed pedestrian movement (Liu & Jiang 2012). Additionally, it was applied to examine how configurationally shortest distance by space syntax method can influence path selection in the context of both urban and sparsely built suburban areas (Chiaradia 2007; Paul 2012).

In another investigation, space syntax was applied in trip generation and traffic assignment complementing the conventional traffic assignment and simulation approaches of the transportation planning discipline. Results indicated that configurational models (axial and segment) positively contribute to the estimation of potential traffic flows of urban street network. (Barros et al. 2006).

A series of papers (Hillier et al. 1993; Hillier 1996; Hillier 1999), now classic, have outlined a generic process by which spatial configurations, through their effect on movement, first shape, and then are shaped by, land-use patterns and densities. Inherently land use pattern follow the hidden property of spatial configuration. Some movement-attractive land uses naturally migrate to more integrated streets (axial lines). The process of attracting uses and multiplying movement has a cyclic nature shaping the land use pattern of urban areas (Hillier 1996; Thakuriah et al. 2012). Topçu et al. (2007) state "The layout of space first generates movement, then movement-seeking land use migrates to movement-rich lines, producing multiplier effects on movement which then attract more retail and other uses, and this leads to the adaptation of the local grid to accommodate the greater density and mix of uses. This dynamic process is called the “movement economy” (Topçu, Topçu, & Deniz, 2007 pp 01).

Taking the movement economy as our point of departure, we hypothesize that configuration with the help of movement first shapes the land use pattern, i.e. determine locations of retail commercial activities and residences, which in turn influence both choices of residential locations and the travel behaviour, particularly choices of non-motorized transport mode.

5. Methods and Data

We started by searching for US cities whose data was freely available in their official websites. We wanted two US cities that are similar in population but different in layout, one gridded and one non-gridded. After a thorough search of numerous city websites, we selected Lubbock TX and Pittsburgh PA. The former is a free standing city while the latter is part of a contiguous urban area. Lubbock is more than twice the size of Pittsburgh but has a third of its density. Its street network is characterized by a gridded structure with longer and fewer numbers of streets than Pittsburgh. Pittsburgh may be described as ‘organic’; dominated by short and larger number of streets (28,374 axial lines) compared to Lubbock (4,770 axial lines, see Figure 1a). Figures 10a and 10b in the appendix visually illustrate the street network differences between these two cities. Other relevant information about the two cities is shown in table 1 below.

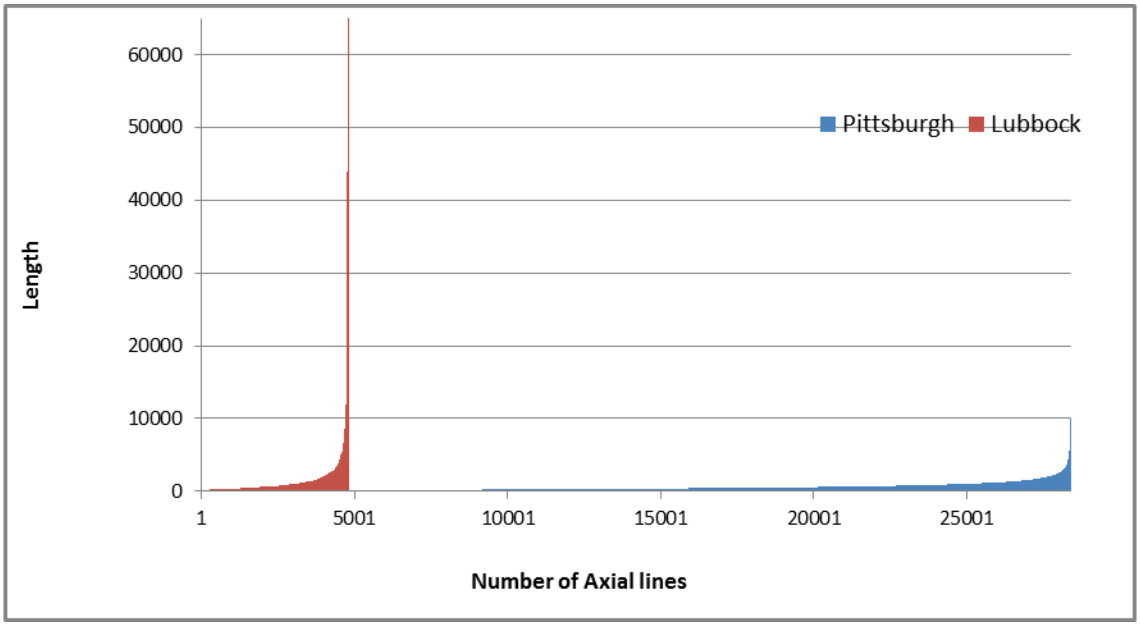


Figure 1: Comparison of Street length distribution of Pittsburgh and Lubbock.

Description	Pittsburgh	Lubbock
Area (Square Mile)	58.3	122.4
Population	305,704	229,339
Density (people per sq mile)	5521.4	1875.4
Racial mix	66% white	75.8% white
	21.1% black	8.6% black
Average travel time to work	22.8 minutes	15.1 minutes
Drive to work	64.3%	92%
Take Public Transport to work	20.7%	1.4%
Bicycle to work	1.1%	0.5%
Walk to work	9.9%	2.7%

Table 1: Spatial and Social Descriptions of Pittsburgh and Lubbock.

Since we took an exploratory approach to our research, we tried to be inclusive and began with a long list of variables. In general, the independent variables are in four categories: land use, social and demographic, transportation, and configurational (see table 3)

No	Variable name	Unit of measurements	
	DEPENDENT VARIABLES		
1	Driving to work	Percentage of workers drive to work places	
2	Bicycling to work	Percentage of workers bicycling to work places	
3	Public Transport	Percentage of workers use public transport to work places	
4	Walking to work	Percentage of workers walking to work places	
	INDEPENDENT VARIABLES		
	Land Use Variables		
1	Population density	Number of people per acre	
2	Age of buildings	Median age in years	
3	Property Value	Median value of properties	
4	Street density	Miles streets per Square Mile	
5	Commercial density	Number of Commercial parcels in census block group	
6	Distance to Centres or Sub centres	Average metric distance	
7	Building density	Percentage of building foot prints	
8	Vacant housing units for rent	Percentage of vacant houses that are available for rent	
	Socio-economic and Demographic Variables		
9	Race	Percentage of race (Black or White)	
10	Family income	Median income of households	
11	Homeowners	Percentage of home owners	
12	Renters	Percentage of renters	
13	Car Ownership	Average number of cars owned	
14	Gross rent	Median gross rent	
15	Number of rooms	Median number of rooms of residential buildings	
	Transport Variables		
16	Travel time	Average minutes spent in home to work trips	
17	Distance to PTS	Average distance to the nearest public transport stops	
	Space Syntax Variables		
	Variable name	**Variable type**	**Lines used to extract the variable**
18	Axial Choice	Choice	Axial Lines
19	Axial Integration	Integration	
20	Angular Axial choice	Choice	Segmented Axial Lines
21	Angular Axial Integration	Integration	
22	Angular Centreline Choice	Choice	Road Centre Lines
23	Angular Centreline Integration	Integration	

Table 2: Variables considered in this study.

The official websites of the two cities and the public website of United States census bureau contained all the data that was necessary for this study and were freely available for downloading. These data were manipulated as necessary using GIS and depthmapX 10 (Turner 2001) to produce the quantitative variables used in this study.

Figure 2: Census Block-Group maps of (a) Pittsburgh and (b) Lubbock.

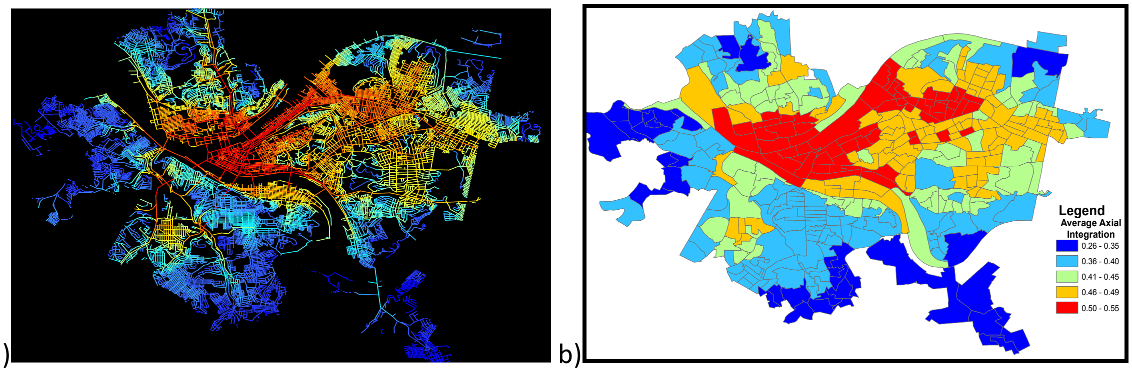
As described earlier, our study began with the assumption that integrated areas attract retail and commercial activates which also become workplaces for a good number of people. These in turn have an effect in the choices of residential locations. Furthermore, we assume that people who walk or bicycle to work will choose to stay close to their place of employment. Therefore, we expect to find more walkers and bikers living close to integrated areas -- not necessarily in the integrated streets themselves. From this point of view, our investigation had to be focused on defined areas of cities rather than streets and axial lines. Additionally almost all information regarding social, economic, and spatial data extracted from open access public websites are readily available at pre-defined sub-areas of cities (generally referred to as polygons in GIS terminology).

To resolve the unit difference between the configurational values that consider streets or axial lines and census variables available in polygons, we decided to convert the linear property of axial lines into census block-group polygons. US census bureau classifies spatial census units hierarchically from smallest to the biggest. The smallest spatial unit is called 'urban block'. It is a group of parcels and buildings enclosed by streets in all directions. Groups of urban blocks make up the second smallest spatial unit called 'census block-group', and many 'census block-groups' together make up a 'census tract'. In total Pittsburgh and Lubbock had 359 and 165 'census block-groups' respectively. The average size of such 'census block-groups' in Pittsburgh was 0.16 square miles, and in Lubbock it was 0.52 square miles. For our purpose we selected a 'census block group' as the spatial unit of this study and all data was assigned to these units.

We fully realise that aggregating space syntax data to the census block groups may have weakened the linear descriptive power of axial lines; however, the distribution of axial values across the city remains similar, and this is visually clarified in Figures 3a and 3b for Pittsburgh and Figure 4a & 4b for Lubbock. One real world advantage of this aggregation method is that it offers significant reduction of data collection costs and efforts because it allows the use of census data that are readily available.

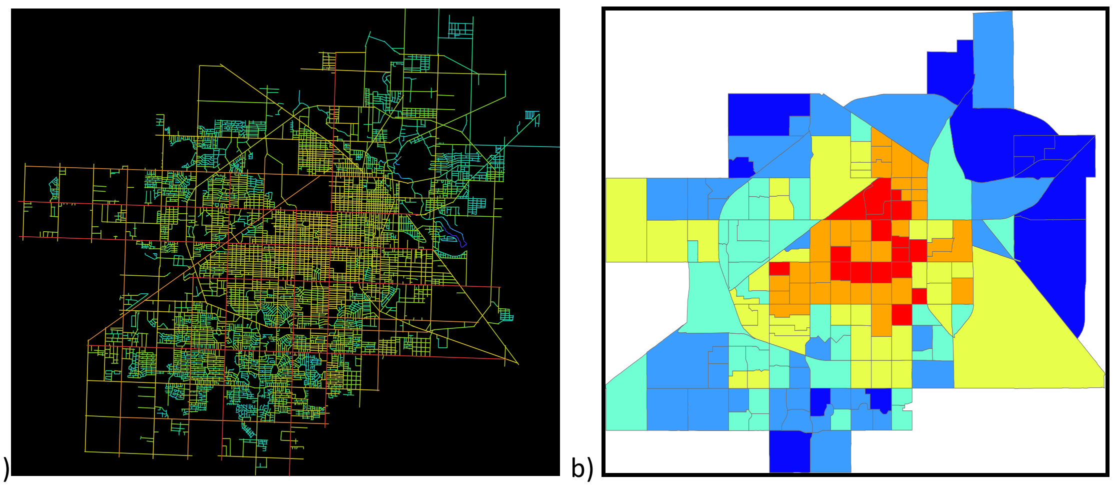
6. Statistical analysis

We were interested in understanding the effects of a large number of variables on the choice of four transport modes to go to work: driving, taking public transportation, bicycling, and walking. For this, we undertook a series of statistical analysis to select the best models for each transport mode.



a) b)

Figure 3: (a) Line map of axial integration (b) Polygon map of average axial integration of Pittsburgh.



a) b)

Figure 4: (a) Line map of axial integration (b) Polygon map of average axial integration of Lubbock.

Since we were considering a large dataset, we began with a collinearity diagnostic test to detect multicollinearity problems between the independent variables. During each step of the collinearity diagnostics test, one variable with highest variance inflation factor (VIF) value was eliminated. The procedure continued until the VIF of all variables were below 10. Consequently, three out of the total 23 independent variables from Pittsburgh (race, VIF value 24.19, angular axial integration, VIF value 17.8, and angular centreline integration VIF value 13.5) and two variables from Lubbock (home owners VIF value 23.1, and angular axial integration VIF value 13.9) were dropped.

The colinearity of axial integration, angular integration of segmented axial lines, and angular integration of road centrelines were expected in our VIF test because they measure similar syntactic properties with different methods. We also tested their explanatory power to each transport mode and discovered that there were no major differences on the models when they were replaced with one other.

The second process was stepwise regression using SPSS statistical software to select variables that most explain each of the four dependent variables. Four stepwise regressions (one for each transport mode) were performed in each city and a model for each dependent variable was selected with appropriate sets of significant independent variables. For Pittsburgh, axial integration was significant in three of the four models: driving, bicycling and walking, (R^2 values of 0.55, 0.37 and 0.46 respectively, see table 3). It must be noted that the space syntax variable was not included in the model of public transport mode. It should also be noted that integration is positively correlated with walking, but negatively correlated with driving to work. In the case of Lubbock, space syntax variables were also included in models of walking and driving to work. However, in this case, instead of axial integration axial choice was selected and it had a similar positive correlation with walking, and negative with driving (table 4).

Pittsburgh **Dependent Variable: Driving , R2 = 0.548, Adjusted R2 = 0.539)**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	93.076	9.983		9.323	0.0	73.432	112.719
Axial Integration	-94.584	16.414	**-0.286**	-5.763	0.0	-126.88	-62.288
Car Ownership	27.292	2.559	0.494	10.663	0.0	22.256	32.328
Property Value	-4.83E-05	0	-0.243	-5.433	0.0	0	0
Travel Time	-0.342	0.124	-0.118	-2.76	0.006	-0.586	-0.098
Population density	-0.235	0.088	-0.11	-2.668	0.008	-0.409	-0.062
Vacant for Rent	-0.354	0.163	-0.086	-2.173	0.031	-0.674	-0.033
Pittsburgh Dependent Variable: **Public Transport, R^2 = 0.522, Adjusted R^2 = 0.513**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	2.925	6.148		0.476	0.635	-9.173	15.023
Car Ownership	-13.953	2.543	-0.345	-5.488	0.0	-18.956	-8.95
Travel Time	0.707	0.088	0.333	8.012	0.0	0.533	0.88
Race (White)	-0.135	0.023	-0.294	-5.905	0.0	-0.179	-0.09
Renters	0.207	0.043	0.268	4.804	0.0	0.122	0.291
No of Rooms	2.511	0.807	0.177	3.112	0.002	0.923	4.098
Family Income	4.14E-05	0	0.109	2.377	0.018	0	0
Pittsburgh Dependent Variable: **Bicycling to Work, R^2 = 0.372, Adjusted R^2 = 0.139**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-6.189	1.077		-5.745	0.0	-8.308	-4.069
Axial Integration	13.757	2.265	**0.327**	6.073	0.0	9.299	18.214
White	0.020	0.004	0.258	4.789	0.0	0.012	0.029
Pittsburgh Dependent Variable: **Walking to Work, R^2 = 0.463, Adjusted R^2 = 0.451**							
Model	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
(Constant)	3.684	7.43		0.496	0.62	-10.937	18.304
Axial Integration	39.303	12.179	**0.175**	3.227	0.001	15.339	63.267
Travel Time	-0.434	0.093	-0.22	-4.655	0.0	-0.617	-0.25
Property Value	2.83E-05	0	0.209	4.07	0.0	0	0
Commercial Density	0.276	0.068	0.191	4.078	0.0	0.143	0.409
Vacant for Rent	0.482	0.12	0.173	4.013	0.0	0.246	0.718
Car Ownership	-9.629	2.055	-0.256	-4.686	0.0	-13.672	-5.586
Gross Rent	0.005	0.003	0.103	2.029	0.043	0	0.01

Table 3: Multiple regression models of four-transport modes for the city of Pittsburgh.

Lubbock Dependent Variable: **Driving to Work**, R^2 **= 0.498, Adjusted** R^2 **= 0.248**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	105.439	3.364		31.340	.000	98.786	112.093
Vacant for rent	-.657	.128	-.385	-5.150	.000	-.909	-.405
Axial Choice	-1.718E-5	.000	**-.261**	-3.399	.001	.000	.000
Travel Time	-.498	.176	-.216	-2.827	.005	-.846	-.150
Lubbock Dependent Variable: **Public Transport to Work**, R^2 **= 0.356, Adjusted** R^2 **= 0.127**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	4.444	1.103		4.028	.000	2.262	6.625
White	-.047	.014	-.282	-3.483	.001	-.074	-.021
Vacant for rent	.127	.056	.182	2.249	.026	.015	.238
Lubbock Dependent Variable: **Bicycling to Work**, R^2 **= 0.381, Adjusted** R^2 **= 0.145**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-1.659	.639		-2.597	.010	-2.921	-.396
Home Renters	.020	.008	.210	2.442	.016	.004	.036
Street Density	.068	.029	.185	2.323	.022	.010	.126
Vacant for rent	.079	.036	.192	2.228	.028	.009	.150
Lubbock Dependent Variable: **Walking to Work**, R^2 **= 0.514, Adjusted** R^2 **= 0.264**							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-5.388	2.287		-2.356	.020	-9.910	-.865
Vacant for rent	.514	.087	.439	5.926	.000	.342	.685
Axial Choice	9.961E-6	.000	**.220**	2.899	.004	.000	.000
Travel Time	.276	.120	.175	2.310	.022	.040	.513

Table 4: Multiple regression models of four-transport modes for the city of Lubbock.

In addition to the global space syntax measures, we also tested the effects of local angular integration (with radius of 400, 800, and 1600 meters) on walking and bicycling. We did not find any statistically significant associations between them in either city.

7. Discussion

Clearly, space syntax variables play a significant role in decisions for walking and driving to work, as was demonstrated by our inclusive methodology. Furthermore, we see that people living in more segregated areas of Pittsburgh and areas with less Choice values in Lubbock preferred to drive. In order to be more confident of our results we went back and made sure that our initial assumptions were justified. These were:

- Retail and commercial areas are located in more integrated areas
- Because retail and commercial areas are also workplaces for a good number of people, and among them who prefer walking will live close to these integrated areas, perhaps not in the integrated areas themselves.
- Drawing from a general understanding of mid-sized American cities, we also expected that home owners will prefer peripheral segregated suburban locations, and more rental properties i.e. more renters will be closer to more integrated areas,
- From this, it easily follows that home owners will also be car owners and their major mode of transportation will be driving, and finally
- A reverse of this argument implies that renters will have fewer cars and will prefer to walk (also assumption 2).

Scattergrams shown in Figures 5 to 10 indicate that in general, our assumptions were statistically significant, albeit not very strong; and in comparison, Lubbock's values were consistently lower than Pittsburgh. Unfortunately, the first assumption, i.e. retail and commercial areas will be located in integrated areas, could not be verified for Lubbock.

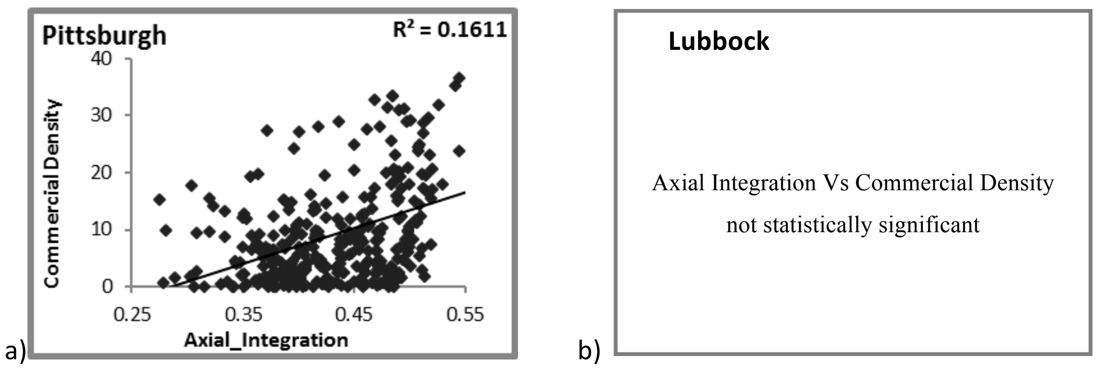


Figure 5: Correlation between Axial Integration and Commercial Density.

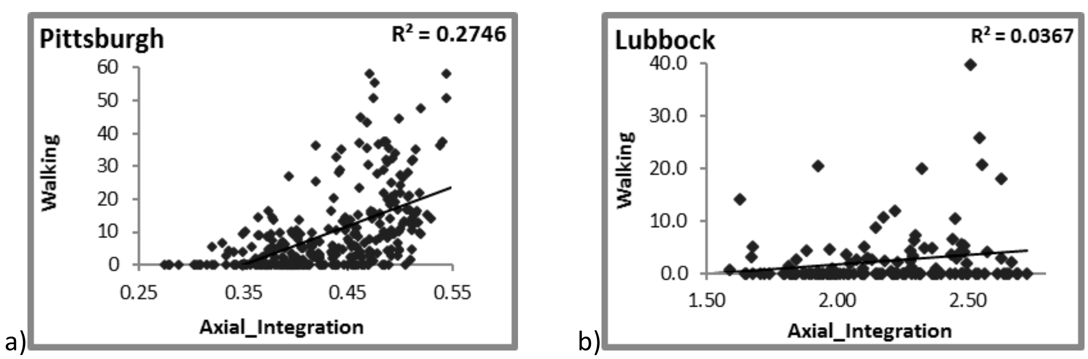


Figure 6: Correlation between Axial Integration and Walking.

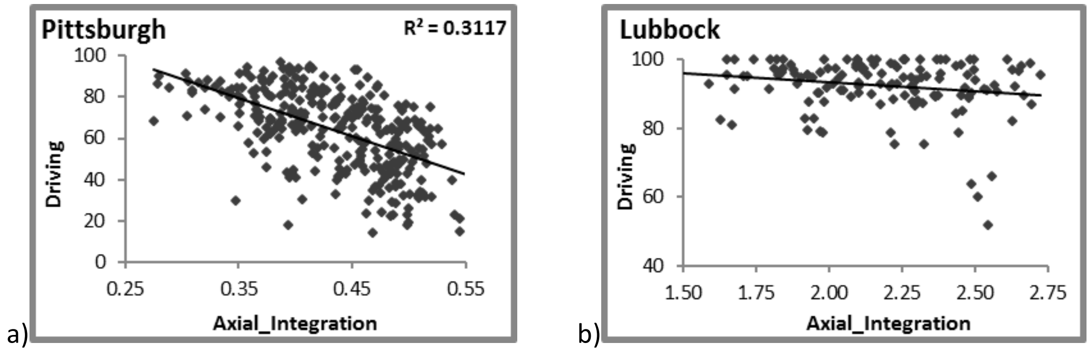


Figure 7: Correlation between Axial Integration and Driving.

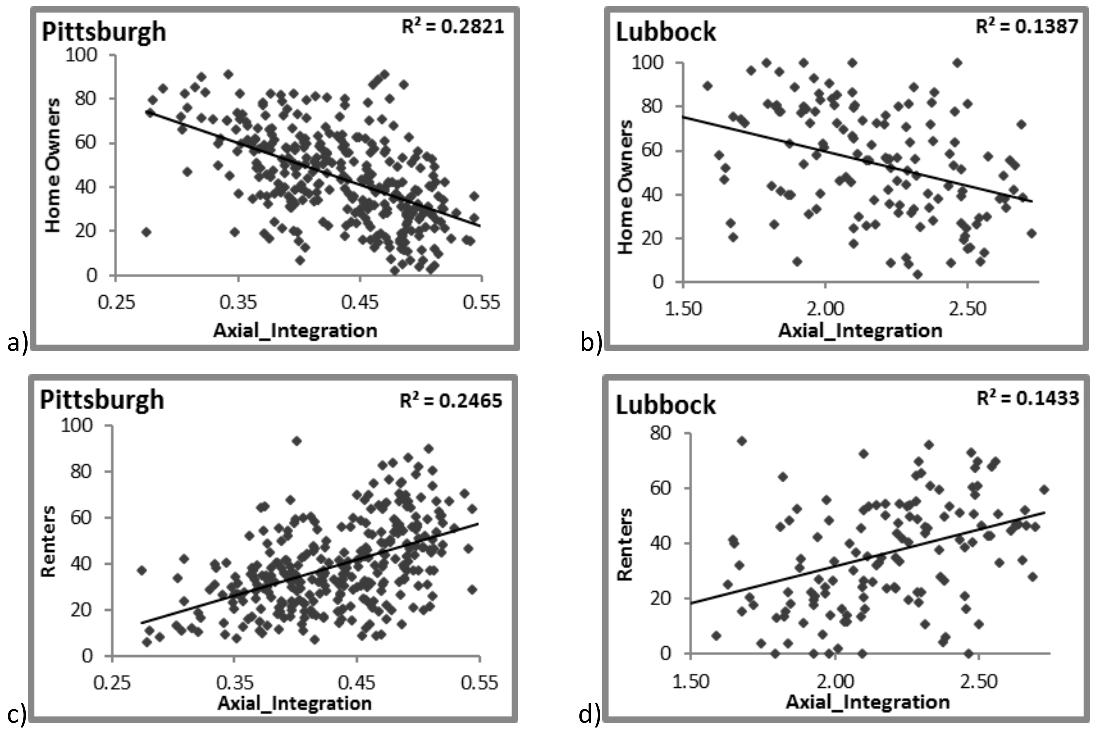
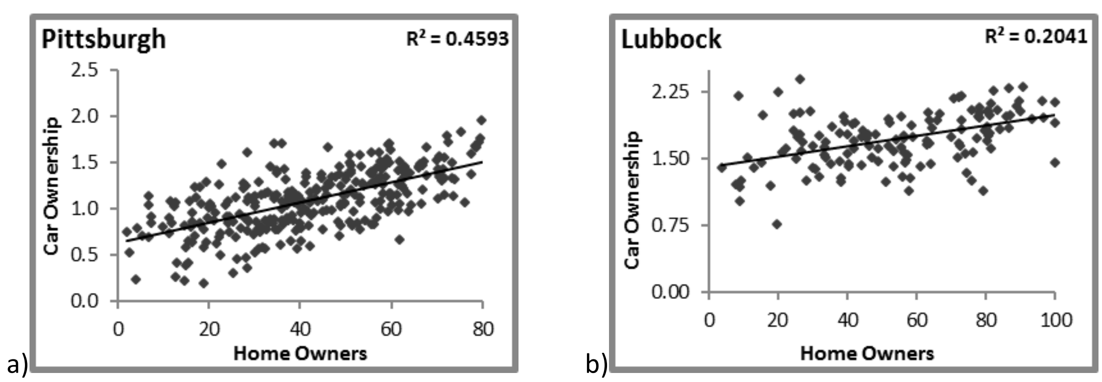


Figure 8: Correlation between Axial Integration and Homeowners/Renters.



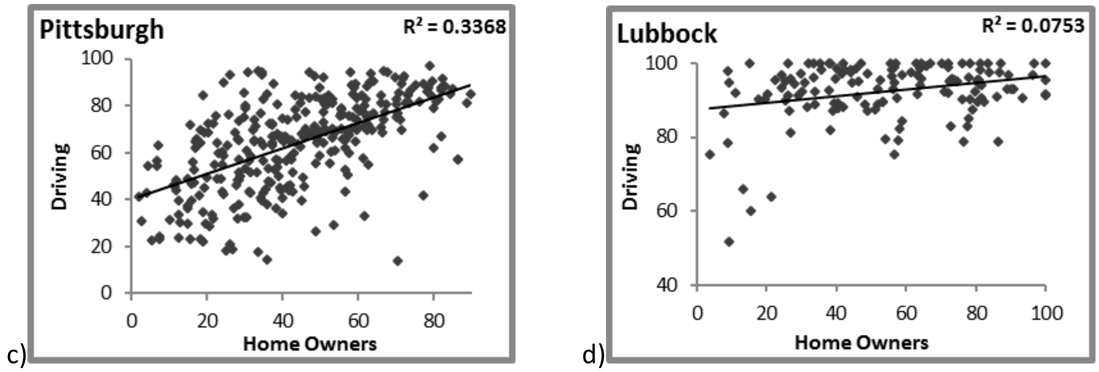


Figure 9: Correlation of Homeowners with Car ownership and Driving.

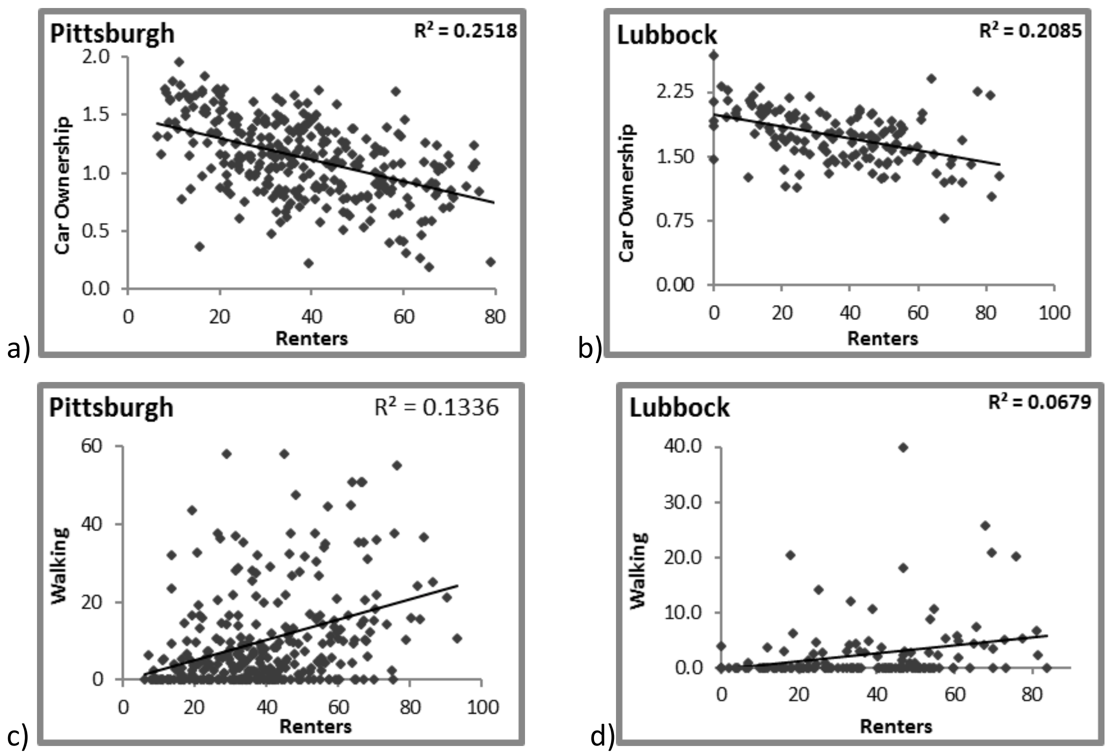


Figure 10: Correlation of Renters with Car Ownership and Walking.

As we had seen from our multiple regressions integration was not selected for Lubbock, but axial choice was. These two variables (with axial lines as units) are correlated amongst themselves, but quite poorly. Indeed, Lubbock's R-value is slightly higher (R^2 = 0.06) than Pittsburgh's (R^2 = 0.02). However, from the aggregated dataset (i.e. census block groups as units) the two variables are strongly correlated to each other with an R^2 value of 0.43 in Lubbock and 0.12 in Pittsburgh. Although Choice was selected in the multiple regression models of Lubbock, Integration was also statistically significant in simple linear regressions explaining driving and walking modes (see Figure 6b and 7b). To get a satisfactory answer to this enigma, we might have to study the specific behaviour of gridded cities, in much more detail taking into account both configurational, socio-economic characteristics and land use patterns. It will be a topic for future research.

This research has shed some light on the explanatory power of space syntax on choices of transport mode to work and the selection of residential locations in urban environments. The findings of this study are important steps toward future research to understand the configuration of urban street network as a generator of movement through which residential development and travel behaviour are understood. As such, it can also be an important tool to achieve the objectives of sustainability by creating walking friendly urban network, to reduce the ever-increasing greenhouse gas emissions. Finally, the methodology of aggregating data into census block groups makes analysis cost effective by negating the need of expensive data collection, as more and more GIS based data are freely and publicly available.

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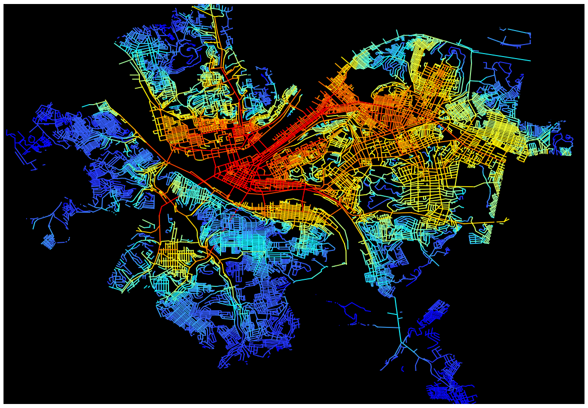
8. Appendix

a) 

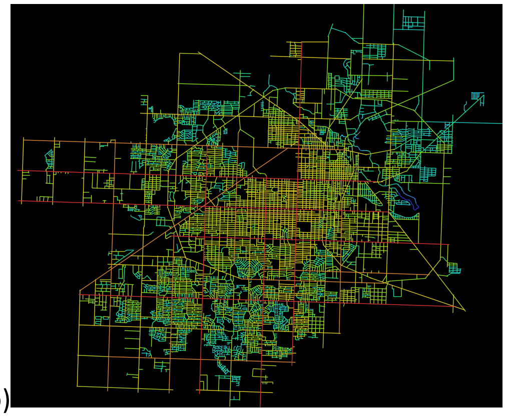
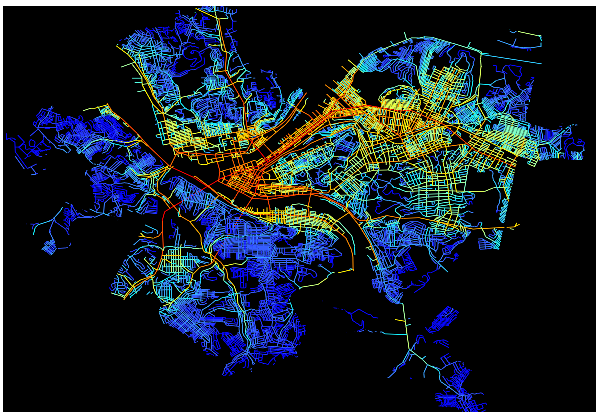
b) 

Figure 11: Axial (topological) integration maps of (a) Pittsburgh (b) Lubbock

a) 

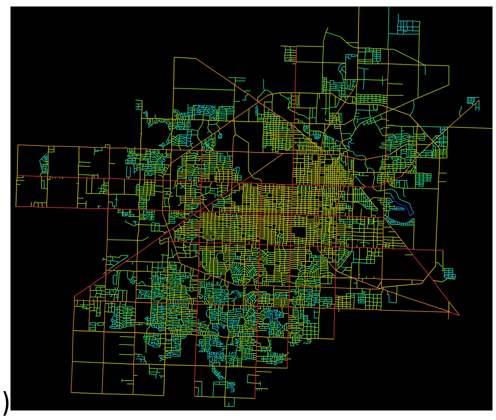
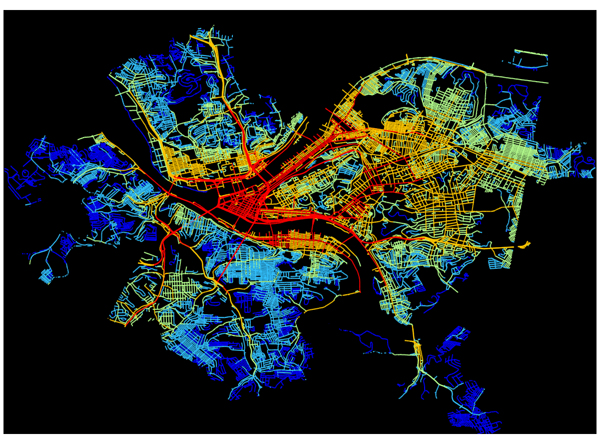
b) 

Figure 12: Angular integration maps of (a) Pittsburgh (b) Lubbock.

a) 

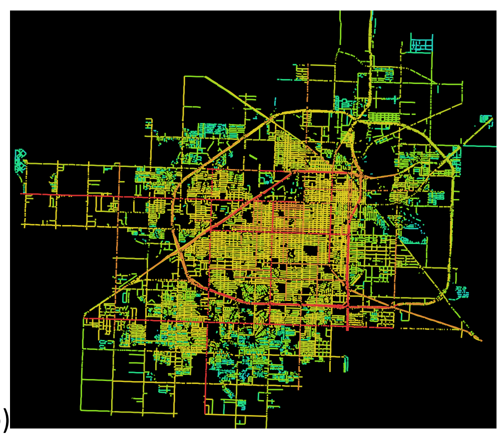
b) 

Figure 13: Road Centreline Angular Integration of (a) Pittsburgh (b) Lubbock.

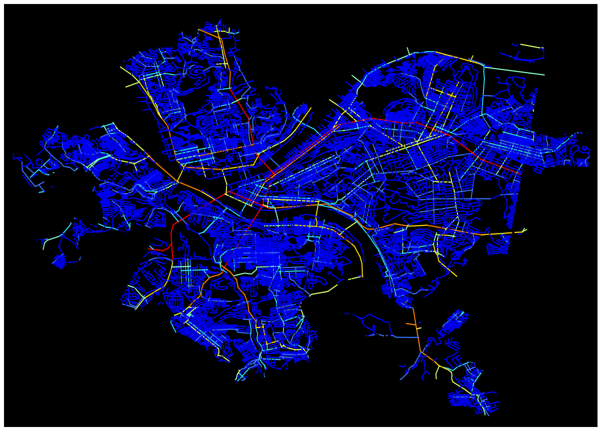
a)  b) 

Figure 14: Axial (topological) Choice of (a) Pittsburgh (b) Lubbock.

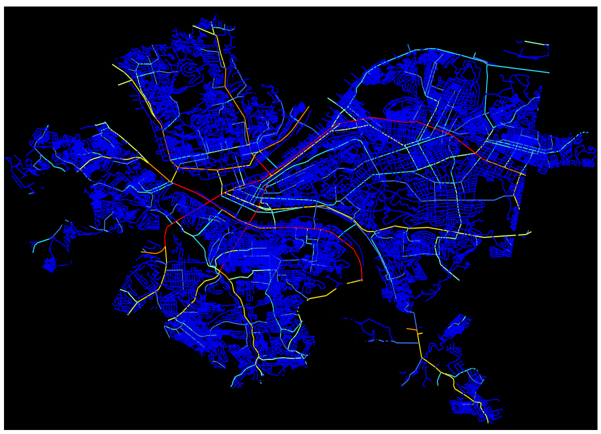
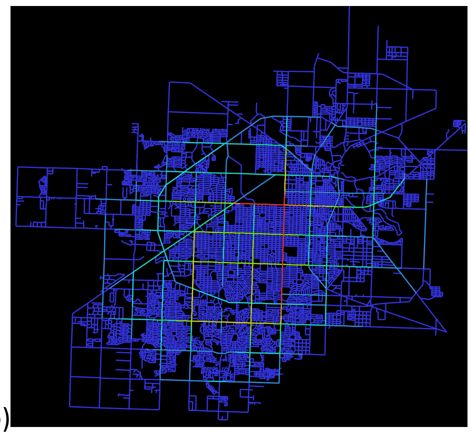
a)  b) 

Figure 15: Axial Segment Angular Choice of (a) Pittsburgh (b) Lubbock.

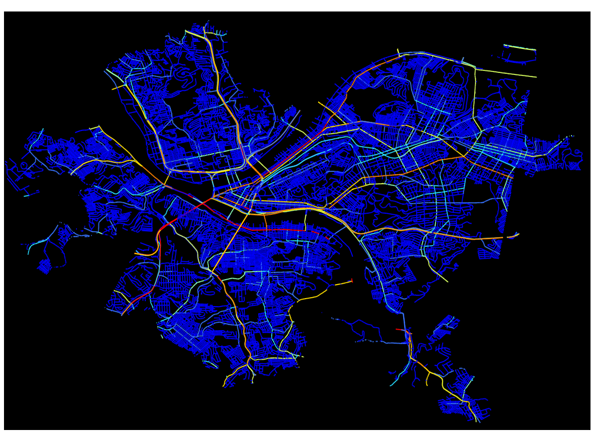
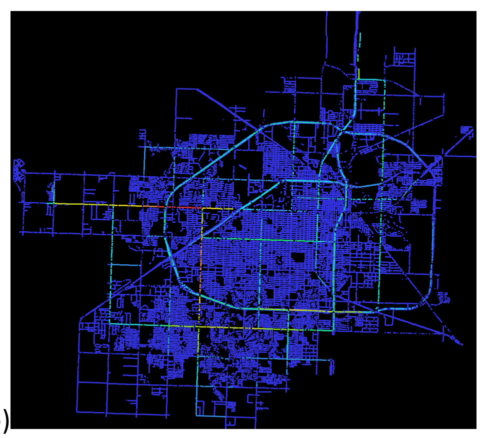
a)  b) 

Figure 16: Road Centreline Angular Choice of (a) Pittsburgh (b) Lubbock.