CALIBRATING AXIAL LINE MAPS

090

Bernd Eisenberg
Institute for Landscape Planning and Ecology, University of Stuttgart

Keywords:

Axial line map
Hamburg
Stuttgart
Location related measure

Bernd Eisenberg
Institute for Landscape Planning and Ecology, University of Stuttgart, Keplerstrasse 11, 70174 Stuttgart - Germany
be@ilpoe.uni-stuttgart.de

Abstract

This paper deals with the impact of different map scale and various morphological features on the configurative representation of cities with axial line maps. It is explored why in two different cities the change in scale and resolution result in very different patterns of integration. It is argued that the underlying morphological properties of the cities are the main factors for the divergence and that differences in scale or the process of generating axial line maps have a minor impact. Axial line maps of the cities of Hamburg and Stuttgart are compared for both cities they differ in level of detail and in scale (1:2.500 to 1:25.000). For Hamburg, different integration patterns evolve, for Stuttgart, a persistent centre of integration remains. A validation with traffic data shows in no case a preference for one of the types of axial line maps. Based on these findings, two location related measures are proposed for estimating the degree of differences between divergent axial line maps. The “rank correlation measure” and the “step depth matrix measure” both enhance the way of analysing and comparing configurations. They have the potential to be adapted to further kinds of spatial analyses.

Introduction and Background

Irritations

This paper was triggered by the irritating observation that, when analysing various axial line maps with space syntax techniques, the city of Hamburg has an unstable centre of global integration. The dissimilarities are striking: The axial lines that indicate the most integrated parts are 1.6 km up to 4.5 km away from each other, or using space syntax terminology, the two closest axial lines are 2 syntactic steps away from each other, the farthest 7 steps. It is worth noting, that none of the most integrated axial lines mark out either the commercial or the political centre of Hamburg[i]. One of the axial lines is along the most traffic loaded street, another axial line is part of the main street of the red light district, a third connects the historic city centre to the North, the fourth and fifth are main traffic arteries, all of them are grouped around the centrally located Alster lake (see figure1).

The underlying axial line maps (ALMs) originate from different basemaps with different scales (see part 3 for details), so first answers at hand are that the variations evolve from the different scales and consequently the different size -numbers of axial lines - of the ALMs compared. Validating the ALMs with traffic data[ii] is therefore the next step. This time the similarities are surprising: Three of the four ALMs tested show significant correlation values both for global integration and global choice, with r^2-values that are promising for further analyses (see table 1).

Figure 1:

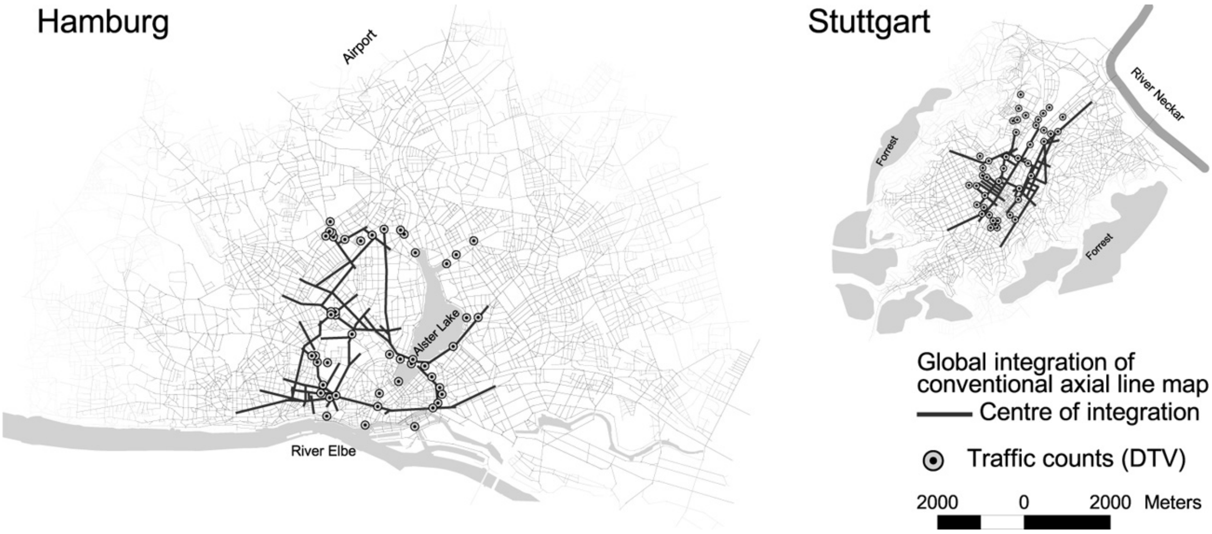
Global integration of four axial line maps of central Hamburg. Highlighted are the 25 best integrated axial lines

In the same way the analyses is performed for different ALMs of the city of Stuttgart. The morphology of the city is quite the opposite to the one of Hamburg. While Hamburg has a vast open space in the centre of the city, the Alster lake, the city of Stuttgart is situated in a basin, with densely built up areas, surrounded by hills that inhibit the growth of the city (see figure 2). The same kind of ALMs, based on different scales, are tested. The analysed ALMs hardly show any differences when comparing global integration values: The most integrated lines are directly connected to each other. They are centrally located at the high street and at the main road through the inner city, passing the historic, political, cultural and commercial centre of Stuttgart. Traffic data of three out of four ALMs again correlates significantly with global integration and global choice, and r^2-values are similar in Stuttgart and Hamburg (see table1).

The results after the first analyses are: In one city, there is a collection of ALMs that indicate an unstable centre of global integration, in another city there are ALMs with a persistent centre of integration. For both cities, attempts to calibrate the configuration with traffic data show no clear preferences for any of the tested configurations.

Figure 2:

Global Integration, conventionally digitized map for Hamburg (HHand) and Stuttgart (SHand)



Two lines of discussion start from here. First, why does the change in scale and resolution result in very different patterns of integration in one case while the changes in scale seem meaningless in the other? Second, are the shifting centres and the stable centres due to morphological properties of the two cities or artefacts of the process of map making?

This leads to further questions that guide the following analysis:

How can the degree of differences between axial line maps be measured? What are the effects of scale and grain on the configurative representation of the city? What are unique configurations, with meaning for analyses of urban morphology?

Clarifying the Issue of Similarity

The following section highlights the need for a clear understanding of the degree of differences or congruence between axial line maps or other representations of space.

There is an increase in digital data that can be used for space syntax analysis: Data that either can be implemented in network analyses as axial or segmented lines, like road centre lines (Dalton et al 2005). Or the kind of data used in this study, a block based cartographic representation of the city, which can be used to define convex space in order to create all line maps and resulting fewest line maps for axial line analyses. Additionally, the development of new analytical tools creates even more types of weighted axial line (Turner, 2007; Dalton, 2001), segmented line, or continuity line maps (Figueiredo and Amorim, 2005). How different are they? Even if one of these line maps proves more reliable than the others and sets the standard, the question of divergence or similarity remains.

A number of studies compare different cities in order to explore fundamental rules of urban growth (Carvalho and Penn 2004) or typologies (Medeiros and Holanda 2005). Therefore it is essential to know whether these cities are actually comparable. Another field of investigation are local to global relations, for instance the implementation of highly detailed maps of small extent into less detailed maps of greater extent. It would be fruitful to know about the degree of difference between the rough sketch and the detailed map and how much the whole configuration is really changed by it. For regional, campus wide and building wide analyses see Read (2005) Dara-Abrams (2006) and Koch (2005).

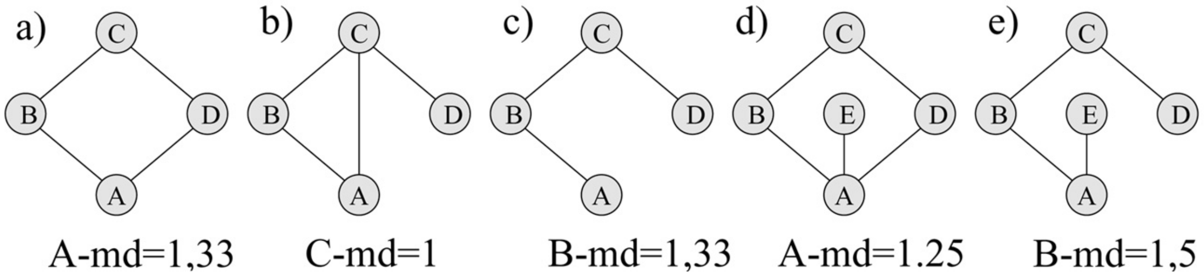
Finally, a very common task, is to compare different networks of movement within one city. This ultimately leads to alterations in the underlying convex space and the ALM. Just by looking at the urban scale, we can easily distinguish between vehicular, bicycle, pedestrian movement and when one decides to take different user groups, one ends up with a whole range of different configurations that can be compared to observation data, land use etc. But how much do the configurations really differ? After all it is still the same city. See as an example Raford. et al (2005) for bicycle movement, Read (2005) for combining movement networks, Van Nees (2005) for pedestrian and car based movement. In order to evaluate these questions, we look for the degree of differences between configurations of ALMs and attempt to describe key parameters.

Configurations and Differentiating Axial Line Maps

Some basic remarks on differences in space syntax measures. A collection of spaces and their connections is called configuration (figure 3a). The configuration is altered and becomes another configuration when a) the number of spaces remain the same but connections between spaces are changed (figure 3b-3c) b) the number of spaces and the number of connections is changed (figure 3d), and c) the number of spaces is changed and the location of connections is changed (figure 3e).

Figure 3:

Modificaton of a configuration. md = mean depth of best integrated space (md=total depth/n-1)



When performing one of the above mentioned changes, the configuration changes altogether. Like in the case of Hamburg, the alterations lead to different “centres" of integration. But just because the integration values (in figure 3 the mean depth values) are different, the underlying structure itself is not necessarily different. Comparing figure 3a and 3d or 3c and 3e shows that the physical form of each pair is fairly similar, despite very different md-values. Hillier (1996, pp 282) explains how different the consequences of minor changes in a configuration for the overall configuration can be. He shows how location matters, but from the pure numbers, it is not possible to decide, if and where exactly the configuration is altered as illustrated in figure 3a and c. However, the impact of a change depends on the size of the configuration and as shown in part three of “Space is the Machine”, it depends very much on the location[iii].

What means differentiating axial line maps under these conditions? The aim of this study is to determine the relationship between configurations on the basis of configurative measures but with a stronger focus on the location of key features. As pointed out in the previous paragraphs, the basic reasons why differences between the outputs evolve are clear. What remains unclear is the degree of differences and where the differences originate from.

Methodology

Testing Scale, Level of Detail, Procedures

What is reasonable to compare? Firstly, the impact of base map scale for the configuration; secondly, different levels of detail; thirdly, different city morphologies' and finally, ALMs that are generated with different procedures.

Scale

Three scales are tested. The standard scale 1:2.500 – 1:5.000, the block map scale 1: 10.000 and the city map scale 1: 25.000. The standard map is conventionally digitised; the block map and the city map are generated with Depthmap software (Turner, 2001; Turner et al, 2005). The block map and the city map are modified because some boundaries of convex space like the ones between open spaces covering land and water areas were missing in the original dataset. For performance reasons, the drawings are also simplified, e.g. the number of vertices is reduced using GIS procedures[iv].

Level of detail

In order to compare different levels of detail, morphological elements were excluded from the conventionally digitized maps. ALMs with axial lines in park space have a higher level of detail. For the Hamburg case, all park related axial lines were excluded. There are good reasons for excluding axial lines in park space from an urban analysis because of unclear representation of park space as axial lines (Dara-Abrams 2006), partially restricted use, avoidance by users.

For the Stuttgart case, about 150 public stairs were excluded, reducing the ALM altogether by 550 axial lines. The public stairs connect the inner city in the basin to the neighbouring areas on the surrounding hills. Excluding them makes sense, for instance for an analysis of solely car based movement.

Table 1:

*Summary of the ALMs tested. (** significance at the .01 level; * significance at the .05 level)*

Description	Procedure	Abbre-viation	Scale	r^2 for traffic data	
				int. r=n	ch r=n
		Hamburg			
conventional ALM	digitized	HHand	1:5.000	.11*	.28**
conventional ALM	digitized	HHand2	1:5.000	-	-
block based ALM	Fewest line Map -subset	HBB	1:10.000	.26**	.33**
block based ALM	Fewest line Map -minimal	HBB2	1:10.000	.23**	.35**
city map based ALM	Fewest line Map -minimal	HCM	1:25.000		.09*
		Stuttgart			
conventional ALM	digitized	SHand	1:2.500		.27**
conventional ALM	digitized	SHand2	1. 2.500	.27**	.11*
block based ALM	Fewest line Map -subset	SBB	1:10.000	.13*	
block based ALM	Fewest line Map -minimal	SBB2	1:10.000	.20**	.23**

Procedures

Different procedures of generating ALMs are compared with the two fewest line maps – subset and minimal – that can be generated with Depthmap Software[v]. Fewest line maps - subset (FML-S) cover all of the convex space and contain parallel and almost identical lines, fewest line maps – minimal (FML-M) are the most rigid interpretation of the rule to draw axial lines as the longest and fewest lines covering all convex space (Turner et. al. 2005). As described in Turner et al (2005, p. 442), in some cases the ideal coverage of convex space can not be achieved with the fewest lines minimal procedure. In those cases the respective lines of the FML-S are copied to the FML-M. For the city map scale, only the FML-M was used and it was not altered at all.

How to Measure Differences?

090-06 Before the measures are explained in detail, the underlying assumptions are described. Because it is the aim to explore the degree of differences between global integration, the proposed measure has to capture the essence of integration, depth and its distribution in the configuration. Second, in order to extend the analysis to conventional graph analysis, a measure related to graph analysis should be tested. Third, location matters and finally, different levels of robustness related to the comparison should be evaluated. Two parameters derived from space syntax analysis – global integration and global choice (betweeness in conventional graph analyses) – are chosen to describe differences between configurations. Since the starting point for this paper was the observation of unstable global integration centres, this parameter has to be used. In order to test the changes of graph properties, global choice is analysed. A two tier approach is used to compare the configurations using the two parameters.

Approach 1: Rank correlation of the axial line values global integration and global choice.

Approach 2: Step depth matrix for highly integrated lines.

Rank correlation

For a comparison across different configurations, integration values are too different (see table 2). Ranking the axial line values according to integration and choice simplifies the values but leads to a comparable structure.

Procedure: The first step is to calculate global integration and global choice. In the second step, the axial lines are ranked according to their values. In a third step, all top 100 ranking lines are assigned the respective values of the other ALMs. In cases where the location of axial lines is too different, no relation is made. In the cases of the division of a line of one AML into two lines in another AML, the highest ranking line is selected as a correspondent. If the line has more than two correspondences, none is selected. The fourth step leads to building a matrix with all top 100 ranks of the ALMs. In the fifth step, the differences between ranks are visualised and in the sixth step, correlations between the ranks for global integration and for global choice are examined.

Step depth matrix

The second comparison is based on the j-graph of the axial line. A j (justified)-graph visualises, step by step the path of a given line through the network until every other axial line is reached. For this analysis, the procedure is simplified and only the sum of the lines reached at every step is taken to generate a step depth matrix. The step depth matrix describes the relation of one line to all other lines, and it shows how many axial lines are reached at a corresponding syntactic distance. Thus differences in integration can be identified in relation to the initial line. As representative lines for the network, the most integrated axial lines are selected. Global choice has no relation to step depth, therefore axial lines with high choice value are not selected.

Procedure: First, the step depth values for the most integrated axial lines of each configuration is generated, using the step depth command in Depthmap Software. In a second step, the number of axial lines reached with every step is summarized. In a third step, a z-value standardisation transforms the line/step numbers in order to make the values comparable across configurations of different size (number of axial lines). In the fourth phase, the range of standardized step depth sum is plotted against the respective step depth. Finally, the results are visually analysed and a proximity index of the depth step matrix is calculated.

Results

Global Integration

A comparison of the global integration values of the ALMs of Hamburg and Stuttgart shows a wide range of integration values (table 2). The biggest differences can be found between the detailed digitized ALM and the block based (subset) ALM of Stuttgart. The variations between the morphologically different ALMs of Hamburg are very small. The roughly 600 "missing" axial lines from parks have no significant impact on the average, minimum or maximum values. The comparison between the two conventionally digitized maps of Stuttgart indicate a bigger impact due to the exclusion of public stairs and park connections[vi]. For the block based ALMs, a similar decline of integration values can be found for both cities (0.82 – 0.74 and 0.85 – 0.75).

Table 2:

Global integration values of Hamburg and Stuttgart. MD = Mean Depth

	Hamburg 135 km²				
global integration	HHand	HHand2	HBB	HBB2	HCM
Count	6326	5615	5164	3942	3605
Mean	**0.59**	**0.58**	**0.82**	**0.74**	**0.86**
Maximum	0.86	0.84	1.16	1.06	1.27
Minimum	0.31	0.28	0.43	0.37	0.49
MD, min	**9.8**	**12.7**	**9.4**	**9.8**	**8.3**
MD, max	26.5	35.8	23.9	26.5	19.8
Min. Length	10	10	26	36	54
Max. Length	3037	3037	4056	3542	4090
	Stuttgart 30 km²				
	Shand	SHand2	SBB	SBB2	
Count	3728	3285	2749	2267	
Mean	**0.61**	**0.54**	**0.85**	**0.75**	
Maximum	1.01	0.90	1.40	1.25	
Minimum	0.31	0.29	0.35	0.33	

Rank Correlations

Visualising rank differences

For each axial line map, the lines are ranked according to the values for global integration and choice. Table 3 shows as an example the differences between the ranks for global integration and global choice of the compared ALMs up to the rank 5 of the conventionally digitized map. For the analyses of Hamburg rank 1-100 and for Stuttgart rank 1-50 are selected. In general, the ranks for global choice seem to be more similar than the ranks for integration in all the ALMs and there seems to be a greater difference between the Hamburg ALMs than between the ones describing Stuttgart.

In Figure 4, axial lines with a +/- 2 difference in rank are coloured with bold black lines, gray lines indicate a +/-10 rank difference and dotted lines a variation of +/-50 ranks. Rows 1 and 3 visualise rank differences of global choice, rows 2 and 4 rank differences of global integration.

In column 1, the difference between the detailed conventionally digitized ALM (HHand, SHand) and the less detailed conventionally digitized ALM (HHand2, Shand2) is illustrated. In column 2, differences between the detailed digitized ALM and the detailed block based ALM (HBB, SBB) are shown and in column 3, the detailed ALM and the block based minimal ALM (HBB2, SBB2) are compared. The two block based ALMs are compared in column 4. In all illustrations, a higher degree of similarity results in more visible axial lines. It does not come as a surprise that the two pairs of ALMs – conventionally digitized and block based – "look" more similar.

Table 3:

Matrix of the global integration ranks and the global choice ranks of four different axial line maps of the city of Stuttgart and five axial line maps of the city of Hamburg. Each of the axial line maps covers the same area but is different in scale and detail

Global Integration Ranks Stuttgart				Global Integration Ranks Hamburg				
SHand	SHand2	SBB	SBB2	HHand	HHand2	HBB	HBB2	CityMap
1	1	3	3	1	2	61	14	145
2	2	5	6	2	1	46	112	80
3	3	1	1	3	3	75	142	74
4	5	3	3	4	5	18	90	38
5	4	14	10	5	4	35	8	37
Global Choice Ranks Stuttgart				Global Choice Ranks Hamburg				
SHand	SHand2	SBlock	SBB2	HHand	HHand2	HBB	HBB2	HCM
1	1	2	2	1	1	1	2	2
2	2	1	1	2	2	2	8	9
3	3	3	3	3	3	3	6	24
4	5	(3)	(3)	4	4	7	11	10
5	4	(2)	(2)	5	7	154	129	170

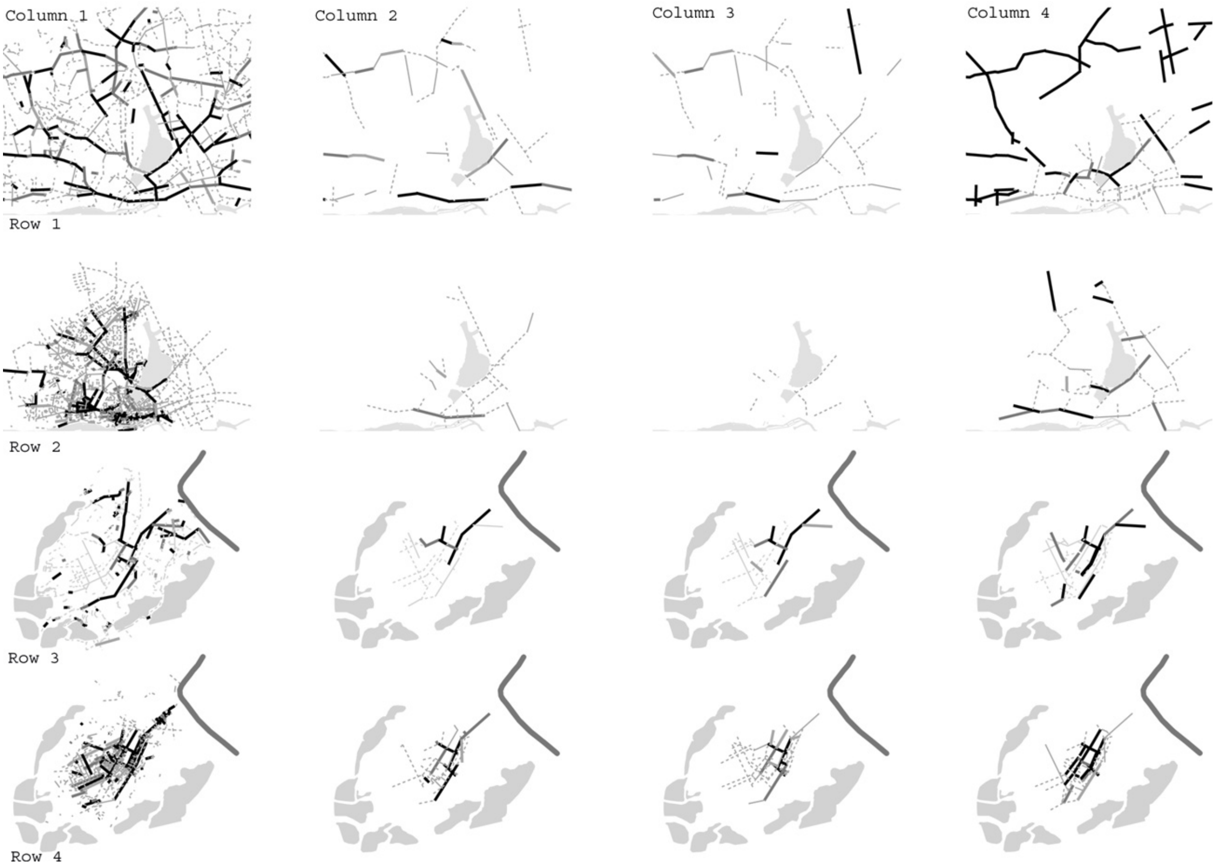


***Figure 4:** Visualising rank differences of global choice (rows 1 and 3) and global integration (rows 2 and 4) for different ALMs of Hamburg and Stuttgart. The axial lines with rank differences +/- 2 are coloured in bold black, +/-10 in grey and +/-50 ranks dotted*

Estimating rank differences

For each ALM, the 1-100 ranking axial lines of global choice and global integration are first selected and then correlated. This is way tables 4 and 5 show different correlation values for the same pair of ALMs, depending on the set from which the 1-100 ranking axial lines are selected. The statistical analyses show that for Hamburg, global choice rank correlations (Kendall Tau) are significant and very high for the two conventionally digitized maps (0.87- 0.95) and high for the two block based maps (0.6 – 0.69).

Table 4:

*Hamburg – Rank correlations (Kendall Tau) for global integration and global choice. Note that numbers of correlated cases differ between 70 and 100, see text for detail. (** significance at the .01 level; * significance at the .05 level)*

Ranks 1-100 or less	Hamburg Global Choice Ranks					Hamburg Global Integration Ranks				
	HH	HH2	HBB	HBB2	HCM	HH	HH2	HBB	HBB2	HCM
HHand	1	.95**	.34**	.37**	.12**		.86**	.26**	.21**	.23**
Hand2	.87**	1	.34**	.37**	.31**	.86**	1	.17*	.16*	.21**
HBlock	.27**	.26**	1	.60**	.22**	.19*	.20*	1	.33**	.06
HBlock2	.35**	.34**	.60**	1	.34**	.25**	.25**	.50**	1	.32**
HCityM	.37**	.38**	.28**	.42**	1	.20**	.21**	.16**	.31**	1

For Stuttgart's conventionally digitized ALMs, the correlation of the integration ranks is very high but differs surprisingly for the global choice ranks. One reason for this variation could in fact show the importance of the public stairs, which are placed at the right locations for shortest paths. The correlation of the block based ALMs are significant and they are stronger than the ones between conventionally digitized ALMs.

Ranks 1-50	Stuttgart Global Choice Ranks				Stuttgart Global Integration Ranks			
	SHand	SHand2	SBlock	SBlock2	SHand	SHand2	SBlock	SBlock2
SHand	-	.81**	.52**	.48**		.79**	.25*	.23*
SHand2	.66**		.59**	.56**	.80**		.33**	.33**
SBlock	.27	.27		.81**	.32**	.29**		.86**
SBlock2	.30**	.32**	.80**	-	.33**	.35**	.87**	-

Table 5:

*Stuttgart – Rank correlations (Kendell Tau) for global integration and global choice. Note that numbers of correlated cases differ between 22 and 50, see text for detail. (**significance at the .01 level; * significance at the .05 level)*

between the original global integration and global choice maps can also be expressed by the parameter introduced. Furthermore, the variations in the configuration due to morphological changes can be clearly differentiated. The impact of public stairs is stronger than the impact of park connection for the respective configurations.

Limitations: Although the selection of 50 - 100 axial lines creates a thorough foundation for correlation analyses, the process of selecting the related axial lines is not free of subjectivity and mistakes. The relation between axial lines at the same location is only secured for the paired ALMs, once axial lines are split or stretched further than the relating axial line, the relation becomes questionable. However, in this study all pre-tests resulted in the same trend as shown in tables 4 and 5.

Step Depth Matrix

The second approach to evaluate the differences between ALMs is via a step depth matrix. While with rank correlations the aim is to compare the whole system with a great number of axial lines, the step depth matrix approach explores the explanatory power of a small number of axial lines (1 - 5) in order to describe variations between ALMs. It does so in describing the whole configuration from the perspective of the most integrated axial line.

Table 6 shows some of the raw data and helps to explain what kind of differences this approach focuses on. Starting from the most integrated line, within the first step, the immediate neighbours are reached, in the example the numbers vary from 14 to 37 for this first step. When progressing through the ALM at a certain step depth, a first maximum is reached; further maxima appear in some ALMs and eventually all lines are reached at a certain step depth. There are two distinct differences that will be explored in the following section. The number of lines per step and the number of steps that is necessary to reach all lines.

ALM of Hamburg	HHand		HHand2		HBB		HBB2		HCM	
Step Depth	steps	lines	steps	lines	steps	lines	steps	lines	steps	lines
First step /connectivity	1	**14**	1	**11**	1	**18**	1	**24**	1	**37**
Second step	2	**55**	2	**40**	2	**56**	2	**91**	2	**99**
1. Maximum	12	**458**	11	**387**	7	**481**	8	**383**	7	**403**
2. Maximum			15	**406**	10	**518**	18	**162**	15	**147**
Last Step	29	**2**	31	**1**	22	**2**	28	**1**	21	**4**

Table 6:

Step depth from the most integrated axial line of each ALM

First, the step depth matrix of the best integrated axial lines of five different ALMs of Hamburg is examined. With a z-value standardization, the number of axial lines per step is transformed, with 0 indicating the mean and 1 the standard deviation. In figure 5, the differences and similarities are clearly visible. The curves for both pairs of ALMs - conventionally digitized and block based - have their maxima at different step depth (step 9 and17) but rise and decline in a very similar fashion. The major variation between the curve of block based subset (HBB) and block based minimal (HBB2) is the number of steps needed to reach all axial lines (21-28 steps). The curves of the conventionally digitized ALMs are also rising and declining similarly with different maxima (single peak, twin peak). The curve of the city map ALM has a maximum between the two pairs and shows the same step depth as HBB.

In Figure 6, the step depth matrix curve of the highest ranking axial line of HHand is compared to the step depth matrix of the axial lines of the four other ALMs, that have exactly the same location. Although the axial lines have very different ranks in their ALMs, their curves rise very similar (peak at step 13-16), indicating that they function very much the same in their respective configurations.

In the example of Stuttgart’s ALMs, the same pairing of curves can be found. Here, the mean step depth values of rank 1-5 is used for comparison. The curves of the conventionally digitized ALMs are very similar in the first half and show greater differences in the second half. The curves of the block based ALMs show first the differences and then the similarities.

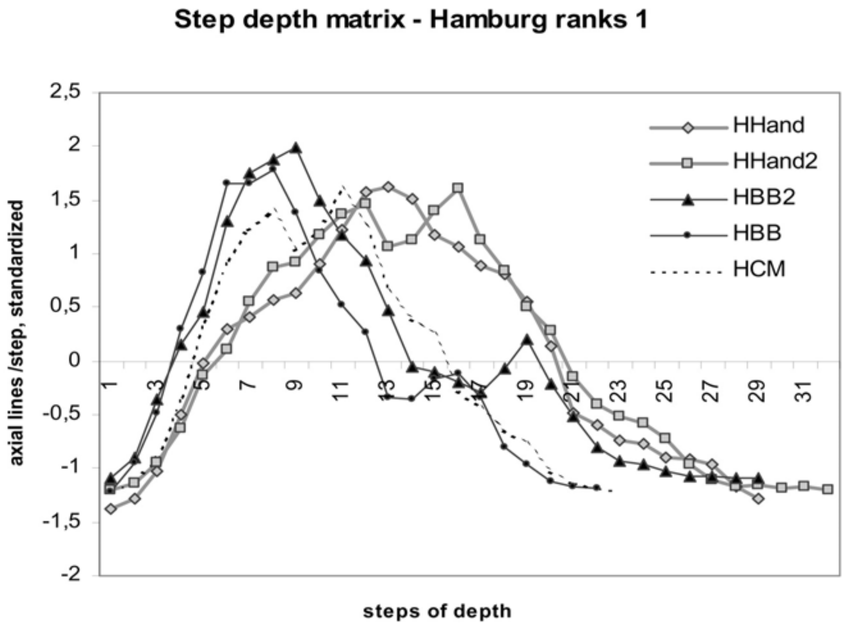


Figure 5:

Step depth matrix of the best integrated axial lines of Hamburg’s ALMs comparing conventionally digitized maps, block based maps and city map minimal

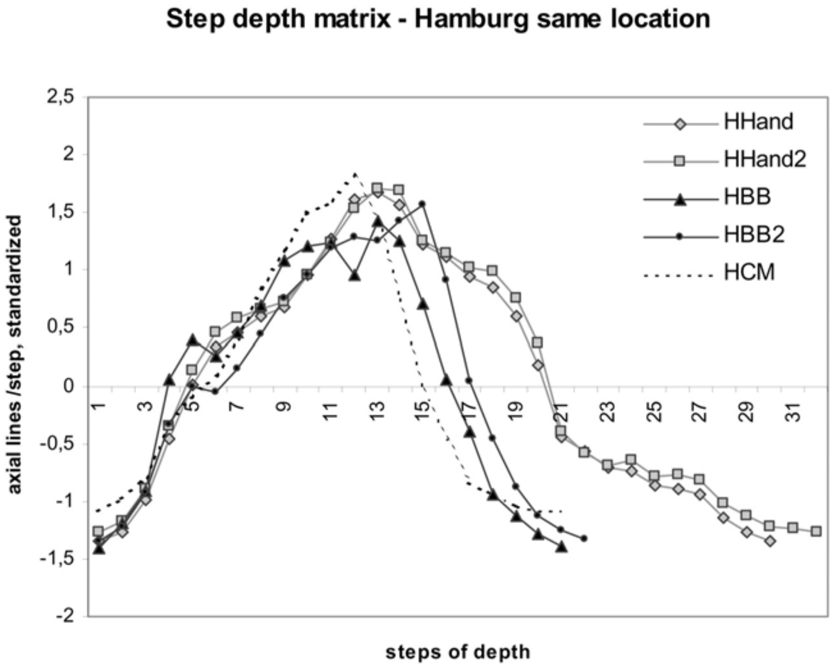


Figure 6:

Step depth matrix of axial lines at the same location, best integrated axial line of Hamburg's conventional ALM (HHand), comparing conventionally digitized maps, block based maps and city map minimal

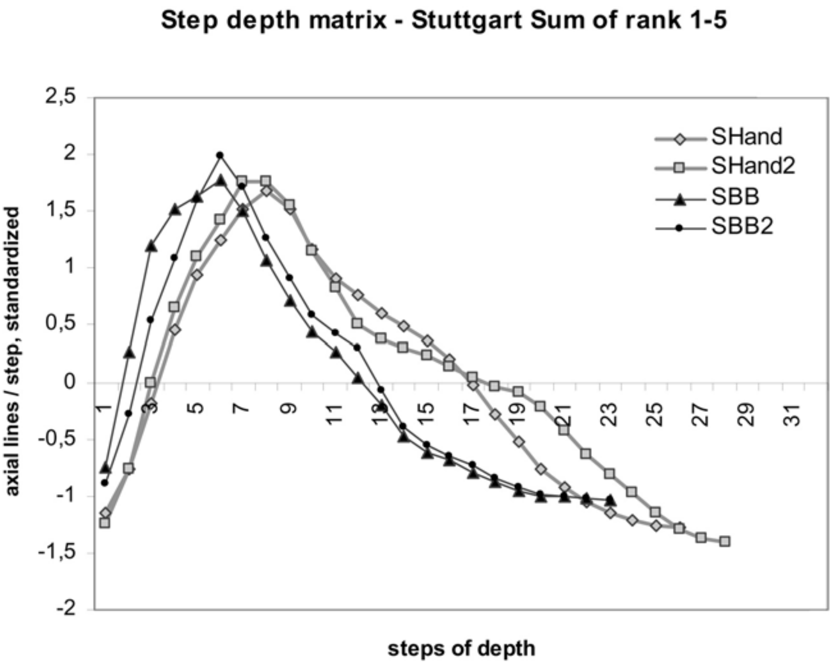


Figure 7:

Step depth matrix of the best integrated axial lines of Stuttgart's ALMs, comparing conventionally digitised maps, block based maps and city map minimal

Proximity index

The visible similarities of the step depth matrix curves can be explored with a proximity analysis (see table 7a-c). The step depth matrices of the paired ALMs perform better, just as their curves look more similar. But also the variations between each step depth matrix become clear. When analyzing Table 7a) and b) together the similarity between the ALMs can be described as follows.

HHand ~ HHand2 > HBB ~HBB2 > HCM.

Comparing only the top ranking axial lines and their respective step depth matrix, a higher similarity between HBB2 and HCM than between HBB and HBB2 can be found, which is not surprising, after all, the axial lines are directly connected.

For the step depth matrices of Stuttgart's ALMs, the trend is slightly different.

SHand ~SHand2 >SBB2~SBB.

The paired ALMs are very similar on the same level for conventionally digitized and block based ALMs. All four step depth matrices show more similarity than the ones from Hamburg.

Table 7:

Proximity analyses

090-12

	Proximity Matrix 1				
a)	**Hamburg** ranks 1				
	HHand	HHand2	HBB	HBB2	HCM
HHand	1	,954	,619	,415	,247
HHand2	,954	1	,589	,422	,261
HBB	,619	,589	1	,894	,848
HBB2	,415	,422	,894	1	,900
HCM	,247	,261	,848	,900	1
b)	**Hamburg** same location				
	HHand	HHand2	HBB	HBB2	HCM
HHand	1	,998	,724	,854	,654
HHand2	,998	1	,704	,833	,623
HBB	,724	,704	1	,928	,928
HBB2	,854	,833	,928	1	,822
HCM	,654	,623	**,928**	,822	1
c)	**Stuttgart** ranks 1				
	SHand	SHand2	SBB	SBB2	HCM
SHand	1	,972	,754	,851	,654
SHand2	,972	1	,769	,864	,623
SBB	,754	,769	1	,974	,928
SBB2	,851	,864	,974	1	,822

Discussion and Outlook

One of the questions raised at the beginning was whether the visible differences between global integration maps can be expressed in a more accurate way and with a higher level of distinction than with standard parameters. The answer is clearly yes. Both location related measures "rank correlations" and "step depth matrix" are able to indicate small differences between similar ALMs as well as similarities between modified or divergent ALMs. For the purpose of this study, only global measures were used for comparison but in principle it works with local integration parameters as well. The measure "rank correlations" could also be used for the analyses of segmented line or weighted line maps and even for a comparison of different line maps. The analyses of configurations with different morphological elements shows that it is manageable to distinguish between the degree of impact caused by various morphological elements.

For the question of the impact of scale, there is no such clear answer. The variations in scale and resolution lead to a different size of the configuration but almost the same explanatory power when compared to traffic models. All but the City Map based ALM show significant correlations with traffic data and the r^2-values encourage further investigations. Scale is not so important for axial line analyses it seems and it is worth testing further base maps for modelling movement networks. The generation of fewest line maps with block based data sets result in a promising outcome and may help support the development of a standard map for configurative analyses.

The questions that led to the work presented in this paper have not been answered entirely. The different locations of the integration centres of Hamburg can not be explained solely with difference in scale. According to space syntax theory, one could argue, that centrally located barriers like the Alster lake have a great impact on depth distribution and integration. That might explain why the configurations are so "sensitive" to the impact of the physical form. The example of Stuttgart also proves the importance of the city's natural settings for its configuration. Because there is simply no space for a different configuration, the variations in scale and detail have only a little impact. In the case of Hamburg, it seems, there is too much space and too many options for just one configuration.

Whether this lack of clearness is a shortcoming of space syntax analyses or a constraint of network analyses in general, should be further explored.

Acknowledgments; Thanks to Karoline and Stefan and the referees for their valuable comments.

References

Carvalho R., Penn A., 2004, "Scaling and Universality in the Micro-Structure of Urban Space", *Physica A* (332) 539-547.

Dalton, N., Peponis, J., Conroy Dalton, R., 2003, "To Tame a TIGER One Has to Know its Nature: Extending Weighted Angular Integration Analysis to the Description of GIS Road-Center Line Data for Large Scale Urban Analysis", J. Hanson (Eds.), *Proceedings*, 4th International Space Syntax Symposium, London.

Dara-Abrams, D., 2006, "Ground Truthing Space Syntax", Proceedings, "The Cognitive Approach to Modelling Environments", *GIScience06*, Münster. (http://www.sfbtr8.uni-bremen.de/papers/SFB_TR_8_Rep_009-08_2006.pdf).

Eisenberg, B., 2005, "Space Syntax on the Waterfront – The Hamburg Case Study", A. van Nes (Ed.), *Proceedings*, 5th International Space Syntax Symposium, Delft University of Technology, Delft.

Figueiredo, L., Amorim, L., 2005, "Continuity Lines in the Axial System", A. van Nes (Ed.), *Proceedings*, 5th International Space Syntax Symposium, Delft University of Technology, Delft.

Fischer, C., Haubrich, A., 2004, "Stuttgarts Stäffeles [Public stairs in Stuttgart]". ILPO, University of Stuttgart, unpublished.

Freie und Hansestadt Hamburg (FHH), 2004, "Durchschnittliche Tägliche KFZ-Verkehrsstärken – DTV Hamburg 2003", Behörde für Stadtentwicklung und Umwelt, (Ed.) Amt für Verkehr und Straßenwesen. [average weekday traffic 2003].

Hillier, B., 1996, *Space is the Machine: A Configurational Theory of Architecture,* Cambridge University Press, Cambridge.

Medeiros, V.A.S., Holanda, F.R.B., 2005, "Urbis Brasiliae: Investigating Topological and Geometrical Features in Brazilian Cities", Van Nes, A. (Ed.), *Proceedings*, 5th International Space Syntax Symposium, Delft University of Technology. Delft.

Baumüller, J. (Ed.) 2004, "Urban Climate 21", CD contains data sets for average weekday traffic 2002.

Porta, S., Crucitti, P., Latora, V., 2006, "The Network Analysis of Urban Streets: A Primal Approach", *Environment and Planning B: Planning and Design*, 33(5) 705-725.

Raford, N., Chiaradia, A., Gil, J., 2005, "Critical Mass: Emergent Cyclist Route Choice In Central London". Van Nes, A. (Ed.), *Proceedings*, 5th International Space Syntax Symposium, Delft University of Technology. Delft.

Read, S., 2005, Flat City, A Space Syntax Derived Urban Movement Network Model, Van Nes, A. (Ed.), *Proceedings*, 5th International Space Syntax Symposium, Delft University of Technology. Delft.

Turner, A., 2007 (forthcoming), "From Axial to Road-Centre Lines: A New Representation for Space Syntax and a New Model of Route Choice for Transport Network Analysis", *Environment and Planning B: Planning and Design*, preprint.

Turner, A., Penn, A., Hillier, B., 2005, "An Algorithmic Definition of the Axial Map", *Environment and Planning B: Planning and Design*, 32(3):425–444.

Turner, A., 2001, "Depthmap: A Program to Perform Visibility Graph Analysis", J. Peponis, J. Wineman, S. Bafna (Eds.), *Proceedings*, 3rd International Space Syntax Symposium, Georgia Institute of Technology, Atlanta.

Van Nes, A., 2003, "A Configurative Approach to Understand Pedestrian-Based and Car-Based Shopping Centres: Configurative Studies on Oslo and Eindhoven", Hanson, J., (Ed.), *Proceedings*, 4th International Space Syntax Symposium, University College London.

i. See Eisenberg 2005 for a comparison between planning visions and guidelines for Hamburg and how they correspond to integration maps.

ii. Standard dataset of average weekday traffic for Hamburg (FHH 2004) and Stuttgart (Baumüller 2004).

iii. See Hillier 1996, p299 "more centrally placed bar[ier]s create more depth gain than peripherally placed bar[rier]s"

iv. Simplify command in ArcGIS 9.1, reducing the number of vertices with a tolerance of 1 meter.

v. Turner et al. (2005) have compared the generated map with a conventionally digitized map. Both maps were based on the same base map and therefore the same convex space extraction.

vi. The main impact comes from the exclusion of public stairs as Fischer & Haubrich (2005) show clearly in their study of a similar area of the city of Stuttgart.