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Towards a multi-scale description of Choice

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Abstract

Cities consist of an intricate network of spaces. Each space is defined by the way it is positioned and progressively connected to all other space within the surrounding spatial network. Space Syntax spatial measures, like Choice reveal spatial patterns within this network of spaces. Radius restricted Choice analyses permit the examination and the comparison of local and wider scale patterns but does not give a holistic multi-scale spatial description of Choice. How can we move beyond single scale spatial descriptions to a multi-scale description of Choice?

This paper proposes formula based approach to multi-scale spatial analysis and in particular Choice. It starts with giving a depiction of Choice. The paper tries to give evidence of the relation between Choice distributions, derived from a spatial model of Central London, and an accumulative Weibull distribution. The parameters that make up the Weibull distribution are further explained and are related to six different case studies found within the studied spatial model of central London.

Keywords: *Multi-scale spatial analysis, Choice, Weibull distribution*

Theme: *Methodological Development and modelling*

Introduction

Cities consist of an intricate network of spaces. Each space is defined by the way it is positioned and progressively connected to all other space within the surrounding spatial network. There is an increasing amount of studies that try to describe how spatial urban structures perform across different levels of scale. (Hillier, 2009) (Hillier, Yang, & Turner, 2012) (Dalton en Dalton 2007) Radius restricted Choice analyses permit the examination and the comparison between local and wider scale patterns but do not give a holistic multi-scale spatial description of Choice. The identification of multi-scale spatial structures like urban centre formations is difficult when using a spatial analyse restricted to just one radius. (Ferguson 2009) How can we move beyond single scale spatial descriptions to a multi-scale description of Choice?

Choice

One of the key elements in Space Syntax spatial description is the segment that represents the space between intersections and convex spaces. One of the spatial measures Space Syntax Limited uses most for urban analysis and pedestrian forecasts is Choice or Through-movement. Choice measures the quantity of movement that passes through each segment on shortest trips with least angular change between all pairs of segments that makes up the whole spatial network. Choice or Through-movement is one of the most used spatial measures for urban analysis and pedestrian forecasts at Space Syntax Limited. The Choice measure can be restricted to a certain metric radius in order to calculate trips within a defined distance from a segment. This allows one to distinguish different spatial structures like the background network at local radii and the foreground network that emerges at wider scales. Although this radius confined Choice measure can be repeated for each radius, it does not demonstrate how a segment performs across different radii. Is the distribution of Choice across all possible radii not as important as at one specific radius, given that Choice of a particular segment changes at different size radii? And if so, how can measure this multi-scale Choice distribution?

Weibull Distribution

The probability that a segment receives more through-movement as it is connected to more and more segments at wider radii naturally increases. The increase of Node Count at a certain increase in metric distance has been proven to follow an accumulative Weibull distribution. (Hillier en Yang, 2012) So if Choice increases over radial distance can it perhaps also be described using a Weibull distribution? When using the logged Choice in order to compare values easier, an accumulative

2-parameter Weibull distribution of Choice follows the formula:

$$\log Choice_{Rk} = \log Choice_{Rn} \times \left(1 - e^{-(Rk\frac{Rk}{a})^{b}}\right)$$

Where *Rk* denotes the radius at k meters, *Rn* denotes the maximum radius that covers the whole system, *a* indicates the “scale factor” and *b* indicates the “shape factor”.

For this study a spatial model of central London is used (Figure 3). The model consists of 25434 segments and has a diameter of 10 kilometer. This model is processed in DepthMap using an Angular Segment Choice Analysis at 20 radii up to 10000 meter with 500-meter increments (500m, 1000m, 1500m, …10000m). An accumulative Weibull distribution is fitted to the Choice distribution for 828 random sample segments using a script that automates a nonlinear algorithm. This non-linear algorithm is part of Microsoft Excel Solver and uses iterative numerical method that trial different values for the “shape factor” and the “scale factor” for each segment until the fitted Choice distribution, resulting from the trialed shape factor and scale factor, differs least from the original Choice distribution.

Segments that described dead-end spaces and thus have zero Choice value across all radii were ignored. The algorithm produces for each sample segment its optimum "scale factor" *a* and "shape factor" *b*. Each Choice distribution of each segment is correlated with its equivalent Weibull distribution.

The resulting correlations give clear evidence that a logged Choice distribution can be described using a Weibull distribution since 91% of the segments have a correlation coefficient of more than 90%. The strong correlation between the Weibull distribution and the Choice distribution shows that the shape and the scale factor are strong indicators for multi-scale Choice performance.

Of the sample segments analysed in this study approximately 10% had a correlation of less than 90% with an accumulative Weibull distribution because their Choice distribution does not follow an accumulative distribution. Their Choice distribution shows a decrease in Choice at wider radii. Some cases have been identified in housing estates. At a local scale, these segments are an integral part of the estate. But at wider scale these estates are relatively segregated from their urban context. The advantage they have on a local scale is surpassed by more strategic connections at a wider scale. Further research in non-accumulative Choice distributions need to be done to shed more light on this phenomenon.

Shape factor

In order to understand the shape factor we need to understand its numerical characteristics better. A histogram of all the shape factor of the sample segments indicates that the shape factor values of the sample segments have a small range. 93% of the sample segments had a shape factor between 0.4 and 0.9. The distribution within this interval seems to follow a normal distribution and has its median at 0.59. More segments and other spatial models need to be fitted to a Weibull distribution to acquire a more precise description of shape factor values.

But how does the shape factor "shape" the Choice distribution? To analyse this, the other factors, the scale factor and $\log Choice_{Rk}$ are kept constant at their respective median values of 1057 and 5.04, while using six shape factors ranging between 0.4 and 0.9.

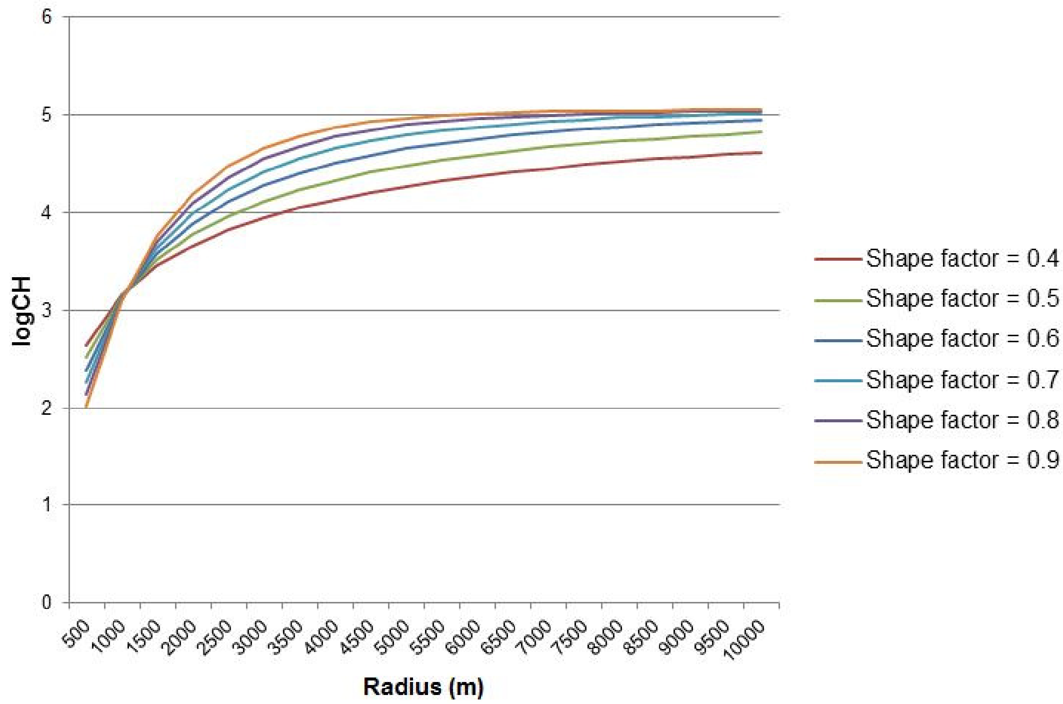

Figure 1 Comparison of Choice distributions following different shape factors

The graph (Figure 1) demonstrates that at wider radii Choice increases. The rate, at which Choice increases, is governed by the shape factor.

An accumulative distribution describes an increase up to a maximum value. The accumulative Choice distributions with a high shape factor, increase rapidly at a local radius and increases at a lower rate at wider radii. This shows that a Choice distribution with high shape factor is mainly established at a local level. Choice distributions with a low shape factor are found to have lower increase rate of Choice at a local scale but a more constant continuous increase throughout all scales.

If the difference between the $\log Choice_{Rn}$ and $\log Choice_{R500}$ can be seen as the Choice potential of the segment, a shape factor shows at what rate of distance the Choice potential is reached.

Scale factor

Understanding of the numerical characteristics of the scale factor is needed in order to know how it describes Choice distributions. The calculated scale factors from the sample segments are distributed much wider than their shape factors. 96% of the sample segments have a scale factor between 100 and 2000 meters. The median lies at 1057.

From general Weibull descriptions we learn that the scale factor indicates at which radius 63.2% (Khan , Pasha en Pasha 2007) of the Choice potential has been reached. The scale factor thus determines the width of the Choice increase across radii. To demonstrate the effect of the scale factor, the $\log Choice_{Rn}$ and the shape factor are kept constant at their respective medians 5.05 and 0.59, while scale factors range between 100 and 2000.

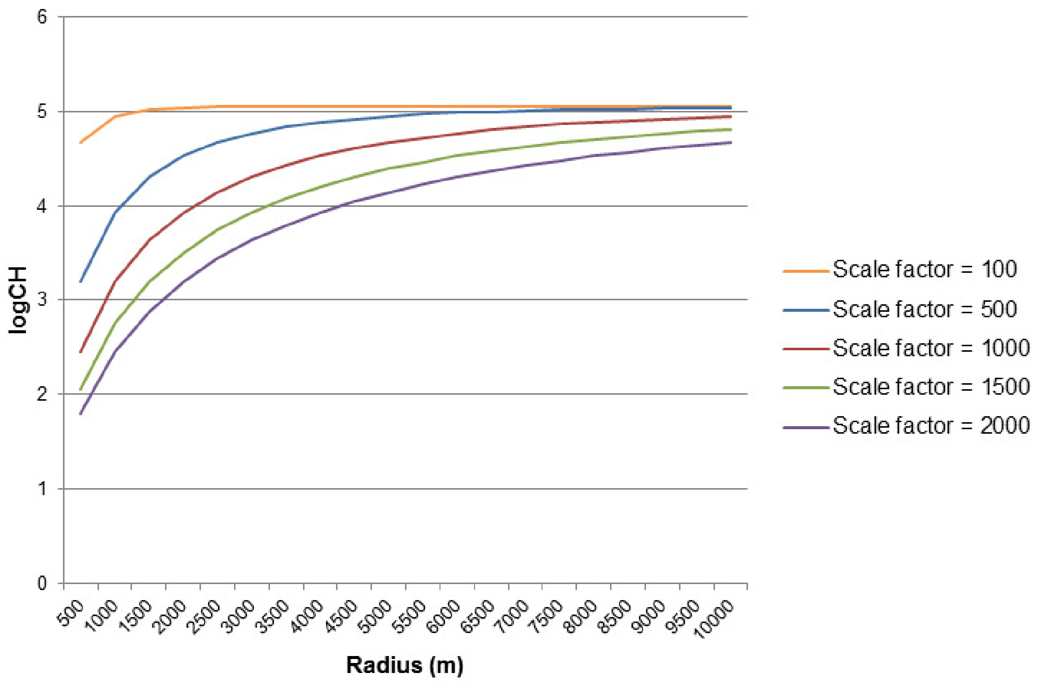

Figure 2 Comparison of Choice distributions following different scale factors

The graph (Figure 2) demonstrates that the scale factor describes the Choice potential, being the increase between $\log Choice_{R500}$ and $\log Choice_{Rn}$. A low scale factor denotes a relative high local Choice, a relative 'flat' Choice distribution and a low Choice potential. A high scale factor indicates a high Choice potential or 'thick' Choice distribution.

Dependence on global Choice

The scale and shape factor govern the curve of the Choice distribution but the $\log Choice_{Rn}$ value fixes the position of the curve. A Choice distribution with a high $\log Choice_{Rn}$ is located 'above' a Choice distribution with a low $\log Choice_{Rn}$. The accumulative Weibull function shows that Choice across radii is a product of Choice on the scale of the whole system.

Case studies

So far this study has found that Choice can be described fairly accurately across radii using accumulative Weibull distribution. The effect of the shape and scale factor on this distribution has been demonstrated through graphs analyses. But how can these parameters be used to describe spaces with different characteristics in the real world?

Six different segments have been identified in the study model of central London; Oxford Street (A), Chiltern Street (B), Euston Road (C), Patshul Road(D), Victoria Embankment E) and a segment in Regents Park Estate (F).

Figure 3 Spatial model of central London showing the location of the case studies

A Weibull distribution was fitted to their Choice distribution to produce their respective scale and shape factor. The Weibull Choice distributions of the six case studies are also plotted on the graph below.

Street name	$logChoice_{Rn}$	Scale factor (a)	Shape factor (b)	R^2 value
Oxford Street	7.88	1530	0.68	0.99
A501 Euston Road	7.10	1200	0.72	1.00
Chiltern Street	3.83	617	0.95	0.95
Regents Park Estate	5.23	570	0.45	0.94
Victoria Embankment	6.53	1330	0.89	1.00
Patshul Road	5.65	1366	0.70	1.00

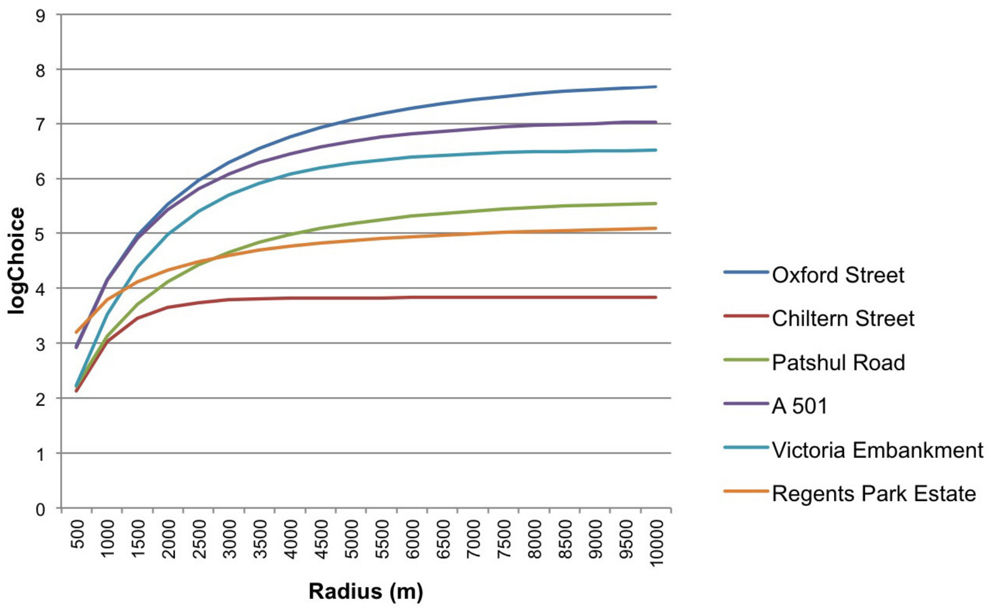

Figure 4 Table with the $logChoice_{Rn}$, the scale factor, the shape factor and the correlation coefficient of the six case studies and a graph showing the Weibull fitted Choice distributions of the six case studies

The graph clearly shows how $\log Choice_{Rn}$ positions the Choice distributions on top of each other and describes their overall performance. At local radii the distributions intersect and overlap, but at wider levels of scale they are clearly separated based on their $\log Choice_{Rn}$. The A501 and Oxford Street for example, have the same logged Choice at a 500m radius but diverge and approach their $\log Choice_{Rn}$.

Oxford Street is the busiest high street of London. It features many mainstream shop chains and department stores but few amenities specifically orientated to its local context. Of the six case studies, Oxford Street has the highest $\log Choice_{Rn}$, the highest scale factor (high Choice potential) and relatively low shape factor (continuous increase rate of Choice). The high $\log Choice_{Rn}$ seems coincide with its high pedestrian movement rates. The high scale factor and the relatively low shape factor indicate that Oxford Street attracts movement at meso and macro scales. This relates to the lack of local amenities and the abundance of mainstream shops that operate on a wider scale.

Chiltern Street, in contrast to Oxford Street, features local services and exclusive shops. Its low scale factor (low Choice potential) seems to coincide with its exclusive character. The high shape factor (only local increase of Choice) describes Chiltern Street's focus on local services.

Regent Park Estate is centrally located but has, like many other post war housing estates in London, a complex over permeable spatial structure. Spaces within the estate are well integrated at a local scale, but are poorly connected to their urban context at a wider scale. The Choice distribution of a segment within Regent Park Estate demonstrates these limitations through a 'flat' Choice distribution or low Choice potential, which is expressed by a low scale factor.

Discussion

The Weibull distribution proofs to be very flexible in describing different Choice distributions by using $\log Choice_{Rn}$, indicating the maximum performance, a shape factor denoting the increase rate of Choice and a scale factor that describes the difference between Choice at a local scale and at a system wide scale or Choice potential. The Weibull distribution correlated strongly with more than 90% of studied segments (dead-ends excluded) suggesting that other spatial networks follow similar behaviour. However theoretical reasons explaining the existence of this correlation should be investigated in future research.

The increase rate of Choice, being the increase of Choice over radial distance, and the Choice potential of a space, being the increase of Choice between local and global radii, are spatial phenomena that emerge across multiple radii and are invisible at an analysis at one specific radius. The shape factor and the scale factor analyzed in this study can provide tools to better understand these phenomena and might provide more insight in the intricate ways spaces connect to other spaces through multiple levels of scales. More research is needed to further investigate the shape factor and the scale factor as spatial descriptive parameters.

In recent projects Space Syntax Limited have started using normalised Choice that divides logged Choice over logged Total Depth. This measure allows the Choice to be compared across different sized systems. Normalised Choice does not follow a clear accumulative distribution as Choice or logged Choice and is therefore less suitable to be directly fitted to a Weibull distribution. However if key spatial measures like Node Count and Choice seem to be governed by 2-parameter Weibull Law perhaps a normalised Weibull Choice distribution is possible.

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