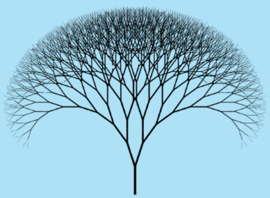
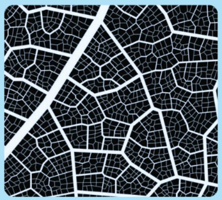
Investigating the Correlation Between Fractal Patterns in Cities & Quality of Life

Background

As the world's urban population keeps increasing it is important to look into designing future cities in a sustainable and efficient way. We chose to look at sustainable city design from a new angle; fractals.

Simply put, fractals are shapes that repeat infinitely. They have the property of smaller sections of the whole shape mirroring the whole shape. They have a fractal or decimal dimension which represents their complexity.





This project investigates whether the natural fractal patterns found in urban road networks and public transport systems impact key city performance metrics. As urban populations continue to swell, designing cities that balance complexity with functionality becomes increasingly important. By exploring the patterns that characterize fractal geometry, we ask: can these patterns inform better urban planning practices that promote sustainability and livability?

Gathering primary data

We used software called QGIS to extract layers from the Open Street Maps repository. This allowed us to create images with specific requests (such as "all main roads in Shanghai"). We made a map of the main roads, all streets, and the public transport network for each of the 50 cities.

We then used a tool called FD Estimator. to calculate the fractal dimension of each image. Simply put this is a measure of its complexity. We did this for each of the 3 types of maps for each city.

We also measured the self-similarity of the map of all streets in every city, using a repository in R.

We limited our study to 50 large cities from around the world, limiting as best we could the outside factors of these cities (Geography)

Secondary data

The dependent variable in our comparison is the quality of life data. We needed a source of data that used the same data collection method across an international list of cities. We took data under these headings: Quality of life, Pollution index, and traffic commute time index. We took the data from numbeo.com which uses crowd-sourcing to get its data.

Data analysis

We used SPSS to run corrolations between our variables

Independent Variables (Fractal metrics)	Dependant Variables (Liveability indicators)
Fractal dimension of Main roads	Overall Quality of life index (QoL)
Fractal dimension of all streets	Traffic commute times index
Fractal dimension of public transport networks	Pollution Index
Self similarity of all streets	

We used the Shapiro-Wilk test (as n = 50) for the normality of our data.

This was to ensure it was normally distributed, which it was.

Tests of Normality		
	Shapiro-Wilk	
	Statistic	Sig.
Traffic commute times	.971	.250
Pollution index	.972	.291
Quality of life index	.971	.243
Fd main roads	.958	.073
Fd all streets	.989	.920
Fd transport	.969	.216
SSall streets	.955	.056

We then ran a bivariate correlation test, measuring the Pearson correlation between each pair of the 7 rows of data we were comparing.

We did more detailed regression + ANOVA tests on:

- FD of All Streets vs Traffic Index.
- FD of All Streets vs Overall QoL Index.
- FD of Main Roads vs Traffic Index.
- FD of Main Roads vs Overall QoL index.
- FD of All Streets vs Pollution Index.
- FD of Main Roads vs Pollution Index.

As these pairs had the highest correlations, of the ones we were interested in.

We also did a multiple linear regression test to see if they make a better model when combined.

The predictors have a variance inflation factor (VIF) of 1.322–1.849. The tolerance is > 0.25 and the values are <4, meaning the predictors show low multicollinearity, i.e. they are different enough that each variable's contribution is not redundant.

	VIF
Fd main roads	1.413
SSall streets	1.479
Fd all streets	1.849
Fd transport	1.322

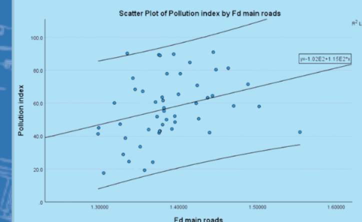
Results

	Traffic commute times	Pollution index	Quality of life index	Fd main roads	Fd all streets	Fd transport	SSall streets
Traffic commute times	1	.602*	-.697*	.319**	.266**	.009	.000
Pollution index	.602	1	-.855*	.312**	.297**	-.118	-.053
Quality of life index	-.697	-.855	1	-.274**	-.223**	.079	-.071
Fd main roads	.319*	.312	-.274	1	.517*	.261*	-.331*
Fd all streets	.266	.297	-.223	.517	1	.371*	-.464*
Fd transport	.009	-.118	.079	.261	.371	1	.097
SSall streets	.000	-.053	-.071	-.331	-.464	.097	1

Pearson correlations between Fractal metrics and Liveability indicators. * indicates a significant correlation and ** indicates one that is significant and is a comparison between a fractal metric and a liveability indicator.

Below are the 2 most significant results we found:

This plot shows the regression of Traffic commute times and the fractal dimension of main roads. From this we can say that ~10% of the variance in traffic commute times is caused by the Fractal dimension of main roads.



This plot shows the regression of the pollution index and the fractal dimension of main roads. Again we can say that ~10% of the variance in the pollution index is caused by the Fractal dimension of main roads.

	R	R^2	Sig. @ 95%
Traffic Commute Times	.414	.171	.071
Quality of Life	.409	.168	.077
Pollution	.440	.194	0.042

The results of the multiple linear regression. The only significant one is pollution. The R^2 value of 0.194 means that 19% of the variance in pollution can be explained by the fractal metrics.

Conclusion

Our project suggests that while fractal characteristics of urban design are linked to certain liveability indicators, they represent only one aspect of a complex urban system. Future city designs should integrate fractals in the design process.

When planning the cities of the future, we recommend that cities have a lower fractal dimension as this will likely improve traffic, decrease pollution and improve quality of life.