Supporting smart urban growth: Successful Investing in Density

FULL REPORT

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Successful investing in density - Implications for investment and policy decision-making

Introduction

This research commissioned by Urban Land Institute (ULI) and New Climate Economy (NCE), supported by a steering group of global real estate and infrastructure fund managers and investors, set out to objectively evaluate the impact of investment in compact, connected urban development on returns[1] for real estate investors, and the implications for carbon (CO_2) emissions and infrastructure cost per resident for the public sector. The scope of the research is global but with a focus on comparing and contrasting quantitative data on cities in OECD nations with that for cities in fast growing developing world regions.

The results of the two-phase study undertaken by a multi-disciplinary research team led by Professor Kathy Pain of the Henley Business School at the University of Reading, are intended to help inform private and public sector decision-making on the ways in which smarter infrastructure investment in 'good density' can help to support investment returns while reducing CO_2 emissions.

The two-phase method

Phase I

In the first phase of the research, the relationship between *good* density (defined by ULI as mixed use, connected, planned, cohesive, liveable, spacious, flexible, design, green and appropriate, Clark and Moir, 2015) and urban form characteristics and real estate investment returns, was investigated. A summary of the findings is presented in the Phase I report.

An interdisciplinary literature review was conducted to generate a shortlist of urban form characteristics linked to good density using inductive and deductive approaches, and to identify relevant data for incorporation in Phase II quantitative analysis.[2] Works reviewed extended beyond the urban design and planning literature to encompass 65 international peer-reviewed academic journals and reports published by official bodies and think tanks, including the ULI and NCE. From the literature review, six core urban form characteristics relevant for good density were identified.

[1] The return on investment (ROI) is a critically important property attribute driving real estate investment.
[2] The framework for identifying relationships between good density and urban form characteristics was developed by conducting an extensive systematic design and planning literature search with advice from external experts, to establish patterns of association (Inductive approach) and by drawing on established knowledge and theories in the literature of other relevant disciplines to test those patterns (deductive approach) (McGhee, et al., 2007).

Core characteristics of urban form identified from literature review		
	**Clustering** Structure	Clustering patterns within cities and at city-region scale determine the level of volume of carbon-generating traffic movement, i.e. travel for work, business meetings, leisure, and agglomeration economies / inward investment.
	**Economic/Employment** Infrastructure	Connectivity to and concentration of foreign investment, quality value adding jobs, labour, skills, diversity and innovation capacity all feature in creating a strong, resilient city economy.
	**Built** Infrastructure	Elements of built infrastructure that impact on good density are mixed use planning, technological and design quality, and amenity at property level and urban landscape scale.[3]
	**Public Transport** Infrastructure	The capacity of public transportation serving a city, accessibility to the public transport network and the quality of services.
	**Green/Blue** Infrastructure	The capacity, quality and accessibility of blue and green infrastructure within cities contribute to ecological sustainability, human health and well-being.
	**Governance** Infrastructure	Appropriate governance underpins good density. It needs to be spatially aware, integrated horizontally and vertically and to have a well-developed, responsible public-private investment strategy.

[3] Due to the high importance of public transport infrastructure in supporting good density noted in the literature reviewed and a lack of globally comparable comprehensive public infrastructure costs data, priority was given to transport infrastructure costs for four city case studies identified in Phase II of the research.

Global indices relevant for the six urban form characteristics underpinning good density were then identified and evaluated to establish the robustness and comparability of their underlying data. 12 indices[4] were finally incorporated in quantitative analysis in Phase II of the study to examine the significance of good density for real estate investment returns.

Good density indices	
Clustering Structure	**Density urban extent** – Atlas of Urban Expansion (AoUE)
Economic/Employment Infrastructure	**Business services** – Globalization & World Cities Network (GaWC) **Financial services** – Globalization & World Cities Network (GaWC) **Innovation** – THINKNOW **Tourism** – EUROMONITOR
Built Infrastructure	**Built up area density** – Atlas of Urban Expansion (AoUE) **Walkability ratio** – Atlas of Urban Expansion (AoUE)
Green/Blue Infrastructure	**Green environment** – Arcadis Sustainable Cities Index **Open space ratio** - Atlas of Urban Expansion (AoUE)
Governance Infrastructure	**Transparency** – Jones Lang LaSalle (JLL) **Low unemployment** – Mayor of London / New York City Global Partners **Low crime** – NUMBEO

Notes:

(1) AoUE data on urban extent and built up area density are based on population per hectare and are together representative of *compact* development, as opposed to simply city *size*.
(2) GaWC business and financial services shed light on commercial office occupation and *functional density,* complementing the AoUE focus on urban *residential density* (population per hectare).
(3) JLL transparency data are taken from an index comprised of national metrics.
(4) AoUE satellite data on walkability are based on accurate metrics available from remote photography however the quality of walking route, e.g. whether a route is *safe* and *enjoyable* to walk is unknown.
(5) AoUE data on built form, urban extent and open space ratio (i.e. size of block or open space) indicate the different *spatial patterns of density* within a given built up area, however *building uses* and *heights* are not surveyed. The GaWC data indicate *commercial office use and* are a proxy for *central business district building heights*.
(6) ARCADIS green environment is a composite city ranking of indicators relevant for good density that draws on a number of reputable individual sources (see Technical Annex IB).

[4] For descriptions of the indices see Technical Annex IB.

Phase II

The second phase of the project focused on quantitative analysis of relationships between good density indicators relevant for the urban form characteristics and real estate investment returns, and their implications for CO_2 emissions and infrastructure costs.

Semi-structured interviews with ULI real estate industry project steering group members were first conducted to provide qualitative insights into fund management and investor interest in supporting good density, how good density is currently incorporated in private sector decision making, and to help with the identification of additional relevant data.[5] A summary of the interview findings is included in Technical Annex II to this report.

To better capture the different dimensions of the real estate market in response to fund management and investor interest in not only returns but investment value and performance, three data sources were used in analysis. The conventional real estate yields[6] data, supplied by CBRE, have been used to calculate returns. We used data supplied by Cushman & Wakefield (CW) on capital value and rents for European markets. Real Capital Analytics (RCA) data on global cross-border real estate portfolio capital flows[7] were also incorporated. Following the standard methodology applied in the academic real estate literature, due to annual point-in-time volatility of real estate performance, average performance has been used to calculate relationships with good density characteristics (see for example, Lizieri et al., 2012). Data available to the research team for all three sources were for the time period since 2008

CBRE data are on a quarterly basis for 63 cities internationally.[8] CW rental and yield data for a sub-set of 27 European cities allowed the incorporation in analysis of data for prime retail as well as office markets.[9] In both cases, data are based on local appraisal information. RCA global data for commercial office property based on transactions values were therefore also incorporated in analysis to shed light on cities that are attracting major property investment flows.

Table 1 summarises the number of cities for each variable for which investment and good density data were available. Due to some cities, and thereby metrics, having large proportions of missing data, and a lack of comparable time-series data, analysis is limited in terms of formal econometric modelling. Also for several good density variables (tourism, transparency, green environment, and innovation) indices provide only the relative rank of cities globally. As a result, we do not report results from regression analysis but use rank correlation analysis instead based on the most recent data from 2016 indices. For the cases in which more than 50 observations are available, we ran univariate and multivariate regressions as a robustness check for our baseline correlation results. Overall, we did not find that using regression analysis leads to different conclusions. It is important

[5] See Technical Annex II for details of the interview research ethics procedure, information sheet and signed consent form, and the questionnaire proformas.
[6] The yield on a property is the annual return on a capital investment as a percentage of the capital value.
[7] Flows of capital into real estate – see Lizieri et al., 2012.
[8] Japanese cities are not included in the CBRE data base and were therefore not able to be included in the analysis.
[9] Residential markets relevant for good density require research in follow up studies, e.g. non-commercial residential property important for affordable housing supply and robust comparable data on the commercial residential market required for global analysis.

to note that this methodology does not account for causality. The relationship between variables has been determined using the Spearman's rank-based correlation coefficient (Spearman. 1904) given as:

$$\rho_{i,j} = \frac{\text{cov}(v_i, v_j)}{\sigma_i \sigma_j} \quad (1)$$

with $\rho_{i,j}$ denoting the Pearson correlation coefficient, $\text{cov}(v_i, v_j)$ the covariance between rank variable v_i and rank variable v_j and σ_i being the standard deviation of rank variable v_i and σ_j being the standard deviation of rank variable v_j. The correlation coefficients are calculated for a cross section of cities' data. The year of the good density data varies for individual indices but for most variables it is based on data since 2014.

The data sources used in the analysis together with data and analytical challenges and limitations, and validity tests run, are detailed in Technical Annex I to this report.

Table 1 Number of observations (*N*) for each variable.

Variable	*N*
Returns after 2008	63
Real estate investment flows	63
Business services	63
Financial services	59
Innovation	63
Low unemployment	63
Low crime	62
Green environment	37
Transparency	57
Urban extent density	50
Built up area density	61
Open space ratio	28
Walkability ratio	28
Tourism	28

The results presented in this report are for global and European levels of analysis. Additional insights are presented for selected cities in mature economies (London, New York and Hong Kong) and developing economies (Beijing, Mumbai and Warsaw) and for four case study cities (London, New York, Hong Kong and Zürich) identified on the basis of interesting global and European correlation results.

Moreover, a prototype working tool for city mapping and visualization has been developed to demonstrate how the present analysis could be taken forward to assist private and public sector investment decision making. Screenshots illustrating the tool interface for the London case study shown in Exhibits 1 to 4, illustrate how in-depth relationships between real estate investment and urban form characteristics important for good density can be informed by the incorporation of detailed local information on potential confounding variables not revealed in global analysis.[10]

[10] Confounding variables are variables not controlled for in analysis. Local confounding variables reflecting spatial heterogeneity could compromise the validity of global correlations (see Technical Annex !B).

Key findings

Global insight – Commercial offices

A focus on commercial office markets for global analysis reflects the strength of available data. Rank correlations between commercial office real estate investment returns and the 12 good density indicators identified in Phase I of the research are shown in Figure 1 and Table 2. Of the 63 cities worldwide with office returns data for the period after 2008, the four cities with the highest returns are: Hong Kong (rank 1), San Francisco (rank 2), Mumbai (rank 3) and Paris (rank 4). Urban form data, urban extent density, built up area density and open space ratio, are available for each of the cities apart from San Francisco.

The outcomes of analysis demonstrate that three of the 12 good density indicators are highly correlated with real estate investment returns, urban extent density (0.68) and built up area density (0.66), as well as transparency (Figure 1 and Table 2). The strong negative correlation between returns and transparency, -0.55 is driven by cities within the US, which have the highest level of transparency but which, on average, have a low level of returns. When US cities are removed from the analysis, the correlation result for returns and transparency is 0.07. Significant correlations are also found between office returns and three other indicators at the global level of analysis, business services (0.36), innovation (0.32), financial services (0.31) and green environment (0.29) (Table 2). The remaining density indicators are not significantly related to returns.

Overall, we see that high density in terms of urban extent and built-up area goes along with high return performance. However, we need to keep in mind that some of those figures are based on a small sample of below 30 cities which may leave some room for bias if the sample is extended (for each figure, significance is shown). Also, the analysis does not account for omitted variables such as demand and supply drivers of real estate investment. In an attempt to account for those, we control for per capita and total volume GDP (Gross Domestic Product) in a multivariate regression setting but do not observe significant changes in our findings.

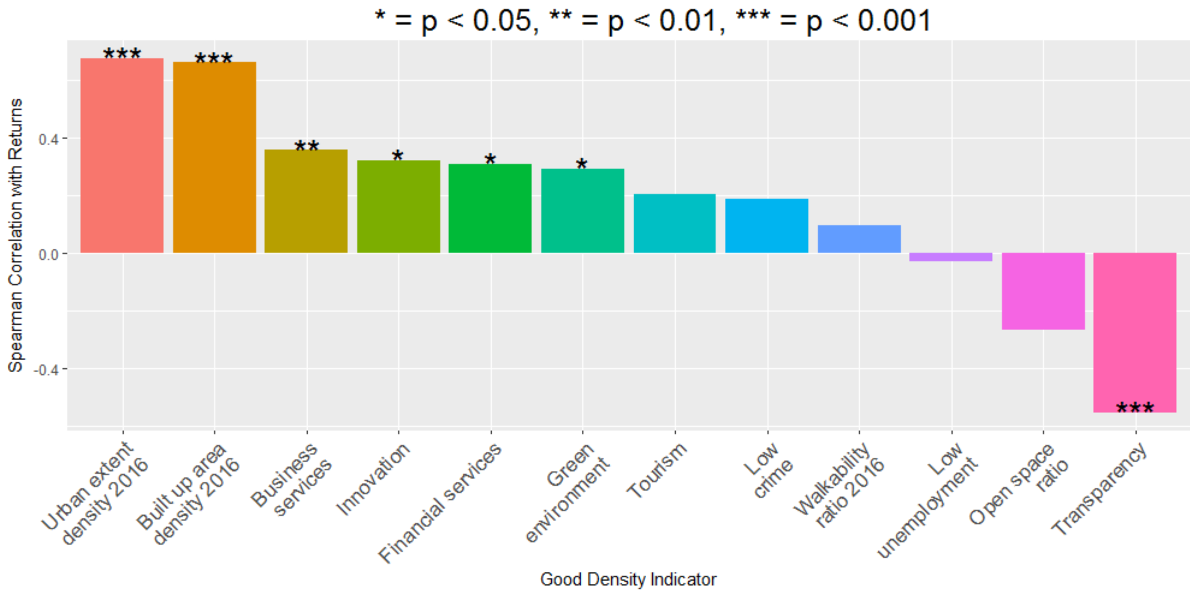


Figure 1 Correlation between returns and good density indicators.
Note: '*P*' indicates probability. A '*p*'-value ≤ p 0.05 is significant.

Table 2 Spearman correlations between real estate investment returns and good density indicators.

p = *p*-value, *N* = number of observations.

Good density **indicator**	Correlation with **returns**	***p***	***N***
Urban extent density 2016	0.68	7.74E-05	28
Built up area density 2016	0.66	1.19E-04	28
Business services	0.36	3.94E-03	63
Innovation	0.32	1.08E-02	62
Financial services	0.31	1.33E-02	63
Green environment	0.29	3.94E-02	50
Tourism	0.20	0.23	37
Low crime	0.19	0.17	57
Real estate investment flows	0.14	0.28	59
Walkability	0.09	0.63	28
Low unemployment	-0.03	0.87	37
Open space ratio	-0.27	0.17	28
Transparency	-0.55	3.49E-06	61

In a further step, we look at cross-border real estate flows. Correlations between commercial office real estate investment flows and the 12 good density indicators are shown in Figure 2 and Table 3.

The results show a very different picture from the return output. Physical density seems not to be significantly related to flows across the international cities. It is rather, innovation that is the most highly correlated indicator, by 68%. Business services and financial services are also highly correlated with investment flows, 0.52 and 0.50 respectively. The other density measures are not significant.

The results suggest that the innovation and quality of services of a city are what is associated with good density when it comes to real estate flows rather than the more traditional measures of urban form. However, the analysis does not account for omitted variables relevant to commercial office demand and supply drivers of real estate capital flows, such as space demand and supply.

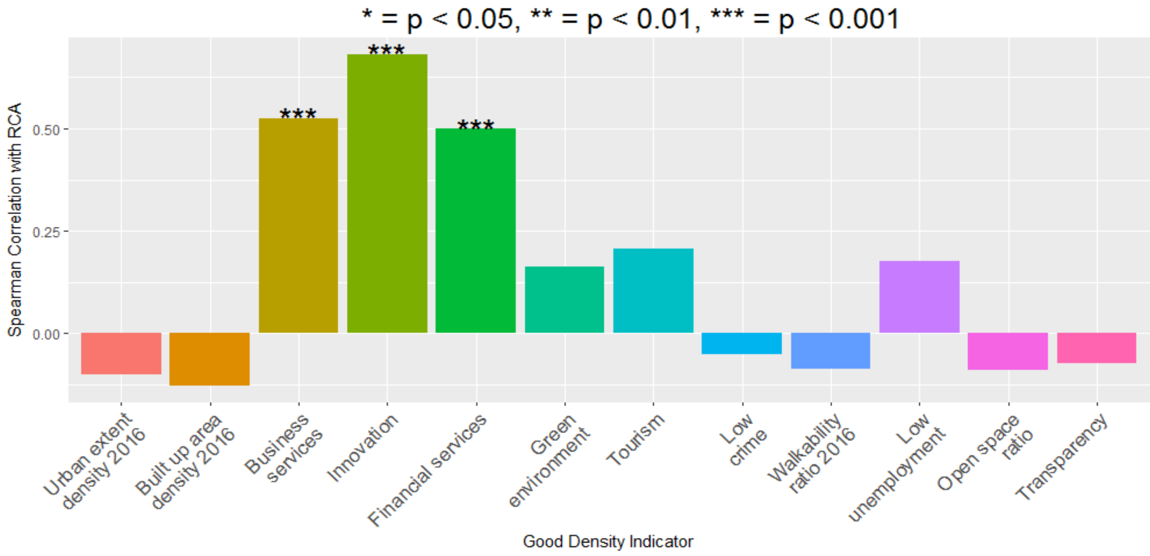


Figure 2 Correlation between real estate investment flows and good density indicators.

Table 3 Spearman correlations between good density indicators and real estate investment flows.

Good density indicator	Correlation with Real investment flows	*p*	*N*
Returns before 2008	0.14	0.28	59
Business services	0.52	1.97E-05	59
Financial services	0.50	5.86E-05	59
Innovation	0.68	2.97E-09	59
Low unemployment	0.18	0.30	37
Low crime	-0.05	0.72	54
Green environment	0.16	0.27	48
Transparency	-0.07	0.58	58
Urban extent density 2016	-0.10	0.62	27
Built up area density 2016	-0.13	0.53	27
Open space ratio	-0.09	0.66	27
Walkability ratio 2016	-0.09	0.67	27
Tourism	0.21	0.23	35

European insight

Figures 3 to 6 and Tables 4 to 7 show correlations discovered between the 12 good density indicators and real estate capital values and rents for retail as well as office markets for nine European cities where urban form density data were also available: London, Paris, Moscow, Milan, Madrid, Berlin, Vienna, Warsaw and Budapest. Given the small sample size (nine cities), generalization on the basis of these results is not possible, however, they offer interesting insights into relationships presenting in selected European mature and developing office and retail markets.

The results overall are in line with the results shown in Figure 1 for the extended sample, confirming that urban extent and built up density measures have the highest correlation with office capital values. Though significance for property performance is not demonstrated, open space ratio is generally negatively correlated with office and retail capital values and rents. Innovation and investment flows are positively correlated with office capital values (by 0.52 and 0.48 respectively – Table 4 and with retail rents (by 0.63 and 0.54 respectively -Table 7).

The strong positive correlation of tourism along with business services with retail capital values (0.55 and 0.47 respectively – Table 6), is of potential interest for further research given that tourism is likely to reflect qualitative aspects of city good density for which reliable global data have not been identified for this study. Tourism is also positively correlated (though without significance) with office capital values, by 0.33 (Table 4) and with retail rents, by 0.43 (Table 7). Tourism resurfaces again later as of interest in relation to investment returns in portraits of cities in developed economies (London, Paris and Hong Kong).

The general lack of significance of walkability found in both the global and the European results, seems likely to reflect the fact that AoUE walkability is a city level metric and does not account for sub-city density variations associated with commercial land use (see Technical Annex IB). Based on the literature reviewed in Phase I, proximity is an important driver of commercial clustering within cities and walkability follows from this (see Technical Annex IB).

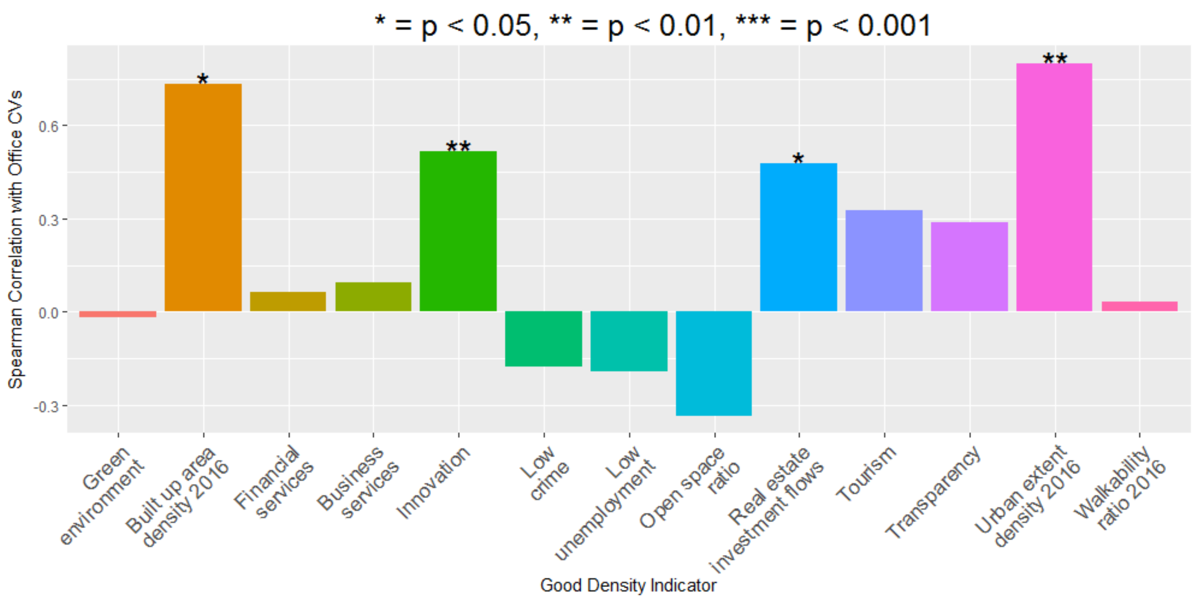


Figure 3 Correlation between office capital values and good density indicators.

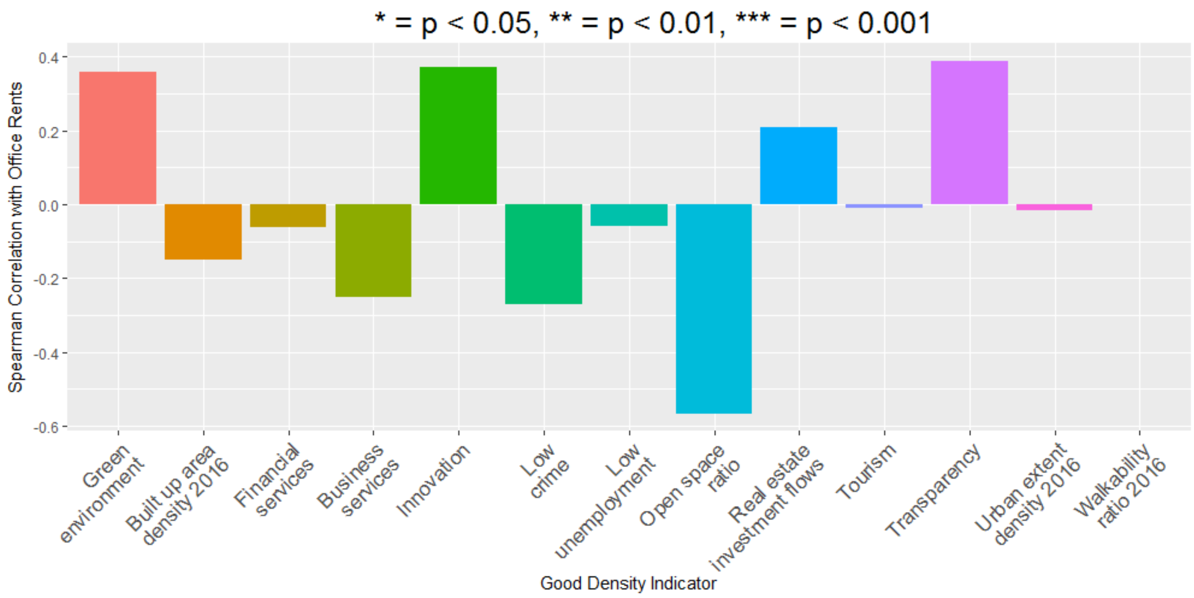


Figure 4 Correlation between office rents and good density indicators.

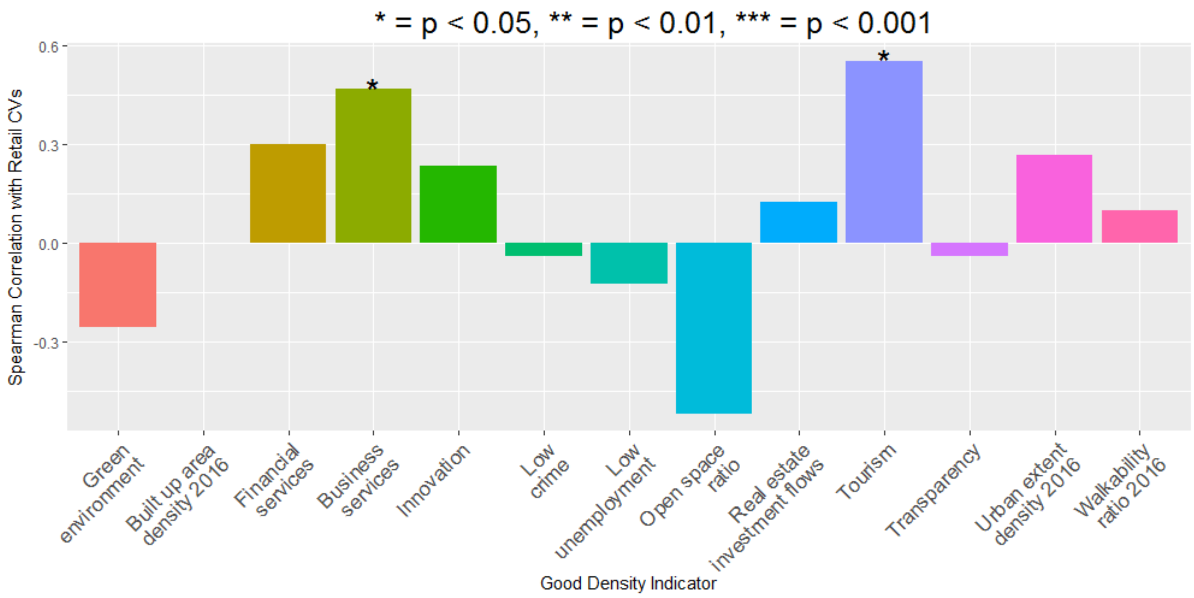


Figure 5 Correlation between retail capital values and good density indicators.

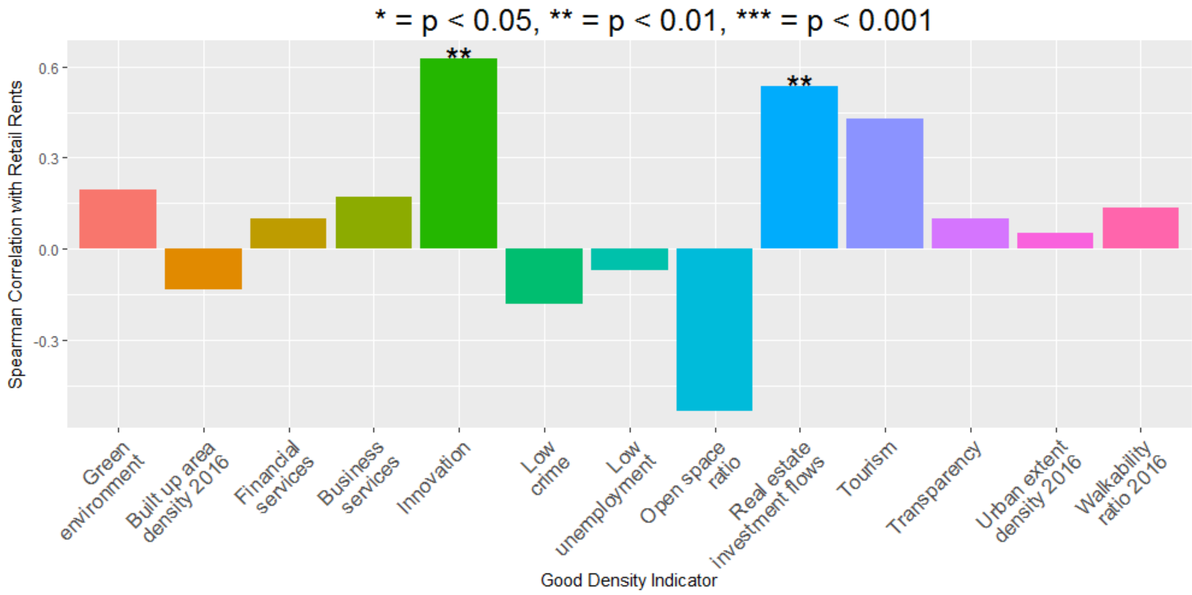


Figure 6 Correlation between retail rents and good density indicators.

Table 4 Correlation between city office capital values (CVs) and good density indicators. *p* = *p*-value, N = number of observations.

	Correlation with office CVs	*p*	*N*
Office rents	0.27	0.22	23
Retail rents	0.22	0.30	24
Retail CVs	0.49	1.45E-02	24
Real investment flows	0.48	2.07E-02	23
Business services	0.09	0.66	24
Financial services	0.06	0.77	24
Innovation	0.52	0.01	24
Green environment	-0.02	0.95	21
Transparency	0.29	0.17	24
Urban extent density	0.80	9.63E-03	9
Built up area density	0.73	2.46E-02	9
Open space ratio	-0.33	0.38	9
Walkability ratio	0.03	0.93	9
Tourism	0.33	0.20	17
Low unemployment	-0.19	0.42	20
Low crime	-0.18	0.43	22

Table 5 Correlation between city office rents and good density indicators.

p = *p*-value, N = number of observations.

	Correlation with office rents	*p*	*N*
Office CVs	0.27	0.22	23
Retail rents	0.35	0.10	23
Retail CVs	-0.06	0.80	23
Real investment flows	0.21	0.35	22
Business services	-0.25	0.24	23
Financial services	-0.06	0.77	23
Innovation	0.37	8.18E-02	23
Green environment	0.36	0.12	21
Transparency	0.39	6.71E-02	23
Urban extent density	-0.02	0.97	9
Built up area density	-0.15	0.70	9
Open space ratio	-0.57	0.11	9
Walkability ratio	0.00	1.00	9
Tourism	-0.01	0.97	17
Low unemployment	-0.06	0.80	20
Low crime	-0.27	0.24	21

Table 6 Correlation between city retail capital values (CVs) and good density indicators.

p = *p*-value, N = number of observations.

	Correlation with retail CVs	*p*	*N*
Office rents	-0.06	0.80	23
Office CVs	0.49	1.45E-02	24
Retail rents	0.23	0.28	24
Real investment flows	0.13	0.57	23
Business services	0.47	2.16E-02	24
Financial services	0.30	0.15	24
Innovation	0.23	0.27	24
Green environment	-0.25	0.27	21
Transparency	-0.04	0.86	24
Urban extent density	0.27	0.49	9
Built up area density	0.00	1.00	9
Open space ratio	-0.52	0.15	9
Walkability ratio	0.10	0.80	9
Tourism	0.55	2.14E-02	17
Low unemployment	-0.12	0.60	20
Low crime	-0.04	0.86	22

Table 7 Correlation between city retail rents and good density indicators.

p = *p*-value, *N* = number of observations.

	Correlation with retail rents	*p*	*N*
Office rents	0.35	0.10	23
Office CVs	0.22	0.30	24
Retail CVs	0.23	0.28	24
Real investment flows	0.54	8.30E-03	23
Business services	0.17	0.43	24
Financial services	0.10	0.64	24
Innovation	0.63	1.03E-03	24
Green environment	0.20	0.39	21
Transparency	0.10	0.65	24
Urban extent density	0.05	0.90	9
Built up area density	-0.13	0.73	9
Open space ratio	-0.53	0.14	9
Walkability ratio	0.13	0.73	9
Tourism	0.43	0.09	17
Low unemployment	-0.07	0.77	20
Low crime	-0.18	0.42	22

Global carbon insight

Global level city CO_2 emissions data gathered by CDP (formerly the Carbon Disclosure Project – see Technical Annex ID) are used here to inform global analysis on the relation between CO_2 emissions, the good density indicators, and real estate investment returns. Reported CO_2 emissions for each city are directly compared to density indicators to calculate correlations.

The 2013 CDP emissions data for more than 50 cities need to be interpreted with caution as the cities are self-reporting and data are based on different assessment methods (rather than observations or consistent methods). However the data represent a broad range of urban areas. Some shortcomings will in future be resolved by the Greenhouse Protocol for Cities (a global reporting standard for cities) launched in 2014. However, ground based (instruments mounted on towers) and satellite observations are necessary to corroborate the emissions. Combining the inventory results with observations would allow emissions to be understood and the response to actions to be assessed. To date, the protocol has not been as widely adopted as necessary for the present analysis (for example, it has not been adopted by the case study cities Hong Kong and Zürich). Differences between emissions reporting approaches and terms included are discussed in greater detail in Technical Annex ID.

Correlations for both low (inverted) *CO_2 emissions per km^2 per person* and *total CO_2 emissions* with the good density indicators are shown in Figures 6 and 7, and Tables 8 and 9.

The CDP data have insignificant correlations between low per capita (per person) emissions, density indicators, and returns after 2008. However, it is interesting to compare the correlation between low *per capita* emissions and commercial office real estate investment returns (0.25, Table 8) with the weaker correlation for *total* emissions (0.16, Table 9).

This result agrees with the Phase I literature review conclusions that population and built density increases are associated with reductions in *per capita* emissions and increases in *per area* emissions (Christen. 2014; Kennedy et al., 2015), suggesting there are efficiency gains despite an overall increase in emissions from increased population and human activity.

CDP CO_2 emissions data are not available for all cities with returns data (for example, for Beijing and Mumbai, Figure 11). However, of the cities included in this Global Carbon Insight analysis, Hong Kong, San Francisco and Singapore have the highest office real estate investment returns relative to low *per capita* CO_2 emissions (Figure 8). Hong Kong also has the strongest relation between high office real estate investment returns and urban form density (urban extent and built up area) of cities having both real estate returns and good density data, globally (see mature economy city profiles and Figure 10).

Paris has similarly high office real estate investment returns to Singapore but also somewhat higher *per capita* CO_2 emissions (Figure 8) whereas Moscow, Los Angeles and Houston have low per capita emissions but much lower real estate investment returns than Hong Kong, San Francisco, Singapore and Paris (Figure 8).

Both Paris and San Francisco have low *total* CO_2 emissions relative to returns (Figure 9).

Interestingly, green environment is positively correlated with low *total* CO_2 emissions (0.34) but there is no correlation between green environment and low CO_2 emissions *per* km^2 *per person* (-0.06), i.e. when accounting for population density.

The correlation between transparency and CO_2 emissions per km^2 per person when excluding US cities (-0.51) was similar to the analysis including all cities (-0.47) demonstrating that this relationship is not a consequence of US cities alone.

Questions of how to interpret these relational global patterns requires attention with the benefit of local information and insights, including on the implications of differing measurement methodologies used.

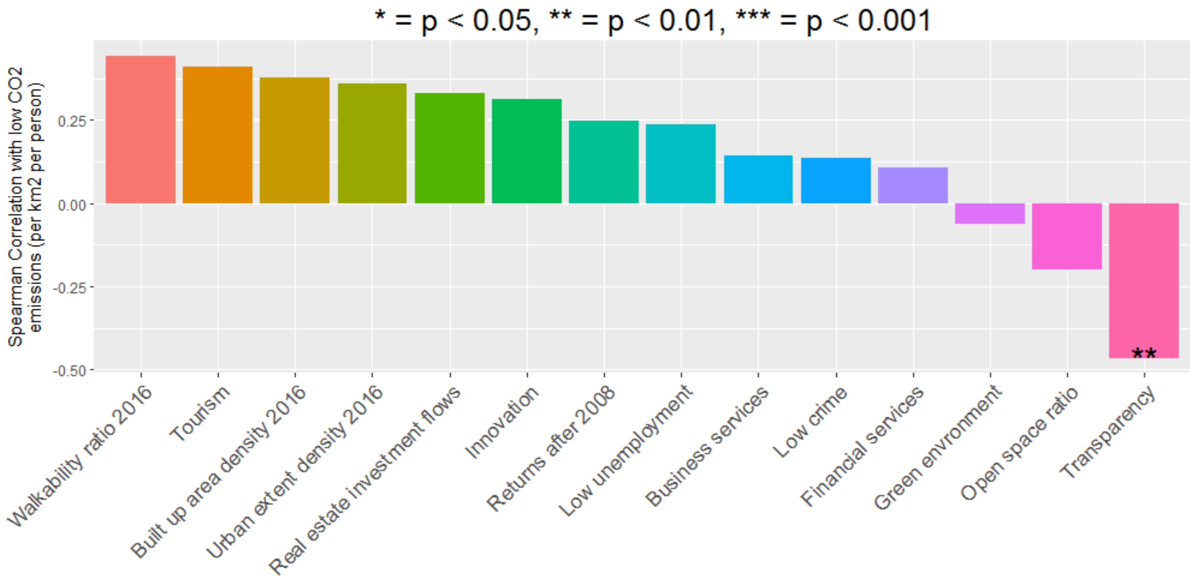


Figure 6 Correlation between low CO_2 emissions per km^2 per person and good density indicators. Note: 'Low CO_2' reflects that emissions data have been inverted to represent good density. A positive correlation signifies a reduction in CO_2 emissions and thereby good density.

Table 8 Correlation between low CO_2 emissions per km^2 per person and good density indicators.

Good density indicator	**Correlation with CO_2 emissions per km^2 per person**	***p***	***N***
Returns after 2008	0.25	0.17	32
Real estate investment flows	0.33	6.85E-02	31
Business services	0.14	0.43	32
Financial services	0.11	0.56	32
Innovation	0.31	8.78E-02	31
Low unemployment	0.24	0.27	23
Low crime	0.14	0.47	30
Green environment	-0.06	0.75	29
Transparency	-0.47	7.25E-03	32
Urban extent density 2016	0.36	0.16	17
Built up area density 2016	0.38	0.14	17
Open space ratio	-0.20	0.44	17
Walkability ratio 2016	0.44	7.45E-02	17
Tourism	0.41	8.23E-02	19

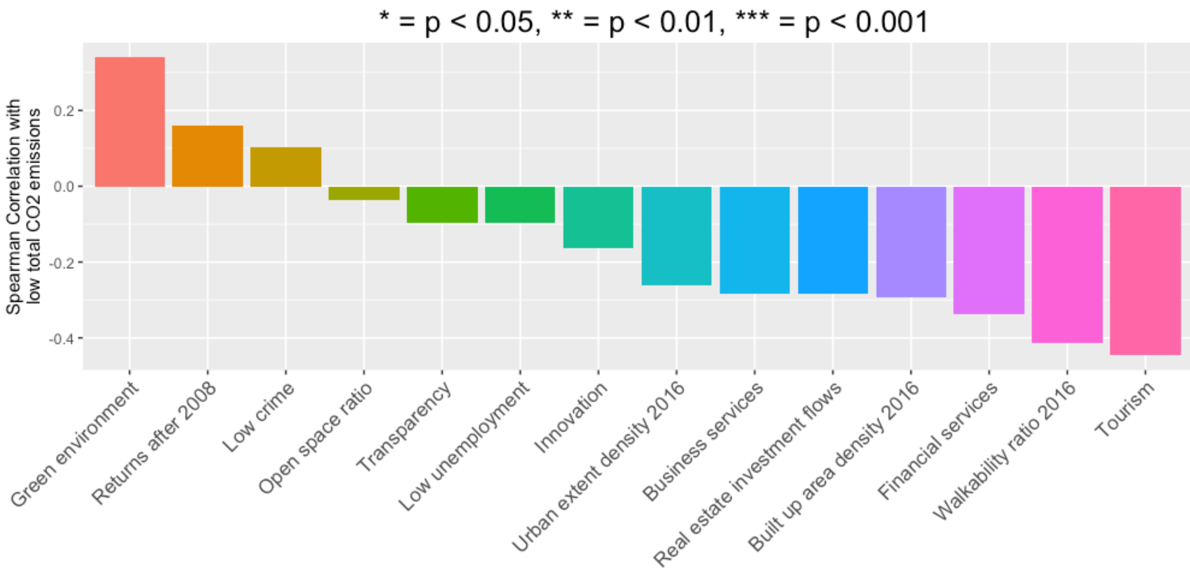


Figure 7 Correlation between total low CO_2 emissions and good density indicators.[11]

Table 9 Correlation between low total CO_2 emissions and good density indicators.

Good density indicator	Correlation with total CO_2 emissions	*p*	*N*
Returns after 2008	0.16	0.39	32
Real estate investment flows	-0.28	0.12	31
Business services	-0.28	0.12	32
Financial services	-0.34	0.06	32
Innovation	-0.16	0.38	31
Low unemployment	-0.10	0.66	23
Low crime	0.10	0.59	30
Green environment	0.34	7.04E-02	29
Transparency	-0.10	0.60	32
Urban extent density 2016	-0.26	0.31	17
Built up area density 2016	-0.29	0.25	17
Open space ratio	-0.04	0.89	17
Walkability ratio 2016	-0.41	0.10	17
Tourism	-0.45	5.59E-02	19

[11] The strong negatively correlation of walkability to low CO_2 may point to the difference between the AoUE sourced walkability ratio and whether or not a city is, in fact, walkable, taking into account qualitative criteria (see Technical Annex).

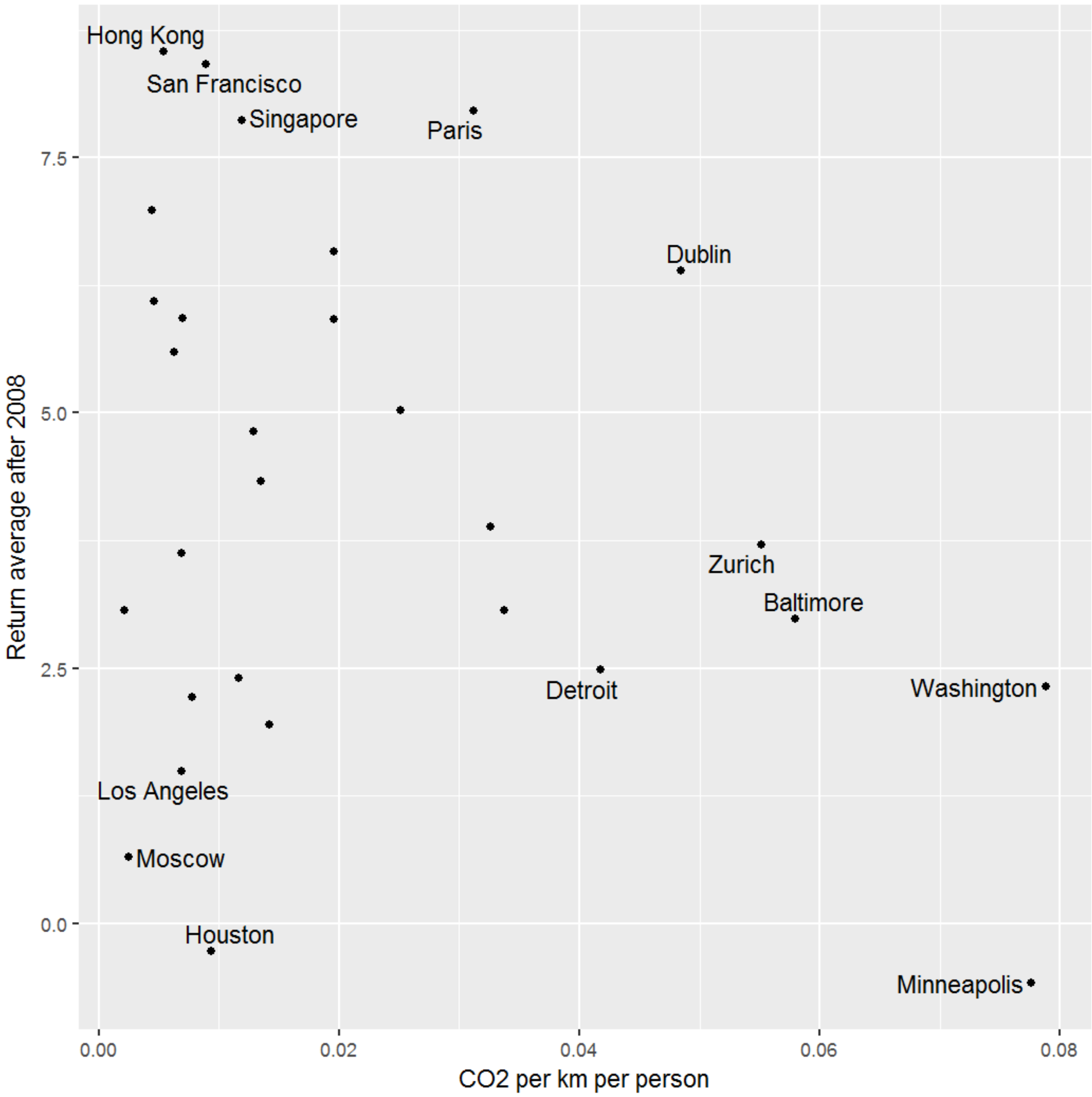


Figure 8 Total CO_2 emissions per km² per person and real estate investment returns.
Note: Here CO_2 emissions data are not inverted and thereby represent 'bad' density.

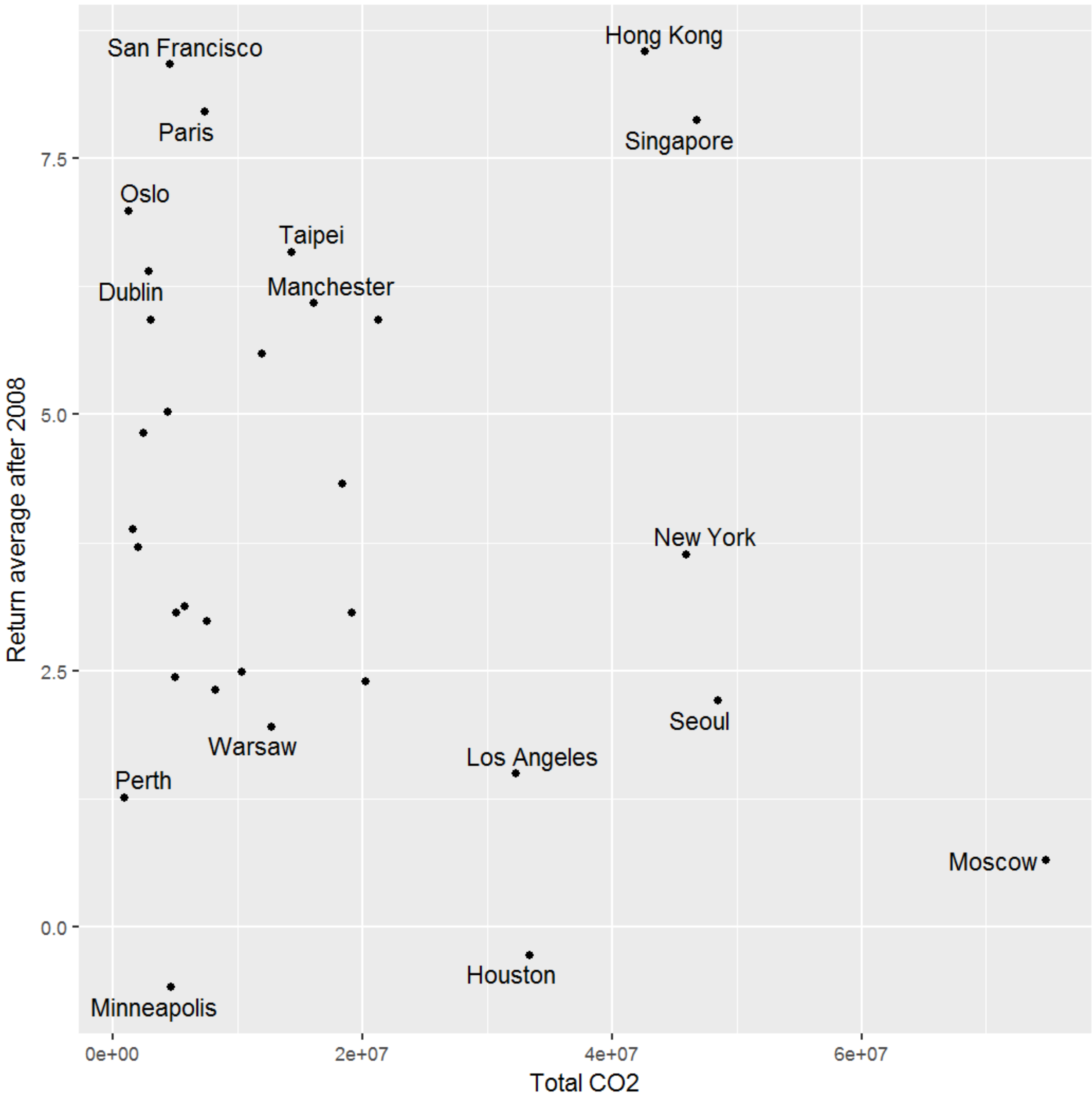


Figure 9 Total CO_2 and real estate investment returns.
Note: Here CO_2 emissions data are not inverted and thereby represent 'bad' density.

City profiles – Mature & developing economies

Six cities were selected from the global level analysis to provide insights into different combinations of good density indicators that are correlated with investment returns in an international commercial office market perspective. The cities are compared here in two separate vignettes examining the cities' rank positions (percentiles) for real estate returns, capital flows, the 12 good density indicators and CO_2 emissions, first for cities in mature economies and, second, for cities in developing economies:

- Mature economies: Hong Kong, London and Paris
- Developing economies: Beijing, Mumbai and Warsaw[12]

Rank percentiles[13] are shown in the vignette portraits to draw out different patterns of association between variables for groups of cities. To distinguish between good density and bad density features clearly, the employment, crime and CO_2 rank metrics are reversed here to show high unemployment, high crime and high total and per capita emissions for each city.

Table 10 presents the population size, urban extent, and density (persons per hectare) for each of the cities based on AoUE data, and also for Zürich which is incorporated in the case study city analysis but which lacks AoUE density data.

Table 10 City populations, hectares and density

CITY	POPULATION	URBAN EXTENT (ha)	DENSITY (persons/ha)
London	11,197,941	250,771	45
New York	18,412,093	951,103	19
Hong Kong	4,322,119	12,278	352
Zurich	*396,027**	*8,788***	*45*
Paris	11,114,026	277,848	40
Mumbai	19,601,845	70,533	278
Beijing	20,669,397	455,684	45
Warsaw	2,298,450	74,279	31

Source: http://www.atlasofurbanexpansion.org/
* *Canton of Zurich Statistical Office*
** *Arealstatistik Standard - Gemeindedaten nach 4 Hauptbereichen*

[12] Warsaw is included in the developing economy city profile due to its well documented substantial growth similar to that of Beijing and Mumbai, since the year 2000 (see for example, Pain et al., 2012).
[13] The rank percentile of a city on a given scale (e.g. returns) is the percentage of cities that have a value equal to or lower than it. For example, if Hong Kong has the highest level of returns, then it will have a rank percentile of 100 as 100% of other cities have lower returns than Hong Kong. It is calculated by dividing the rank of the city by the total number of cities, and then multiplying it by 100 to turn it into a percentage e.g. percentile rank of A = (rank of A / number of observations) x 100.It is not known what global and local factors that are not accounted for in the present analysis may potentially impact returns in the portraits of the individual cities presented here. Nevertheless, the associations between variables revealed by the rank correlations analysis suggest interesting variations in relational patterns between these six cities.

Hong Kong, London and Paris

Of the cities in mature economies examined, Hong Kong and Paris have the highest office investment returns (Figure 10). However, Hong Kong's high urban form density (urban extent and built up) marks it out from the other cities, not only in the vignette perspective but also in a global perspective, as already discussed.

Paris notably achieves just slightly lower returns than Hong Kong, with a much lower level of urban form density. This result indicates that although built form density is generally a major contributor to higher returns, other aspects of good density, besides urban form, are likely to be important also for returns in some cities (see Technical Annex IA).

A common pattern amongst the three cities is the strong representation of investment flows, business services and financial services and, interestingly, tourism. Open space ratio is low for all three cities.

Other interesting findings from this vignette are, first, Hong Kong's low open space ratio relative to urban extent and built up density. Nevertheless it has low crime and unemployment levels relative to London and Paris.

Second, the relationship between CO_2 emissions per person per hectare and total CO_2 emissions of Hong Kong (low emissions per person but high total emissions) is reversed for London and Paris (lower total than per capita emissions).

Of the three cities, Hong Kong therefore has the highest real estate investment returns (marginally higher even than Paris) but also the highest total emissions, whereas London has the lowest total emissions relative to its investment returns despite having lower built up and urban extent density than Hong Kong.

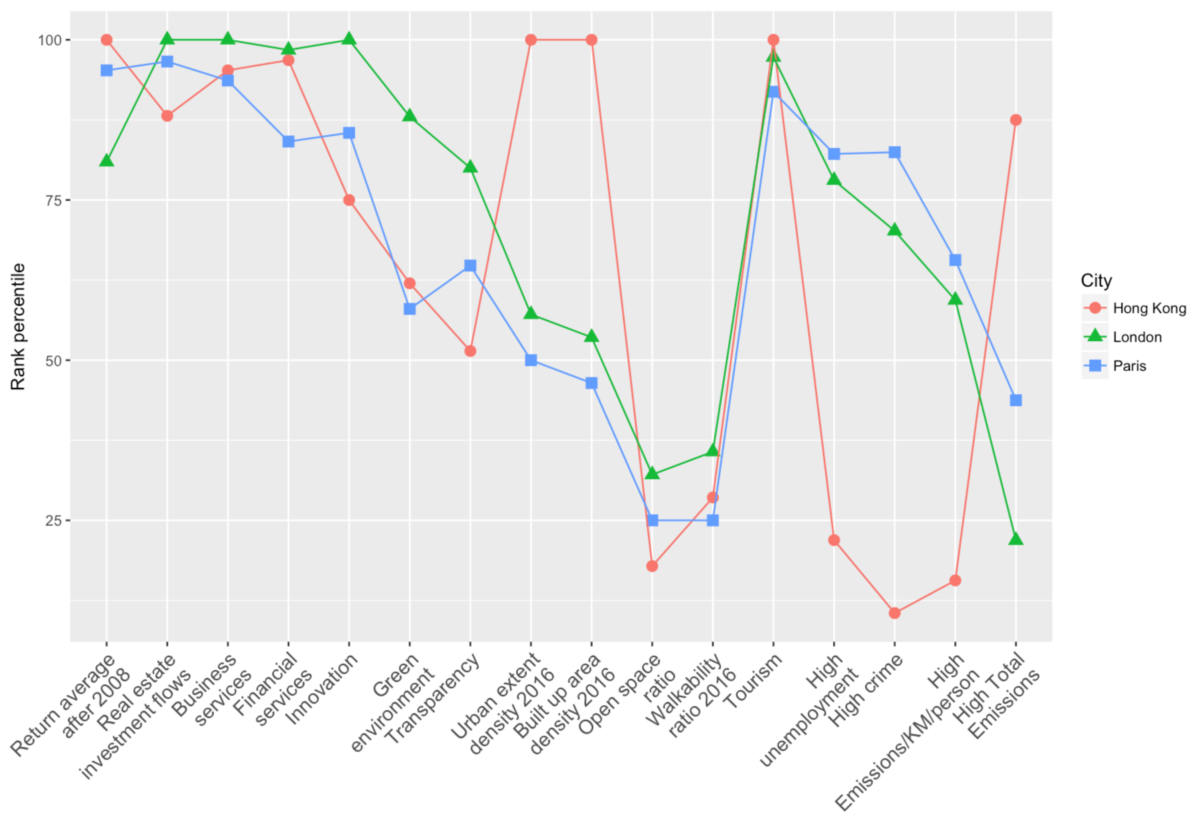


Figure 10 Good density profiles for Hong Kong, Paris and London.

Note: CO_2 emissions data are not inverted and therefore represent 'bad' density.

Beijing, Mumbai and Warsaw

Of interest in studying the patterns of relationships between good density indicators for the cities in developing economies, is that although investment flows, business services and financial services are most highly represented in Beijing, it is Mumbai that has the highest urban form density and also the highest returns of all three cities (Figure 11). Nevertheless, both Mumbai and Beijing have higher urban form density than the European cities analyzed in the two vignettes (Paris, London and Warsaw).

Each of the three cities has a high representation of business services nevertheless and, to varying degrees, financial services. However, it is striking that innovation, which was shown to be highly correlated with returns at the global level, is relatively less well represented here, especially for Mumbai and Warsaw. Also, tourism, which is strongly represented in the mature economy cities, is far less prominent amongst the good density indicators in these developing economy cities.

Green environment and transparency are also low for all three cities, especially green environment for Beijing and transparency for Mumbai. Open space ratio is lowest for Mumbai. In the context of the negative correlation of open space ratio with returns at a global level, the ratio for Beijing stands out however, demanding further investigation employing local information.

Warsaw has the lowest returns of the three cities despite its relatively high business services representation. The city's recent rise, along with other Polish cities, as a location for business processing activities as opposed to the more specialized financial and business services that are concentrated in mature economy cities may explain this apparent anomaly (Pain and Van Hamme, 2014; Cushman Wakefield, 2016).

Other positive good density indicators represented for Warsaw are a high open space ratio relative to that of Mumbai, and low crime relative to both cities, especially Mumbai. CO_2 emissions data are not available for Mumbai and Beijing. Warsaw has higher total CO_2 emissions than emissions per person per hectare and is thereby in line with the general relationship noted at a global level.

The different patterns of good density indicator relationships with returns and CO_2 emissions between the developing and mature economy cities warrant further examination in discussion with real estate actors, investment agents, and government bodies in each city. For example, the potential for tourism and innovation in future to act as contributing significant factors supporting returns and capital flows alongside existing urban form density and business and financial services.

The results on CO_2 emissions, total and per capita, and their relationships with open space and green environment and returns for cities in mature and developing economies requires in-depth local investigation into confounding variables such as patterns of travel by car linked to urban form and differences in climate, rainfall, vegetation and growing seasons that impact emissions in cities in different world locations.

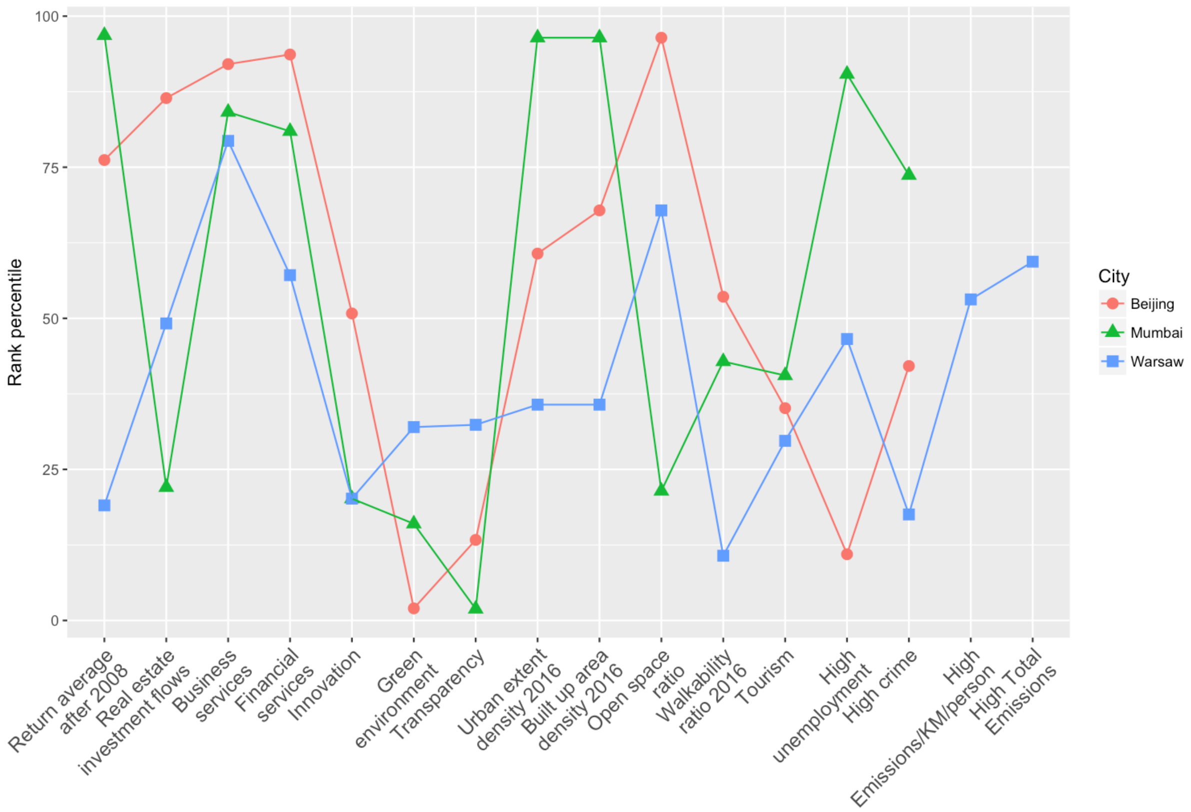


Figure 11 Good density profiles for Beijing, Mumbai and Warsaw.
Note: CO_2 emissions data are not inverted and therefore represent 'bad' density.

Landscape level insight - Visualizing good density

Four cities were selected for development as case studies for visual analysis on the basis of their correlations between different good density indicators and office real estate investment metrics identified in global analysis: Hong Kong, Zürich, London and New York.

Four cities case study overview

As Figure 14 shows, urban form density data are not available for Zürich however it is included in analysis here because it has the highest correlation at a global level between green environment and real estate investment returns. However, Zürich returns are not the highest and unlike London, New York and Hong Kong, Zürich has a weaker representation of investment flows and innovation relative to business and financial services.

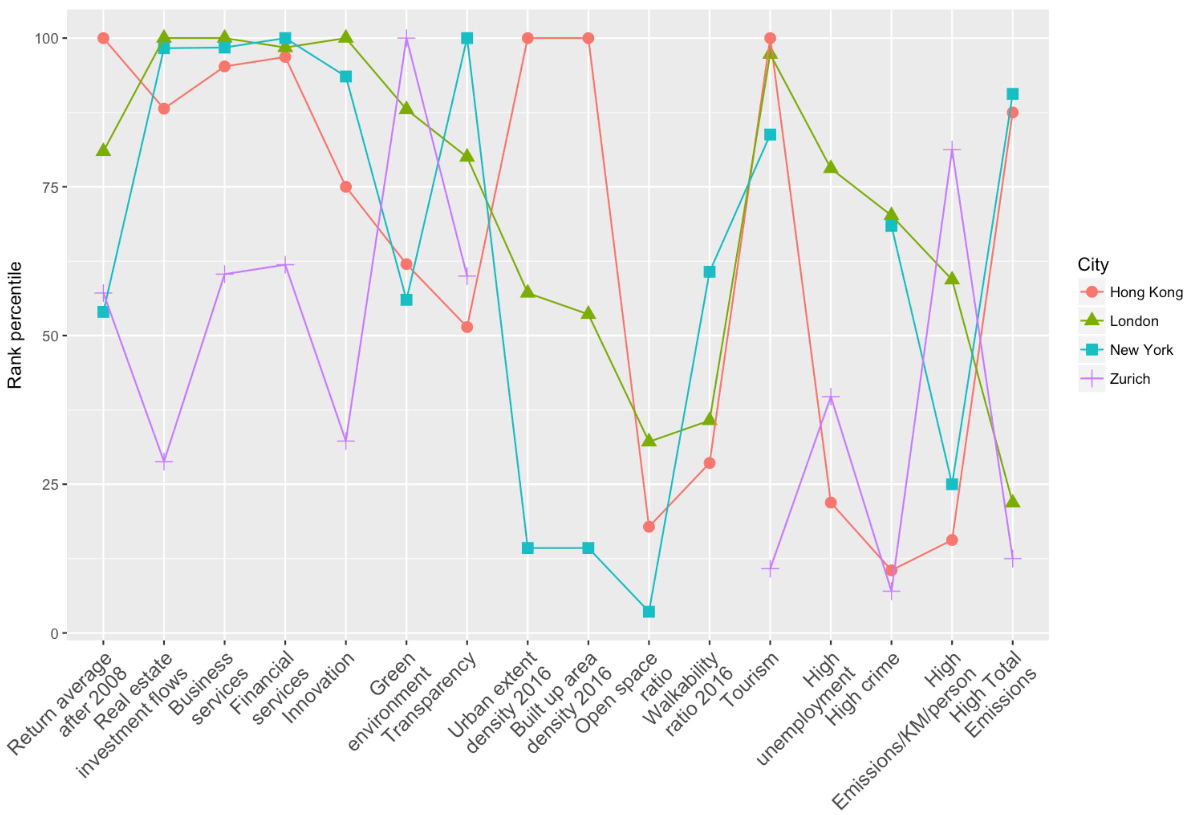


Figure 12 Good density profiles of Hong Kong, London, New York and Zürich.
Note: CO_2 emissions data are not inverted and therefore represent 'bad' density.

Of the four cities, London and New York have the strongest representation of business services and financial services, found to be positively correlated with real estate investment returns and investment flows at a global level. Yet of the three developed economy cities, Hong Kong has the highest returns. This pattern of association supports the general finding on the significance of compact built density for investment returns. The strong relationship between urban extent density and built up density and returns for Hong Kong contrasts with the lower urban form density of London, and especially New York.

Despite New York having lower investment returns than Hong Kong and London (and the lowest urban form density of all four cities), in common with Hong Kong, it has a low open space ratio along with high total CO_2 emissions and low per capita emissions. It is interesting to speculate whether Zürich's high green environment score is related to its low level of total CO_2 emissions.

Visual analysis for good density

London was found to have the most accessible sources for city and sub-city level data required for visual analysis and was therefore able to be developed to include a series of metric overlays illustrated in example Exhibits 1-4. The London visual mapping tool, demonstrates the potential value of visual analysis for informing private and public sector investment on the spatial structure of good density and the relationships between urban form characteristics at a landscape level. Exhibit 1 shows air quality, transport and property deals on one screen to illustrate how individual maps can be overlaid to assist spatial analysis and inform decision making.

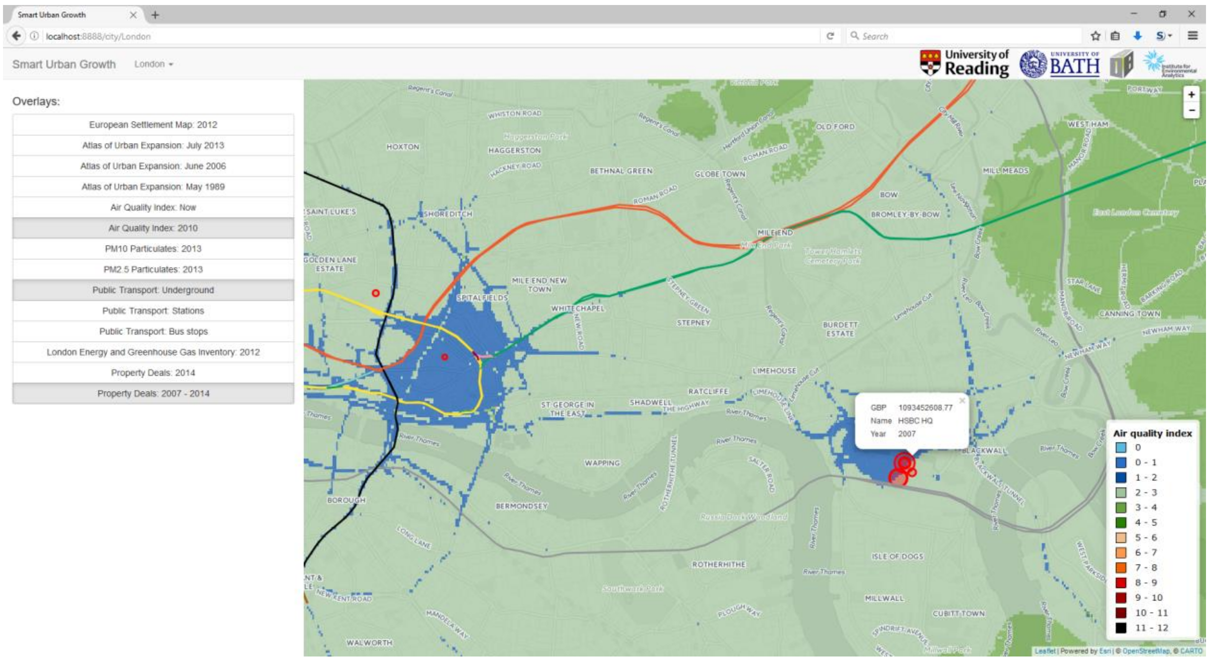


Exhibit 1 London air quality, transport and top-20 property deals, 2014 (first three quarters).

Future in-depth research would allow the incorporation of more detailed local micro- and property level data for other cities and across larger functional urban area scales that spill over official metropolitan boundaries (Hall and Pain, 2006) and which will have different local residential and employment market structures that are determinants of mobility patterns, CO_2 emissions and displacement (see Technical Annex ID).

Findings from the Phase I literature review suggest that urban form and open space patterns within cities are significant influences on the location and the magnitude of CO_2 emissions. Therefore, visual mapping assisted management of open space ratios in densely developed areas, has potential value in terms of reducing emissions and in supporting resilient property values and returns.

Real estate investment

Real Capital Analytics property transactions data have been incorporated in visualization for the top-10 office deals in the period 2007-14 in each of the four cities to illustrate the spatial pattern of major investment flows and concentration in their respective office property markets.

For London, the top-20 transactions in 2014 (1st three quarters) are shown in Exhibit 2, confirming the localised clustering and concentration of high-value transactions found common in each city. This spatial pattern highlights the significance of land values, building heights and commercial floor space, for major investment flows, that are not apparent from the population based density metrics incorporated elsewhere in analysis.

The lower top-ten transactions value for Zürich (6%) will reflect its smaller global business and financial services and commercial office market size relative to New York (40%), London (35%), and Hong Kong (18%).

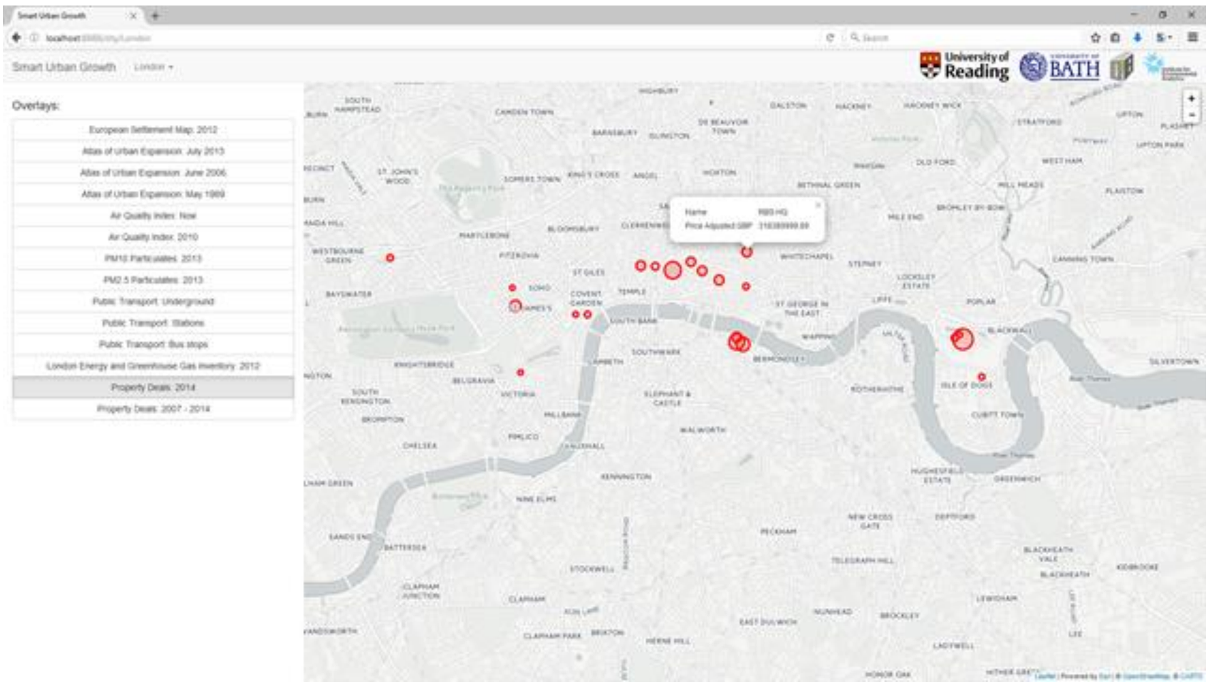


Exhibit 2 London top-20 property deals, 2014 (first three quarters).

Carbon emissions

For CO_2 emissions/km2/person 2015, the rank order of the four case study cities from lowest to highest emissions km2/per person is: Hong Kong (rank 1), New York (rank 2), London (rank 3), Zürich (rank 4) however, the data for Zürich can't be directly compared with that for the other three cities due to the use of different definitions used in city analysis (see Technical Annex ID). Furthermore, city-level statistics can obscure important variations at finer-scales.

Visualization techniques can reveal heterogeneity that is important to frame investment and policy.

Exhibit 3 illustrates the incorporation of borough level data illustrating CO_2 emissions variations in London and the location of high CO_2 levels in the central business district and around the Heathrow air and the motorway complex to the west of the city.

Findings from the Phase I literature review suggest that increasing urban density can act to displace emissions to less dense, less regulated areas. For example, people may decide to live outside an urban greenbelt and commute into the city from a suburban community. In this situation, a portion of transportation emissions have been displaced outside of urban boundaries, but the total emissions may not have been reduced. Within a city, the distribution of open space will also affect spatial patterns of urban density as well as CO_2 emissions.

Urban CO_2 emissions are a result of complex scale interactions between urban form, including open green and blue space, climate, environmental and social, economic and market factors. Therefore, a simple correlation between total CO_2 emissions and real estate investment does not take into account local differences in climate and emissions from building heating for example.

Different growing seasons between cities, for example, in high latitudes vs low latitudes, vegetation amounts (e.g. the inner city in London vs residential London have very different amounts of vegetation) which will offset some CO_2 emissions whereas seasonal bare vegetation will also emit CO_2, and this will change with climate.

The complex interrelations between determinants of both total and per capita emissions illustrates the need for global studies to be informed by more comprehensive and accurate local data and the development of relevant metrics such as CO_2 per unit floor space or relations between per capita emissions and per capita GDP with which to compare diverse cities. This work was beyond the scope of the present research.

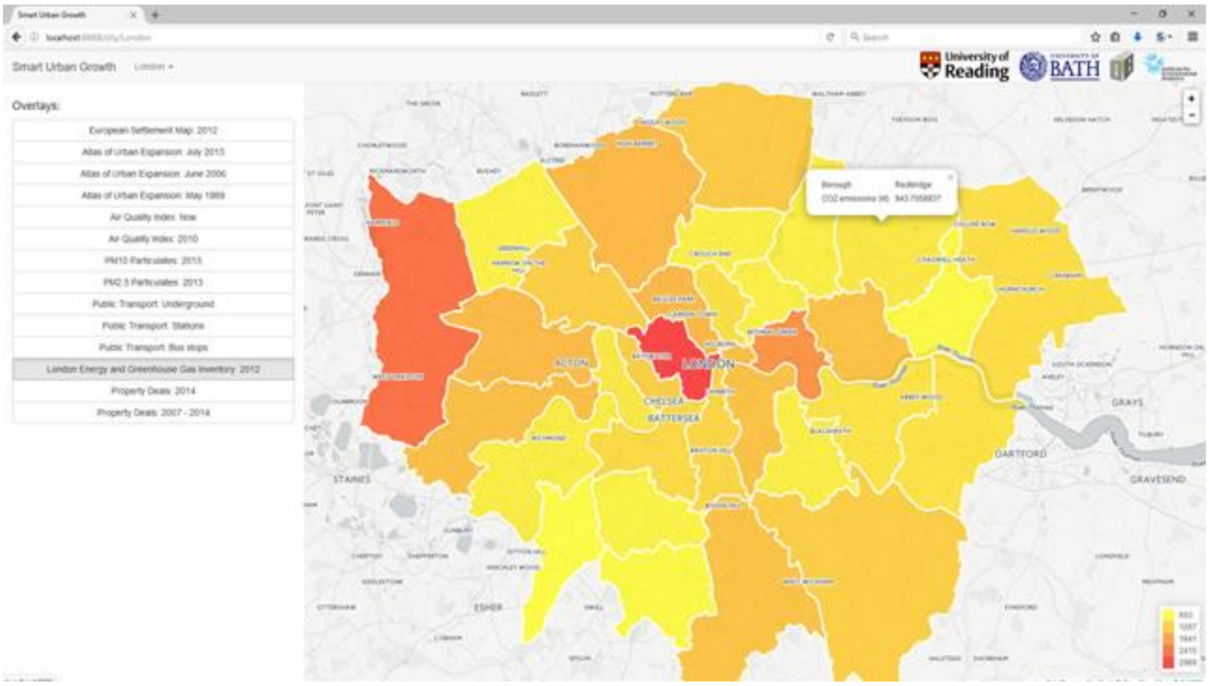


Exhibit 3 London energy and greenhouse inventory, 2012.

Public transportation infrastructure & costs

Exhibit 4 incorporates the London example of the public Underground transport network in visualization. The location of stations shown here is of particular importance for accessibility. Mapping inter-modal transport hubs is also important in relation to passenger and freight transport mode exchanges, for example, from cars to mainline rail services (Hall and Pain, 2006). Investment in public transportation infrastructure and services provision could help to reduce CO_2 emissions and displacement of those emissions which impact in dense city locations (Foster et al., 2010).

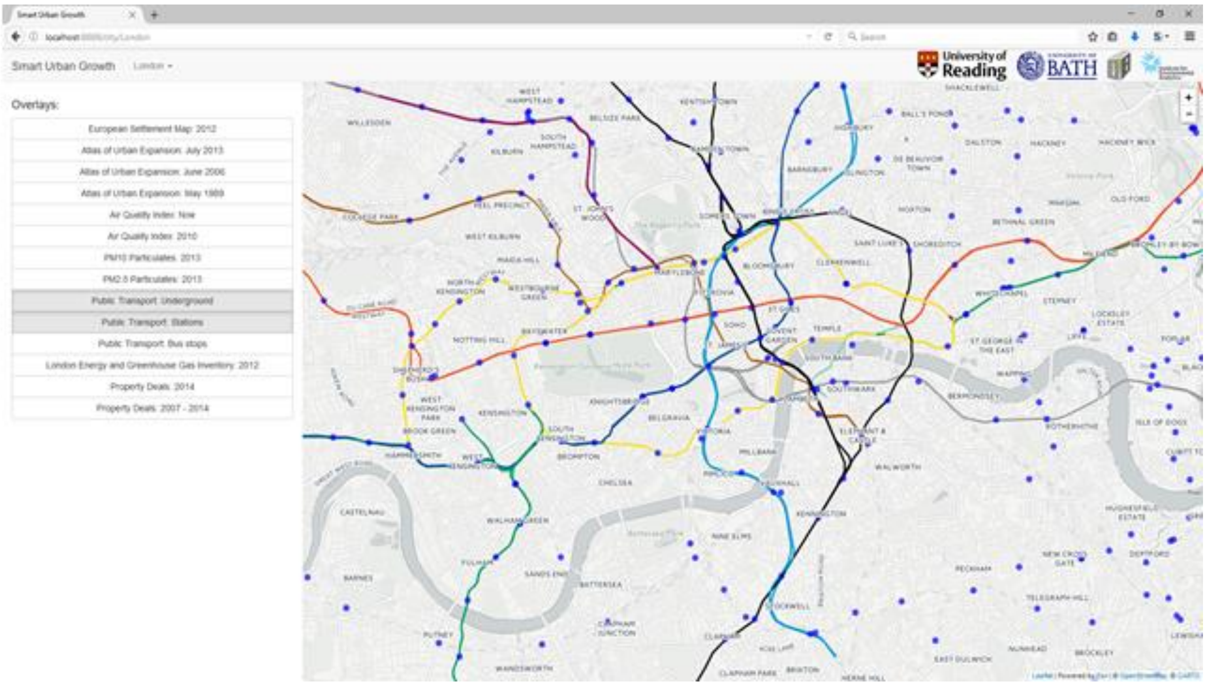


Exhibit 4 London public underground and stations.

Figures 13 to 15 provide information on public transport data, including costs and passenger numbers, for each of the four case study cities.

In theory, public transport unit operating and routine maintenance/renewal costs should fall with greater density, all things being equal, due to fuel efficiencies, shorter routes, etc. however other key factors play a part in the determination of actual costs, such as physical aspects (topography/geography of a city), different funding/organisational models and type of local economy/employment (determining travel needs).

Public transport costs per passenger are greater in London and New York than in Hong Kong. Density of population and spatial variations in housing costs (and therefore average length of journey) may play a part however this may be due in large part to differences in labour and other unit costs. Due to issues of differing cost definitions, caution is needed in comparing estimates of operating costs per passenger between the cities however they are consistent with London Transport Authority study findings (LTA, 2011, p. 5, - see Technical Annex IE).

The link between public transport infrastructure costs and good density and by extension investment returns is complex and deserving of much further research beyond this project. In theory there is a likely link between transport operating costs (indicating size and usage of a city public transport network) and CO_2 emissions, and more generally with business efficiency in terms of worker and client accessibility, and their costs of transport options. Likely specific good density indicator relationships are: employment, business services, green environment, tourism, and walkability (due to lower car usage) although others such as crime would be interesting to look at too in a larger follow up study.

The literature reviewed highlights the great importance of public transport infrastructure investment for both sustainable development and sustained economic growth (for example, Taylor et al., 2003; Hall and Pain, 2006). Bearing in mind the data limitations encountered (see Technical

Annex), the relationship between transportation infrastructure costs, good density and sustained real investment flows and performance therefore warrants joined-up public-private sector decision-making attention. Securing comparability of data between cities is a relevant part of the research and decision-making processes in order that comparable datasets can be used to analyse the link to good density.

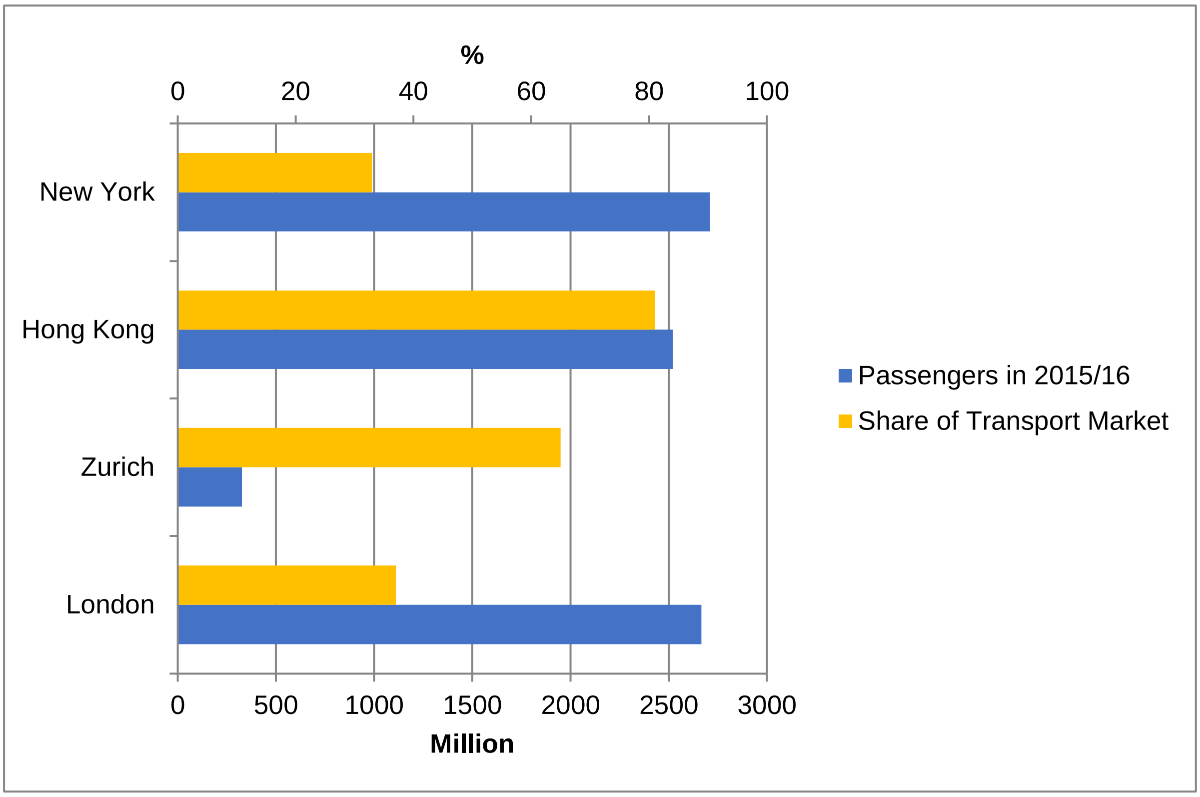


Figure 13 Public transport passengers and shares of transport market[14] in 2015/16.

[14] Share of transport market refers to the percentage of passenger journeys by public transport compared to all passenger journeys as reported through travel surveys.

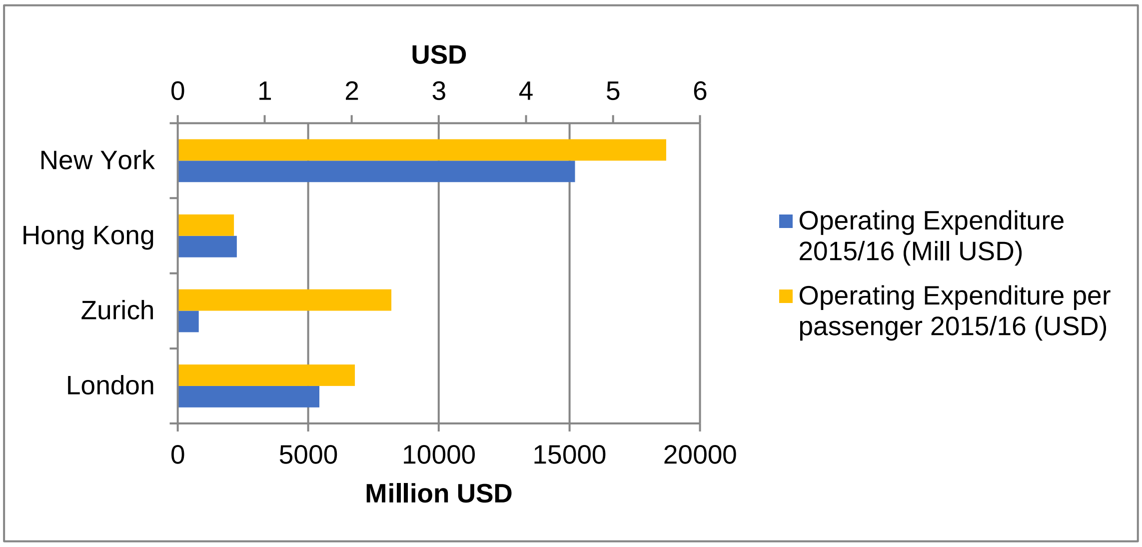


Figure 14 Public transportation total operating expenditure and per passenger2015/16[15]

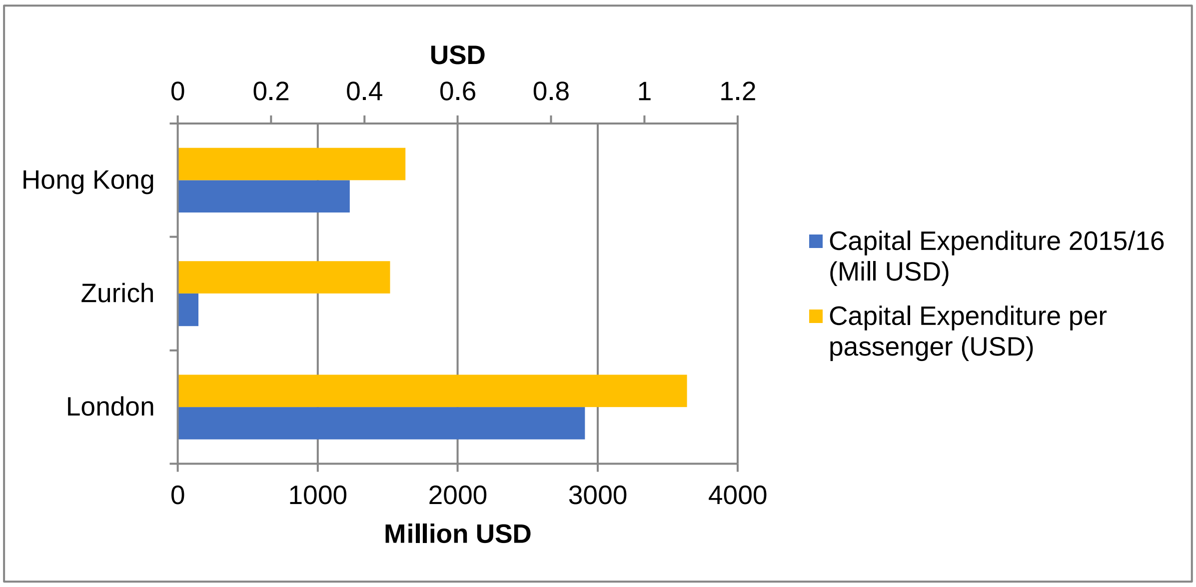


Figure 15 Public transportation total capital expenditure and per passenger 2015/16

[15] Caution is needed in comparing city operating costs. In particular, the New York operating cost total is likely to include renewal and maintenance expenditures (for which no separate figures were found) while these expenditures are not included in the other city operating cost totals.

Successful investing in density - implications for investment and policy decision-making

This study set out to evaluate the impact of investment in compact, connected urban development on returns for real estate investors and the implications for CO_2 emissions and infrastructure cost per resident for the public sector. Here we reflect upon the results overall to identify concluding inferences. Despite data availability limitations encountered preventing advanced econometric analysis, the Spearman approach to analysis has revealed interesting contemporary patterns of association (Spearman, 1904) between real estate, good density variables and CO_2 emissions which have implications for infrastructure investment for city governments.

Good density and real estate investment performance

While the direction of causality between real estate returns and good density variables is not clear, the research shows where there are strong positive relationships which can inform decision making on appropriate density measures relative to investment data. Positive and negative correlations identified have been validated using significance tests (see Technical Annex IC and IF).

For the largest sample of cities analyzed, nine variables have been found to be positive measures of good density for purposes of real estate investment in commercial office assets. Six of these are significant, however tourism is shown to be strongly associated with returns in some cities.

GOOD DENSITY GRADIENT – OFFICES (Returns)
Urban extent density ***
Built-up area density ***
Business services **
Innovation *
Financial services *
Green environment *
Tourism
Low crime
Walkability

Note: Significance: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Urban extent and built up area density are the most strongly positively correlated variables with office returns, providing quantitative evidence that more densely developed cities are associated with higher returns for investors. The association between real estate performance and dense, compact urban development is confirmed by the results on office capital values for nine major European cities (London, Paris, Moscow, Milan, Madrid, Berlin, Vienna, Warsaw and Budapest). This is an important result given the dearth of real estate studies directly investigating the spatial determinants of investment performance empirically.

Relevant for policy makers, the results also demonstrate that population and built densities highly related to returns, are associated with reductions in per capita CO_2 emissions. In other words, despite the overall increase in emissions associated with increased population size and human activity, dense cities have efficiency gains.

Investment in dense cities can therefore be expected in general to have notable 'win-win' advantages in terms of returns on investment and mitigation of climate change in the context of contemporary continued world population increase and urbanization (United Nations, 2017).

Some general differences between patterns of association between good density and returns are found in mature and developing markets. In addition, variations exist for individual cities within these markets, as illustrated for example by mature economy cities Hong Kong vs Paris, and developing economy cities Warsaw vs Mumbai.

In addition, city level analyses show that even though statistical significance of correlations with returns is not demonstrated at the global level for all nine positively correlated variables, tourism is nonetheless strongly represented in the four mature economy city cases, Hong Kong, London, Paris and New York. So the balance between positively and negatively related density variables to returns in each case examined, sheds light on important issues for city investment, risk-adjusted returns and priorities for policy in different world locations.

Importantly, real estate capital value performance for the nine European cities included in the analysis indicates that office and retail asset classes have a different balance of associations with good density, which demands further research.

GOOD DENSITY GRADIENT – RETAIL (Capital values)
Tourism *
Business services *
Financial services
Urban extent density
Innovation
Walkability

Note: Significance: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.
Results confined to nine European cities: London, Paris, Moscow, Milan, Madrid, Berlin, Vienna, Warsaw and Budapest.

Furthermore, contemporary dynamic changes in the retail sector including the location of property assets and linked goods supply chain logistics and consumer travel patterns (Dawson, 2012) can be expected to have a bearing on carbon emissions across cities and wider urban regions.

The significance of tourism and business services for retail performance in the European context is of interest given the association of both variables with high office returns in a global perspective in the mature economy city portraits.

The other good density indicators for which data were available for comparative analysis have not been found to be positively correlated with real estate performance. However, the results highlight that a focus on individual cities is necessary to deepen understanding of nuances important in understanding relationships between both good and bad density, and property performance.

Implications for risk-adjusted real estate returns

The research indicates that investor judgements regarding whether returns can be expected to be positively or negatively correlated for specific commercial office and retail investments, and associated risk, should take city good and bad density into account alongside other sources of risk applied in standard property level comparative risk indices (i.e. debt, leasing, building, tenant, etc.).

The calculation of risk-adjusted returns commonly assumes that increased risk exposure (for example, associated with opportunistic investments) should, in theory, attract an increased return on investment. However, a key message from this research is that bad density in the form of open space ratio is negatively correlated with returns across asset classes and performance measures.

While perceived risks in real estate investment evaluation are often subjective, statistically significant positive correlations between good density variables and asset performance could be incorporated in strategic evaluation of potential investment rewards for different asset classes.

GOOD DENSITY REWARD FACTORS OFFICE INVESTMENT	
Urban extent density	0.68
Built up area density	0.66
Business services	0.36
Innovation	0.32
Financial services	0.31
Green environment	0.29
GOOD DENSITY REWARD FACTORS RETAIL INVESTMENT	
Tourism	0.55
Business services	0.47

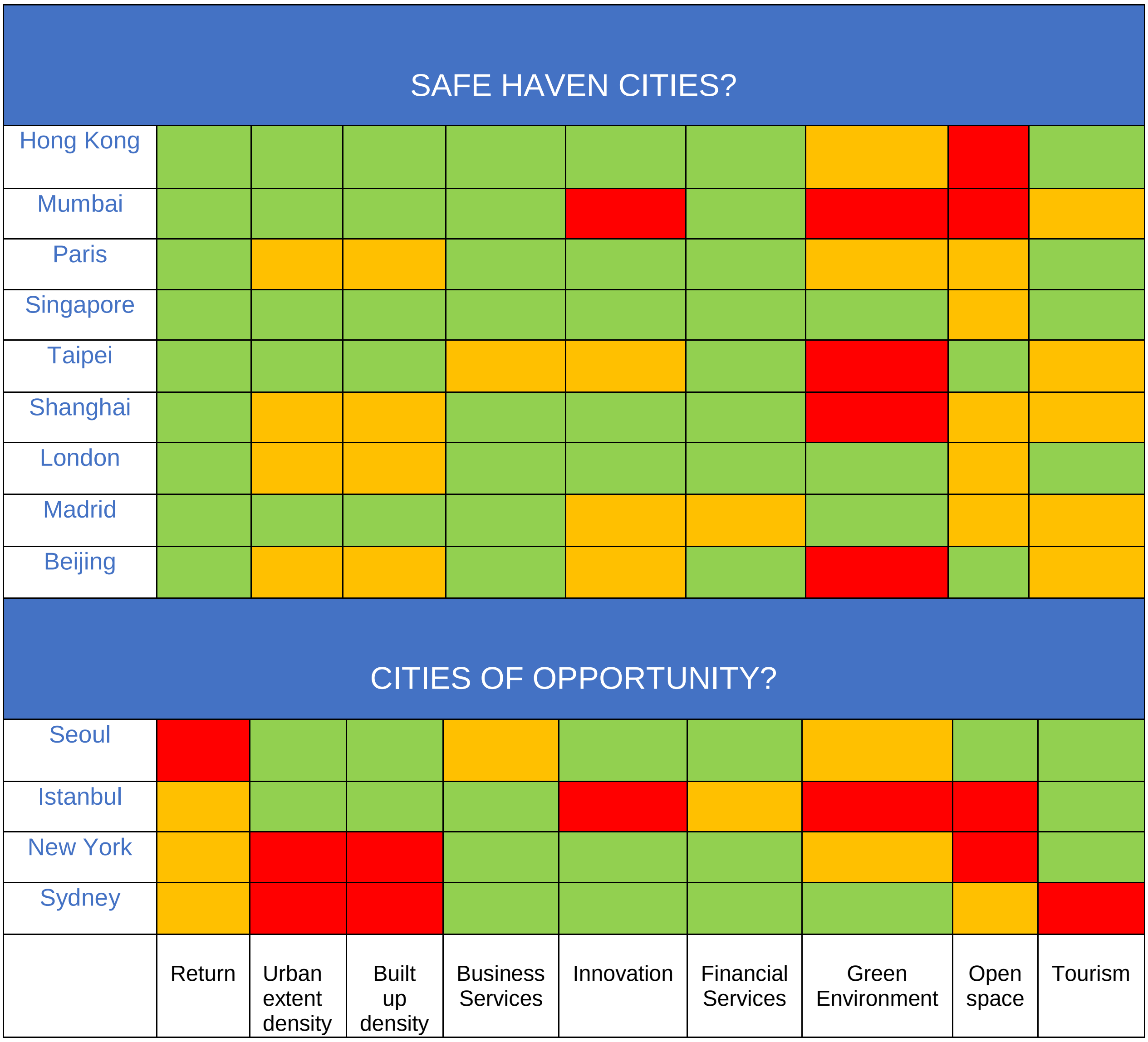
Bearing in mind the data limitations emphasized in this report, this research suggests that in calculating comparative risks and rewards for competing investment opportunities in commercial office markets, property in high density cities with strong business services, innovation, financial services and green environment, should have a higher return score and a lower risk score than equivalent property in cities performing less well on these measures. Similarly, in calculating comparative risks and rewards for competing investment opportunities in retail markets, property in cities with strong tourism and business services, should have a higher return score and a lower risk score than equivalent property in cities performing less well on these measures. By assigning quantitatively researched good and bad density scores to investment evaluation, calculation of the balance between overall risks and rewards of competing opportunities could be better informed.

In addition to the need to take into account different relations between good density and office vs retail asset classes, the research shows that investors should take a market (developed vs emerging) and city-specific decision-making approach to investment in order to achieve more accurate assessment of potential rewards and risk at the property level; for example, despite its negative correlation with performance in general, open space ratio varies for different cities.

Of the cities in the world with complete data available for office returns and good density variables, the profiles of thirteen cities manifesting interesting associations for eight variables, including tourism, are illustrated next using simple traffic lights colour coding to denote differences in overall patterns based on percentile rankings: Red – low (0-25); Amber – median (25-75); Green – high (75-100). The cities are split into two groups according to their existing returns performance to illustrate aspects of good density that may need to be improved in order to either boost or sustain their returns performance going forward.

Incorporation of local good and bad density data based on visual analysis would allow the incorporation of property-level risk associated with density, for example, asset location relative to public transport nodes and green space vs traffic flows, congestion, displaced CO_2 and air quality. Both city and property-level density data (illustrated in the visualization tool demonstrator) need to be considered in order to achieve optimal risk-adjusted returns for short-term holding periods and, at the same time, to invest in and assure good density that is essential for long-run sustainable development and portfolio resilience. The case of New York in particular (Figure 12), illustrates the need for sub-city analysis to accurately pinpoint good density within large urban areas.

Analyses incorporating time series data would allow good and bad density trajectories of individual cities to be taken into account in policy and investment decision making. This is particularly relevant for emerging economies where rapid urbanization and increasing concentration of business and financial services are occurring. For example, this research found that Guangzhou in China ranked 17th city in the world for financial services concentration and had returns on commercial office real estate investment that exceeded those for New York.



Note: The CBRE returns data do not include Japanese cities – see Annex IC.

Supporting smart urban growth – agenda for real estate, policy and research

When the quantitative results are reflected upon against the backdrop of the literature reviewed, patterns of association revealed by the Phase II quantitative correlations and rank percentile city portrait analyses, allow us to highlight eight specific issues for good density requiring the particular attention of decision makers and further research: 'urban density', 'tourism', 'CO_2 emissions', 'walkability', 'open space', 'green environment', 'transport' and 'urban form'.

Urban density

The major observation from global analysis that dense urban form (urban extent and built-up area) goes along with strong office real estate investment performance, is best illustrated by Hong Kong which has the highest commercial office investment returns and the highest urban form density of the cities surveyed.

This relationship exists for cities examined in both mature and developing economies, however, the association between other significant variables (innovation, business and financial services, and green environment) for returns, varies between markets. For example, Mumbai's high office returns are strongly associated with high urban form density while business and financial services and capital investment flows into the office market are strongly associated with returns in Beijing. Similarly, the high office returns of Hong Kong are less associated with innovation than is the case for New York and London. It is noteworthy that London, and especially New York, have lower urban form density and lower returns than Hong Kong.

Tourism

Although tourism is not found significant for office investment returns or capital flows at the global level of analysis, in the retail markets of the nine European cities analyzed, tourism is shown to be highly associated with capital values. Furthermore, the individual developed economy city portraits suggest that tourism may be associated with high office returns for some cities, as illustrated by Paris where, despite having a much lower level of urban form density than Hong Kong, only slightly lower returns are achieved.

The city portraits and the comparisons between them, therefore suggest that although urban form density is most strongly correlated with returns from a global perspective, other aspects of good density may also contribute importantly to returns in individual cases. It would seem then that for some cities, property performance is determined by *more than* city morphological (population and physical) density. However, tourism (along with innovation) is less well represented in the developing economy cities examined, Beijing, Mumbai and Warsaw, and this finding demands attention in follow-on qualitative research involving local experts.

There is currently a lack of reliable 'soft' good density metrics for incorporation in a robust global comparative quantitative analysis. However, tourism is likely to reflect a number of city qualitative good density attributes that together have significance for property performance measures. The results on tourism for retail performance as well as for office performance for mature economy cities, provides quantitative evidence supporting the hypothesis of the commutability of cultural capital to economic capital in cities (Pain, 2008a).

Carbon emissions

Albeit significance is not demonstrated, combining all good density and office performance variables in global CO_2 analysis shows a positive correlation between nine urban form density indicators, urban low *per capita* CO_2 emissions and returns on investment (0.25). By contrast, ten good density variables are negatively correlated with low *total* CO_2 emissions (returns correlation, 0.16).

Recent United Nations statistics indicate that the present global population of nearly 7.6 billion has increased by one billion people in just over one decade (United Nations, 2017). The efficiency gains found for dense/compact cities in terms of reductions in per capita emissions despite their population size, intense activity and mobility, is therefore clearly of great importance in the context of world population growth.

For the mature economy cities included in the portraits, it is noteworthy that, similar to Hong Kong, Paris has very high returns but it achieves this returns level with lower built up and urban extent density coupled with higher per capita CO_2 emissions than total emissions. This relational pattern implies that there may be scope to deliver higher carbon efficiency gains in Paris with a higher density urban form development scenario going forward. However densification would need to be sensitive to impacts on other good density characteristics in a spatial context, for example, tourism, open and green space.

Comparable emissions data for Beijing and Mumbai were unavailable for the present study, however, the United Nations (2017), highlights that China and India remain the two most highly populated countries in the world, with 19 and 18 per cent of the global population total respectively (United Nations, 2017). The findings on the correlation between morphological density, economic and financial services and investment performance for Mumbai and Beijing demonstrate the case for built form density in these rapidly developing and urbanizing economies.

CO_2 displacement and local concentrations highlight risks for human health and well-being associated with other traffic associated air pollutants, illustrated by the visualization tool for London. Therefore, the negative correlation of low CO_2 emissions per km^2 per person with urban extent and built up area density, requires further investigation.

Walkability

The research results demonstrate that the relevance of walkability for commercial office and retail property performance cannot be demonstrated based on satellite data alone. Nevertheless, the correlation between innovation, business and financial services and property performance is indicative of a relationship with walkability.

Literature reviewed in Phase I of the study indicates that innovation in these knowledge-intensive economic sectors is dependent on clustering and close proximity (Taylor et al., 2003), walkability is therefore implied. Furthermore, there is evidence from a small emerging real estate literature of links between spatial proximity and property returns (for example, Zhu and Milcheva, 2016).

However, as discussed in Technical Annex IB, physical proximity does not necessarily mean that a place or route is environmentally pleasant or safe to walk.

Given the results from this study on total CO_2 emissions, their spatial displacement, and the implications of intense traffic flows and congestion for air quality and human health (for example, nitrous oxide exposure, DEFRA/DoT, 2017), an important conclusion is that the environmental quality of walkable urban spaces should be prioritized in future research, in policy initiatives and in investment decision making.

Open space

As in the case of tourism, emissions and walkability good density indicators, the correlations for open space do not show statistical significance for either office or retail property performance. Nevertheless, it is striking that open space ratio is generally negatively correlated with office returns and office and retail capital values and rents.

Furthermore, open space ratio is low relative to economic and investment returns for all cities presented in the city portraits and case studies (Hong Kong, Paris, London, New York, Mumbai) apart from Beijing and Warsaw (Zürich lacked open space ratio data).

Given the significance of urban form density for investment returns, the contrast between Hong Kong's high density and its low open space ratio, illustrates an evident spatial tension underlying the relationship between city morphological density, returns and open space. This tension seems likely to impact on housing prices and affordability also.

Green environment

Green environment is one of the good density metrics shown to be positively correlated with office returns and rents, and (though not significantly) with office capital flows, retail rents and total CO_2 emissions.

The individual city portraits reveal city level differences that illustrate interesting patterns across the mature and developing economy vignettes. Green environment is low relative to economic and investment measures for Beijing and Mumbai and, to an extent, Warsaw. In contrast, green environment is higher relative to those same measures for New York, Paris, London and Hong Kong (this is despite Hong Kong's low open space ratio) and is highest for Zürich.

From these results it would seem that, as for CO_2 and walkability, green environment and its relationship with open space ratio, demands attention in investment and policy decision making in order to assure that beyond urban form density, economically successful cities have good density 'in the round'. For example, could lessons for good density be learned from Zürich's high green environment score relative to its low total CO_2 emissions? Urban form density data including on open space ratio, and local data on car and public transport use for example, would be required to investigate this pattern of association in depth. Even though no correlation between green environment and low CO_2 emissions per km^2 per person was found, in the research literature, green environment has been found to offset some CO_2 emissions.

Transport

City infrastructure costs were found to lack consistent recording and reporting, preventing the incorporation of monetary data in global or European comparative analysis for this study. This finding highlights an important area for national government attention internationally in view of the relevance of public-private sector financing for infrastructure in general.

Transportation infrastructure is highlighted by the present research as being of critical importance for good density. Not only is public transportation infrastructure a fundamental requirement to support accessibility and connectivity for economically sustainable cities and linked property investment but this research demonstrates its critical importance for reducing emissions linked to climate change and supporting the sustainability of green environment, air quality and human health, locally.

As highlighted by literature reviewed in Phase I, both physical public transportation infrastructure and efficient services and capacity must be present in a city. The present study highlights the need for fine-grained mapping of urban functions and physical clustering at sub city and urban region scales in order to plan effectively for travel demand and thereby reduce overall CO_2 and other emissions and displacement linked to heavy traffic flows.

Although it has not been possible to incorporate residential assets in the present quantitative analysis, the literature highlights the impact of locational patterns in housing markets and affordability, relative to employment and retail development, for the costs and feasibility of public transportation infrastructure and services provision required to reduce traffic flows by road (Taylor et al., 2003; Hall and Pain, 2006).

Urban form

The global findings endorse the importance of the six urban form characteristics identified from the Phase I review of the multi-disciplinary literature as relevant for relationships between *good* density and resilient real estate investment returns. The six characteristics underpin successful investment in density:

Clustering *structure* and ***Built*** *infrastructure* determine *compact* development, *proximity* and *connectivity*, open space ratio essential for good density and a green urban environment that mitigates climate change. Compact urban form (built and urban extent density) and green environment are found to be positively associated with real estate investment performance.

Economic and Employment *structure* determines city *concentration* of high-value economic sectors, globally *networked firms, skilled people* and *innovation capacity* important for a sustainable economy. Knowledge intensive business and financial services, and innovation, are found to contribute positively to real estate investment performance.

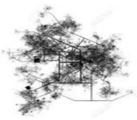
Public Transport and ***Green/Blue*** *infrastructures* determine the *connectedness* of cities and *accessibility* by modes that limit CO_2 emissions and displacement on the one hand and can mitigate against air pollution and human health risk on the other hand. Green environment is positively associated with real estate investment performance and public transport can support this.

***Governance** infrastructure* determines the *coordination* and *strategic planning* and *policies* needed to ensure oversight and orchestration of development to deliver and sustain good density as a whole. Built density, compactness, business and financial concentration, innovation and green environment are all highlighted as positively associated with real estate investment performance.

Good density agenda for real estate

A '4-C Model' illustrates key issues arising from findings from the literature reviewed and empirical evidence from the quantitative analyses that require attention for successful investment in density.

For investment managers, the 4Cs are important considerations. Good density is demonstrated to underpin real estate investment performance but if good governance is not prioritized, resilient performance could be compromised. With good governance, lower CO_2 emission rates and healthier cities could be achieved, which should impact positively on property values, rents, returns, capital flows and liquidity. The possibilities for beneficial incorporation of visual analysis to assist investor and public sector decision making at the urban landscape and property levels look promising.

<table>
<tr><th colspan="3">4-C model for successful investing in density</th></tr>
<tr><td></td><td>Clustering
Structure</td><td rowspan="2">Compact – Proximity, Connectivity</td></tr>
<tr><td></td><td>Built
Infrastructure</td></tr>
<tr><td></td><td>Public Transport
Infrastructure</td><td>Connected – Accessibility, Communications, Networked</td></tr>
<tr><td></td><td>Economic/Employment
Infrastructure</td><td>Concentrated – People, Skills, Capital, Firms, Knowledge, Innovation</td></tr>
<tr><td></td><td>Governance
Infrastructure</td><td rowspan="2">Coordinated – Planning & Policy spanning functional urban area</td></tr>
<tr><td></td><td>Green/Blue
Infrastructure</td></tr>
</table>

Good density agenda for planning & policy

Based on the overall findings of Phases I and II of the research, four dimensions of good governance are singled out for attention to address potential collisions between drivers of good and bad density acting across different urban functional and spatial scales, and to encourage good density characteristics required for overall urban resilience as a city's built up area and urban extent increase.

Each dimension follows from the key findings from the report and is therefore important to inform the '4-C' model for successful investment in density. Real estate investment due diligence needs to take into account the amount of risk likely for a given property investment held for a given time period. Therefore prospective investments in cities lacking a coordinated governance infrastructure to support good density should have a higher risk score than for cities with appropriate governance processes and measures in place.

At the city scale, coordinated action is needed to design into urban form, quality, safe, built and green environments and open spaces, walkability, transport links, etc. and to protect heritage and natural green and blue environments (historic buildings, parks, allotments, gardens, vegetation, rivers, lakes, etc.) which are essential components of good density.

Effective governance incorporating robust data across key metrics from the property scale to the urban region scale is also needed to plan functional interactions that impact on dense urban spaces in an integrated way (Hall and Pain, 2006; Barlow et al., 2017).

In the UK, a recent Royal Town Planning Institute response on the UK Government's 2017 draft *UK Air Quality Plan* consultation (DEFRA/DoT, 2017), endorses these key research messages in stressing the need for Government recognition of the: "critical relationship between urban form, infrastructure and air quality", the need "to join up land use and transport planning so that new developments prioritize active travel – walking and cycling – and public transport", "to develop technical capacity to create maps that integrate land, transport and infrastructure" and "to guide developments towards locations that make use of public transport, walking and cycling" (RTPI, 2017).

Spatial dimension

– Urban form and clustering, land use, mobility patterns

Functional dimension

– Economy, skills and employment, innovation, financial flows

Social dimension

– Accessibility, affordability, appropriate, inclusive

Environmental dimension

– Carbon emissions, air quality, climate change, human and planetary health

Good density agenda for research

This research has highlighted that market and city-specific analysis incorporating longitudinal data series for predictive analysis is clearly essential to guide responsible private and public sector investment decision making. The importance of tourism as a component of good density also highlights the significance of qualitative determinants of good density. A key finding from the research is the lack of transparency in these important areas for study.

In addition, missing data across essential good density measures, unregulated and inconsistent self-reporting, different methodologies applied, different data reference dates for density measures, and an absence of urban function and scale-relevant data are identified as challenges. Improved data are also needed to permit the inclusion in analysis of controls for potential confounding variables, including qualitative variables which, as discussed in Technical Annex IA, in some instances need to be informed by local knowledge. Furthermore, a spatial overview of changing physical and functional development patterns at sub-city and urban region scales is required to better understand drivers underpinning bad and good density. For example, to visualize how household composition, residential and employment markets, and their density variations, determine flows of traffic and emissions displacement.

There is considerable potential to take forward the research begun in this study valuably with better data which are summarized here.

Quantitative data …

Global coverage, reference dates/time variance, robustness of sources/ methods/bias, transparency, comparability, analytical significance

Analytical scale …

Global, country, regional, metropolitan and landscape levels of analysis

Qualitative data …

Behavioural drivers, urban design quality, appropriateness

Some specific research directions that seem valuable to pursue include:

- More detailed European real estate investment insight analysis.
- US real estate investment insight analysis and comparison with Europe (e.g. by incorporating NCREIF data available for US markets that are a direct measure of total returns).
- Longitudinal analysis of relations between the main components of returns - yields and capital values - and good density for exogenous factors.
- Incorporation of data distinguishing between different densities, including non-population based densities (e.g. incorporating UrbiStat data).
- Analysis of how city level 'collective good densities', e.g. tourism, innovation, green environment etc., can, in combination, contribute positively to investment value, returns and liquidity.
- Data collection and analysis to include building heights and massing to better define, measure, and understand urban form density (e.g. incorporating LiDAR light detection remote sensing data).
- Collection of additional detailed local information on public transport services, inter-modal transfer and connectivity times, and factors determining transport costs and their relationship to good density.
- Urban functional area analysis incorporating time series data on urban living and work patterns that contribute to CO_2 emissions and displacement across spatial scales, and the role of open space and green infrastructure in relation to CO_2 emissions and human health and well-being.
- Development of city visualization to incorporate more and better data relevant for good density-urban form characteristic relationships, for more cities in mature and developing economies, including modelling being pioneered by the University of Reading Meteorology research team to allow a consistent methodology to be used within a city, and local context-specific qualitative appraisal (e.g. design quality).
- Exploration of good density minimum and maximum tipping points/thresholds (e.g. Phase I expert advisor suggestion that in Hong Kong a plot ratio > 8 is not desirable and evidence on minimum densities required to support high quality public transport infrastructure).

Supporting smart urban growth: Successful Investing in Density

TECHNICAL ANNEXES

ANNEX I – DEFINITIONS, DATA, SOURCES, METHODS, CHALLENGES

A. Quantitative analysis of the relationship between good density and real estate investment performance - Overview

The relationship between real estate performance and density is a generally under-explored research area. However, recent macro level analysis of international real estate investment shows a concentration of commercial office property capital flows in the dense business districts of financial centres in the world's largest economies (Lizieri and Pain, 2014; Henneberry and Mouzakis, 2014; Stevenson et al., 2014; McAllister and Nanda, 2014; Fuertz, et. al. 2015). At the same time, micro-level econometric studies focusing on US cities, indicate that physical distance and other measures of proximity such as economic and financial distance, are an important influence on real estate investment returns in housing as well as commercial real estate markets (Zhu and Milcheva, 2016; Milcheva and Zhu, 2016a). Also, at the micro level, spatial relationships between the underlying properties of real estate companies are shown to have a significant effect on their performance. Proximity across the property holdings of real estate companies can predict higher return correlations across the firms, controlling for size, book-to-market, and momentum characteristics (Milcheva and Zhu, 2016b; Milcheva and Zhu, 2016c).

Quantification of relationships between investment performance and urban form characteristics representing *good* density in a global analysis presents significant challenges relating to the definition, methodologies, quantification, and measurement of good density however.

Defining good density

Density has historically been seen both as a cause and, in recent times, also as a solution to a range of urban problems (Pain, 1976; Blowers and Pain, 1999; Davis, 2006; Angotti, 2006; Neuwirth, 2006; Tonkiss, 2014 cited in McFarlane, 2016; Adams at al., 2015). Defining what makes density good as opposed to a contributor to urban problems is therefore subject to debate. Density defines what a city *is*, but it is a relative concept that can relate to different urban characteristics and urban scales (Davis, 1965; Rapoport, 1975; Bridge, 2009), complicating analysis.

Density can relate to the mix and layout of buildings and property floor space in different uses, to both 'open' private and public space, to economic and financial activity, and to urban resident and working population, wildlife, crime, disease, traffic, pollution, heat and water, etc., that move into, out of and within urban space at different scales (Braun, 2006; Adey, 2010). These densit*ies* of cities are uneven and heterogeneous, as opposed to smooth features of development, reflecting constant variable flows, connectivities and intensities over space and time (Cook et al., 2007; Castells et al., 2007; Keil, 2014; McFarlane, 2015). Pinning down what 'good' density is, and its links with urban form and real estate performance, therefore requires insights into relationships between many variables.

The definition of ‘good density’ formulated by Clark and Moir (2015) for the Urban Land Institute which was the basis for the present study reflects the heterogeneity of urban density. Following a cross-disciplinary literature review in Phase I of the research, the concept of ‘economic density’ which was not represented in the Clark and Moir (2015) definition, was added to analysis by the research team. This addition was in recognition of the relevance of economic urban form characteristics for both urban sustainability and investment returns (Lizieri, 2009; Lizieri and Pain, 2014). Agglomerating economic activities such as knowledge-intensive global business and financial services are regarded in the literature as contributing importantly also to ‘densities of innovation’ (Glaeser and Saiz, 2003; Mahroum et al., 2010; McFarlane, 2016).

The challenges presented for research are set out in detail in this Technical Annex for each of the four metrics specified for analysis in the research brief in turn, i.e. urban form characteristics, real estate investment, CO_2 emissions, and infrastructure costs to city governments per person. But beyond more readily quantifiable good density measures, the relationship between good density and returns is confounded by the qualitative nature of other characteristics of density that together determine whether density is actually *good*.

Methodological issues

Following from the number of variables and potential interactions that underpin good density, qualitative considerations are needed to inform analysis as explained further in relations to urban form (Martin and Secor, 2014). To reflect the variegated nature of good density, such considerations should include the quality of property and landscape design, and of the lifestyles, work, and health and well-being of different social groups, genders and age groups. Differential mobility and access to urban resources, including open space, and differential exposure to pollution (Guagliardo, 2004; Graham and McFarlane, 2015), for example, would need to be included in a thoroughgoing analysis of how good density relates to real estate investment and returns. Qualitative measures of how human behaviour impacts good density considerations, investment and returns, is of equal importance, however behavioural research in this field is generally lacking.

Of particular relevance for research on real estate investment and returns are the ways in which ‘sentiment’ and ‘familiarity’ of economic, financial and real estate actors, shapes good density as well as investment, impacting pricing, liquidity and returns on investment. Such considerations require attention in international research to allow appropriate control variables to be incorporated in global modelling (Henneberry and Mouzakis, 2014; Lizieri and Pain, 2014; Milcheva and Zhu, 2016c; Pain, 2017; Akakandelwa et al., 2017).

For example, Henneberry and Mouzakis (2014), argue that the pricing of office property investments in non-core UK regions is affected by a ‘familiarity’ heuristic adopted by investors who are clustered in London and who introduce irrational biases in investment location and pricing, ignoring the intrinsic investment characteristics of those markets. Variations in inherent characteristics of regional markets are found not to have significant effects on their yields. Investor behaviour is therefore concluded to constitute a systematic geographical factor behind significant property supply variations, reducing investment performance.

‘Soft’ qualitative characteristics of cities and real estate markets can therefore be important determinants of good vs bad density that are confounding variables in present quantitative analysis.

Quantification

A void in robust real estate data capable of informing international analysis is also well-established (Lizieri and Pain, 2014). Deficiencies include a lack of data based on consistent analytical methodologies and data cleaning, and a lack of data on emerging real estate markets and non-commercial property required for global comparisons related to good density (Lizieri, 2009; Pain, 2017).

Data on non-real estate good density characteristics have proved similarly elusive to capture for global level analysis in this research due to variations across characteristics and cities in definitions, concepts, and analytical frameworks, methods and reporting processes. In addition, both real estate and other good density data are generally available at country or city level as opposed to sub-city and city-region levels (Hall and Pain, 2006; Pain, 2006, 2008b, 2012; Taylor et al., 2008; Keil, 2014) which are shown from the literature reviewed to be critically important scales for analysis of good density in this study.

Furthermore, census data on urban population, demography, economy, employment and income and land use and housing price data, fail to reveal the complexity of fluctuating flows (Pain and Hall, 2008) and intensity 'rhythms' (McFarlane, 2015) associated with good and bad density at different spatial scales. Glaeser and Florida and their co-authors, for example, emphasise that not only is density critical in driving urban success by "speeding the flow of ideas" (Glaeser and Gottlieb, 2009, p. 1) but also greater levels of urban density and diversity provide the "eternally conducive environment for generating the human creativity that underpins innovation, entrepreneurship and economic growth" (Florida et al., 2017, p. 93).

Despite a prolonged and extensive search for robust global indices representative of good density urban form characteristics able to inform quantitative analysis, just 12 indices were identified to take forward in analysis (see Annex 1B).

Measurement

Analysis of causal relations between variables in robust multivariate analysis was not possible in the present study due to some indices providing city rankings only, a general lack of time series data, variations in data reference years and variations in the number of cities represented in the indices. Furthermore, in a global scope analysis, the influence of worldwide local factors is unknown.

However, local factors may influence the relationships between good density and real estate value significantly because value is not simply a by-product of demand for urban property and space use value, and location. As a portfolio investment, property stores value as a financial asset, and influences liquidity, capital flows, rents, and capital values, yields and returns on investments (Lizieri, 2009, pp. 181-182; Lizieri et al., 2012). Attempts to explain rental levels for international financial centres using a standard regression model find anomalies between cities. The largest anomalies are Mumbai, Dubai and Dublin where predicted rents are substantially higher than observed rents) and Shanghai, Johannesburg and New York (where observed rents are sharply lower than estimated costs (Lizieri et al, 2012, p.281). All six anomalies found are explained by local market and economic contexts.

The significance of local factors and context as determinants of relationships between property markets and density is reinforced by a recent United States study of the effects of spatial distance from the Boston central business district in shaping Massachusetts population density distribution (Epifani and Nicolini, 2017). A Bayesian frailty technique is used to control for heterogeneity, accounting simultaneously for other factors identified with proxies for natural amenities and ethnic composition in the period 1930-2010 for 51 municipal areas, using the years 1880 and 90 as external benchmarks. It was found that the city's accessibility has not always been the dominant determinant of population density distribution. The influence of other spatial factors working together is important, such as changes in urban economic structure, ethnicity and the mortgage market. The results illustrate the need for long time series data in modelling for covariates that reflect locally specific factors.

So in addition to the need for robust, directly comparable indices for good density and for different property sectors, these need to be spatially fine-grained with time series data for densely and less densely researched cities and real estate markets for corresponding spatial scales and time periods (Lizieri, 2009, p.300).

Limitations of the present analysis

Present research limitations in terms of longitudinal data availability and quality, including data on qualitative and behavioural factors, mean that variables that may together be significant for real estate investment and returns cannot currently be accounted for in global analysis. As discussed, a wide range of factors is potentially significant to what good density is, to the ways that good and bad densities flux over space and time, and to how those fluxes map onto different cities globally (Clark and Moonen, 2005) and onto investment returns. Given the complexity of potential interrelationships and interdependencies between factors underpinning good density highlighted by the literature reviewed for this study, results from multivariate analysis are likely to be misleading as a guide to investment.

Instead this research has adopted a simple approach to analysis which illustrates in a straightforward way, *patterns of association* between investment returns and a selection of metrics representing good density urban form characteristics singly. The 'P' value, or calculated probability, is shown for all correlation results presented.[16]

In this report we present correlations, i.e. relationships between a dependent (returns) variable and one independent (good density) variable in turn, derived using a Spearman rank correlations analysis similar to univariate correlations in regression analysis. A Pearson correlation check was run using data however to check the validity of the rank correlations in the absence of comparable good density longitudinal data at the global level, no causal or predictive inferences can be assumed.[17]

There is a need to test the predictive ability of good density for returns in future studies. Our work provides the groundwork for multivariate regressions incorporating multiple density variables for cities for which longitudinal data are available. Since multiple variables are likely to interact in different ways for each city, local assessment based on time series data will be important to frame

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[16] A p-value weighs the strength of evidence and is always between 0 and 1. A p-value close to 0.05 is considered marginal.

[17]

investment decision-making. What we can say on the basis of the present study is that, of the cities[18] and variables examined, density and compactness are well related to real estate investment returns.

Emerging data and analytical methods

In future work, visual analysis of 'layers' of heterogeneous urban form characteristics that make and unmake urban good density trialed in the research could in future projects be assisted by the incorporation of Internet, satellite and hand-held mobile digital 'big' data illustrating fluctuating flows and intensities to inform private and public sector investment decision making (Cochrane and Pain, 2004; Sheller, 2004; Harrison and Pain, 2012; Wilson, 2014; Tang et al., 2016; Pain, 2016; Barlow et al., 2017):

> "…certain urban classes are inherently imprecise due to the difficulty in integrating various social and environmental inputs into a precise definition. Social components often include demographic patterns, transportation, building type and density while ecological components include soils, elevation, hydrology, climate, vegetation and tree cover." (2016, p. 212)

Potentially, real-time and longitudinal quantitative and qualitative data for individual cities and city-regions could eventually be used to map fluid changes in the natural and urban built environments, including building use, heights, floor space and massing, and the movement of people, goods, information and capital that make and unmake good density. Information on the spatial relationships between good and bad density urban form characteristics revealed by visual analytics could eventually be incorporated in fuzzy sets analysis to build 'fuzzy urban indices' (Tang et al., 2016) with which to compare the performance of cities relative to returns in a global context; and 'fuzzy clustering' could be used in hypothesis testing (Nayak et al., 2014). Good quality *local* data are essential to be able to describe, test and pin down what makes a good density city at the *global* level.

B. Urban form: Approach and challenges encountered

Key findings from the review of literature relevant to the relationship between good density and urban form in the first phase of the research highlighted that:

1) Determining the definition of density is critical (e.g. physical, social/perceived, spatial).

2) There may be a possible density maximum threshold (e.g. a Hong Kong plot ratio of 8).

3) Optimal densities will vary from context to context (e.g. level of vertical growth and tolerance of crowding).

4) Measurement of urban form elements is still in its infancy (e.g. automated assessment using Google's StreetView) so qualitative assessment will be needed at least in short term.

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[18] An inevitable consequence of the focus of the project on the relationship between good density and real estate investment returns is that only cities represented in real estate data indices are included in the analysis.

5) Governance and management are critical to good quality urban form.

6) Expertise is required for such management is considerable, and unlikely to be achievable in globally competing market.

General availability and quality of urban form data

The overarching finding from the development of a globally comparable model of the relationship between good density urban form characteristics and real estate investment returns was the paucity of urban form data at the global level. Other than the Atlas of Urban Expansion (AoUE), national level data sets (e.g. World Bank, WHO) and city indices (see data quality limitations below), there are no global data sets available on urban form that we could find in Phase I of the research. It may be possible to develop a method that sources regularly updated municipal level data from multiple cities, but there was not time in this study to attempt that.

Findings on availability of urban form data:

This study focused on the exploration of globally comparable data sets. This global focus narrowed the range of urban form data sets available considerably.

A first activity considered the main city indices. A mapping exercise of the following, provided as an appendix in the Phase I report, revealed the extent of city indices' coverage of potential indicators that mapped on to the ULI definition of good density: Economist Intelligence Unit, Siemens, Arcadis, PwC, Habitat, AT Kearney, MORI, Z/Yen, Mastercard, City Mayors, NUMBEO, Mercer.

Given the limited coverage of urban form quality amongst many of the indices, an early proposal was to use four indices that provided the most comprehensive coverage of the ULI characteristics of good density – Arcadis Sustainability, Siemens Green City, EIU Liveability and business and financial services supplied by GaWC – as a proxy for good density, given that they would cover a good range of urban form aspects: e.g. urban metabolism, liveability, spatial considerations, clustering. However, while these four indices provide good global coverage of cities across a good range of indicators, their validity as a proxy for good density is uncertain and unsuited to quantitative analysis. Furthermore, the Siemens index was regionally comparable only, and so could not be used in a globally comparable model.

A second activity combined the findings from the literature review with grey literature to produce a comprehensive list of 184 sub-topic areas, which describe the ULI definition of good density. The intention of this exercise was to identify potential data sets for use in the global model. For example, ULI 'mixed use' includes: mix of use, mix of tenure, mix of age, employment density, etc. While municipal level data was available for a number of these indicators, they would have to be collected on a city-by-city basis. In other words, there are very few (regularly updated) global data sets covering these key areas. From that master list therefore, only 25 possible indicators were found, and of those 25 only 12 were deemed suitable for quantitative analysis to determine the relationship between good density urban form characteristics and real estate investment returns.

The clear finding from this exercise is that critically important data relating to urban design and qualitative dimensions of good density required for global comparative analysis are absent.

Key challenges were:

An example of the importance of this data limitation is the AoUE data used to denote 'walkability' and 'open space' ratios based on metrics available from remote satellite photography (i.e. size of block or open space, connectivity of street network). They do not account for variations in the *quality* of walking route or open space so therefore cannot be taken to infer whether a place is walkable, or not, or whether open space is attractive or not. In addition, while the data provide a global-level source on compact morphological density (built up, urban extent and open space) they do not shed light on functional density which is expected to have importance for economic growth and investment returns. These limitations of data available at the global level, points to the need to explore the gathering and collation of municipal level data on a city-by-city basis.

Good density indicators researched

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The 12 selected good density Indicator definitions

Urban extent density – the ratio of the total population of the city and its urban extent, measured in persons per hectare (Atlas of Urban Expansion, AoUE). Urban extent maps are created using Landsat satellite imagery. Urban extent density is the average density of the entire urban extent of the city because it is this measure that translates a city's population into the overall area it occupies (AOUE, 2016, Volume I – Areas and Densities, p. 28, http://www.atlasofurbanexpansion.org/).

Built-up area density – the ratio of the total population of the city and its built-up area, measured in persons per hectare (AoUE). Built-up area density is the density of the built-up area within the city's urban extent because this measure is independent from the degree to which a city may be fragmented. Built-up area density is always higher than urban extent density. Because the urban extent of the city contains its urbanized open space, urban extent density is not independent from the city's level of fragmentation while built-up area density is (AoUE, 2016, Volume I – Areas and Densities, p. 28).

Open Space Ratio – the share of city land in open space including open countryside, forests, cultivated lands, parks, vacant lands that have not been subdivided, cleared land, and water bodies: seas, rivers, lakes, and canals. Fringe open space and captured open space, taken together, make up the urbanized open space in a given study area. Fringe open space consists of all open space pixels within 100 meters of urban or suburban pixels. Captured open space consists of all open space clusters that are fully surrounded by urban and suburban built-up pixels and the fringe open space pixels around them and that are less than 200 hectares in area (AoUE, 2016, Volume II – Blocks and Roads, p. 30).

Walkability Ratio – the average ratio of the beeline distance and the street travel distance for 40 pairs of sample points within the locale that are more than 200-meters apart (AoUE, 2016, Volume II – Blocks and Roads, p. 37).

Green Environment – 11 individual metrics comprise the ARCADIS index representing 'green environment':

- Natural catastrophe exposure The International Disaster Database
- Green space as % of city area Siemens Green City Index
- Energy use Energy Information Administration (EIA)
- Renewables share Energy Information Administration (EIA)
- Energy consumption per $ GDP Energy Information Administration (EIA)
- Mean level of pollutants World Health Organization
- Greenhouse emissions in metric tonnes (per capita) CDP Cities open data
- Solid waste management (landfill vs recycling) World Bank
- Share of wastewater treated OECD & FAO Aquastat
- Access to drinking water (% of households) World Health Organization
- Access to improved sanitation (% of households) World Health Organization

Business and Financial Services – A quantitative measure of the Global Network Connectivity of a city. An interlocking network model builds upon the aggregated location strategies of leading global service firms across cities. However, the connectivity measurements and consequently the global connectivity ranking rely on information about the importance of a city within a firm's office network, (i.e., its service value) http://www.lboro.ac.uk/gawc/rb/rb368.html . GNC is thereby a proxy for total global business services functional concentration. Financial Network Connectivity (FNC) is a proxy for global financial services concentration. The most recent 2016 GNC and FNC data incorporated in our analysis are not freely publicly available.

Transparency – The JLL Global Real Estate Transparency is based on 139 variables relating to transaction processes, regulatory & legal frameworks, corporate governance, performance measurement and data availability for 109 markets worldwide.

Low Crime – The NUMBEO Crime Index is an estimation of overall level of crime in a given city. Crime levels range from lower than 20 as very low, crime levels between 20 and 40 low, crime levels between 40 and 60 moderate, crime levels between 60 and 80 high and crime levels higher than 80 very high. The rank order of the data is reversed for the present research to represent good density. Although national records of crime committed may be accurate, the data are less reliable for cross country comparison analysis due to differences in crime reporting and national legislative differences in how crime is defined: https://www.numbeo.com/crime/rankings_current.jsp

Low Unemployment – *New York City Global Partners* reports city average unemployment rates drawn from reputable statistical sources The rank order of the data is reversed for the present research to represent good density

Innovation – The Innovation Cities™ Index measures a city's innovation potential as an innovation economy. Pre-conditions for innovation are measured using a 3 factor score. 445 cities are classified based on Index scores into 5 classifications:

NEXUS: City is a critical nexus for large number of economic and social innovation segments, on an ongoing basis.

HUB: City has dominance on key economic and social innovation segments based on current global trends.

NODE: City has a strong performance across many innovation segments, with key imbalances or issues.

All developed cities should score in these top 3 bands. Emerging cities should aim to score in these 2 bands:

INFLUENCER: City is competitive in some segments, but is out of balance on many segments.

UPSTART: City has potential strong future performance, with some further improvement.

Cities that score below the Upstart band are not classified as they scored below a 50% possible score.

Tourism – EUROMONITOR data record city arrivals for cities in a total of 135 countries. Arrivals refers to international tourists, i.e. any person visiting another country for at least 24 hours, for a period not exceeding 12 months, and staying in collective or private accommodation. Each arrival is counted separately and includes people travelling more than once a year and people visiting several countries during one holiday. Domestic visitors are excluded. This encompasses all purposes of visit, such as business, leisure and visiting friends and relatives. The data are sourced directly from national statistics offices, airport arrivals, hotel/ accommodation stays and other methods.

C. Real estate investment: Approach and challenges encountered

The review of real estate literature in Phase I of the research highlighted how contemporary property investment, rents and capital values are linked to the economic and financial activity of cities. In prime commercial office markets especially, the occupier, supply and investment markets are interlocked through the activity of global business and finance occupiers who are also investors in property, either directly through acquisitions, indirectly through investment in funds, through property company share-holdings, or through investment in securitized debt products based on office property (Lizieri and Pain, 2014).

Globalization and World Cities (GaWC) Research Network data incorporated in the research as a good density indicator record the presence of these global business and financial services firms in cities worldwide and calculates quantitatively the connectivity of cities in their commercial networks. For full technical details about the GaWC model and measurement method and data available since the year 2000, see: www.lboro.ac.uk/gawc.The GaWC metrics therefore contribute data to the analysis that focus directly on densely clustered in high yield city office markets and associated high-skilled specialised labour that may contribute to real estate investment returns (i.e. the good density characteristic, economic & employment infrastructure). The concentration of the offices of these services, in general, in central business districts makes them a proxy for high-value commercial floor space (Lizieri, 2009). A lack of equivalent times series data for other good density variables prevented comprehensive longitudinal analysis relative to real estate investment returns.

General availability and quality of real estate investment data

A challenge for the present research was that while spatial determinants of investments and returns are implicated by some literature as noted in the Interim Report, there has been a dearth of studies that have set out to directly investigate these interrelationships.

A related challenge for international real estate research specifically is the lack of consistent analytical methodologies applied across countries. Data gathering practices vary and there is a lack of comparable data on rents and yields, especially for studies looking across developing and mature markets, and particularly for markets other commercial offices. Testing for common factors would require careful data identification, collection and cleaning.

Important further challenges for the present research are the lack of data for the *sub-city* micro and property and *city-region* levels, which are also important scales for the assessment of good density urban form characteristics and their correlation with returns. More detailed case study work at city-region and sub-city levels is required.

A lack of qualitative research on behavioural investment differences and sentiment limits ability to evaluate the relationships between good density and investment value, market liquidity and risk, and differences in these between world economic regions, countries and cities internationally.

Findings on availability of returns data:

City level real estate returns data as opposed to national data (available from MSCI at the time of the study) were required for comparative global urban analysis.

CBRE city level appraisal based yield data for commercial office markets are available for 68 cities globally with quarterly data from 2000. Yield data were converted to provide estimates of changes in capital value from 2008 to 2016. In accordance with standard methodology in the scholarly real estate research literature, average data were employed in analysis due to the volatility of point-in-time returns.

Cushman Wakefield city level appraisal based data are available for 27 European cities with rental and yield data across offices and prime retail with annual data from 1980 and quarterly data from 1992. As for the CBRE analysis, the data used were from 2008 to 2015, which is the period for which data were available.

Real Capital Analytics property transactions data are available for commercial office markets across 146 countries worldwide since 2000. The data used were from 2008 to 2014.

Due to the different data ranges available from the three sources and to smooth annual variations (Lizieri et al., 2012), average data were used as dependent variables.

Caution is necessary when considering the results. The CBRE and Cushman Wakefield data are based on estimates of rental values and yields in each market by local agents whose methods may vary. For this reason, we also refer to Real Capital Analytics data which are based on actual recorded property transaction values. It must be acknowledged that RCA data collection relies on the accuracy of reported deals. RCA make every effort to check and triangulate information, but there may be issues with data accuracy in less transparent markets.

Due to an absence of consistent time series data and large portions of missing data for several variables, the research does not attempt to conduct detailed econometric analysis with causality testing or to estimate how good density indicators might relate to different elements of returns. Regression analysis was therefore rejected early on in the second phase of the project. Instead, the analysis seeks to propose a quantitatively informed framework for identifying relationships between good density and real estate investment returns. To this end, a simple city ranking method was applied using a Spearman procedure. Analysis of the return performance of office markets provides an overview of correlations with good density.

As a validity check on the Spearman correlations, a Pearson procedure which calculates association (Spearman, 1904) was applied for the good density indicators with robust (non-ranked) data available. The outcome confirms that the Spearman rank correlation results are valid (see Table i). For example, the Pearson result for the correlation between urban extent density and returns is 0.60 compared with the Spearman value of 0.68. The difference between the two results relates to the fact that the Spearman correlation only considers the order/position of city ranks, while the Pearson test focuses on the value of each observation. However, given the skew of some of the good density variables, the Spearman rank correlation results are considered the most robust and are applied in the results reported.

Annual GDP data were collected for all cities in our sample from Brookings Global Institute (https://www.brookings.edu/research/global-metro-monitor/) with a view to their inclusion in the analysis to control for the size and the economic performance of a city. We have assessed the rank correlation of GDP and GDP per capital with each of our density measures as shown in Table XYZ. We find that GDP has a correlation of 0.4 for real estate capital flows and a rank correlation with real estate returns of 0.64. The relationships are stronger when we account for GDP per capita with correlations of 0.4 for flows and -0.13 for returns. Those results show that the relationship between GDP and flows is more pronounced than the one between GDP and returns. This may indicate that while controlling for GDP when relating real estate performance to density measures, we would not expect the relationships to be strongly changed when accounting for GDP. This is in line with results from a multivariate regression analysis in a two and a half year international European Union funded study found a minimal relationship between city-level GDP and a range of city connectivity variables relating to urban sustainability and economy (Van Hamme et al., 2012; Pain and Van Hamme, 2014; Pain, et al., 2015). As validity test on the rank based results excluding GDP, we conduct both univariate and multivariate regression analyses. In the latter we control for GDP along each density measure separately. We find that the relationship between capital flows and density variables is weaker overall as compared to returns. Innovation has the highest explanatory power for capital flows out of all density measures. The majority of them have no significant effect. When controlling for GDP, innovation still remains significant. However it seems that adding GDP considerably improves the explanatory power of the overall model. Returns are significantly related to overall and financial GNC but overall GNC still explains only about 15% of overall return variation in a univariate setting. Controlling for other factors such as GDP and innovation does not change those results considerably. Other density measures cannot be looked at due to the low estimation sample of less than 30 observations.

Table i Absolute Pearson correlation between returns and good density indicators.

	Absolute Pearson correlation with returns
Real investment capital flows	0.22
Business services	0.39
Financial services	0.39
Low Unemployment	0.05
Low Crime	0.22
Urban extent density 2016	0.60
Built up area density 2016	0.61
Open space ratio	0.28
Walkability ratio 2016	0.09

Investment data for visualization case study cities

In general, there is a lack of quantity of data and of transparency to permit quality case study work – additional volume, market and geographical coverage is needed.

Due to the absence of reliable and comparable sub-city or property level returns data, RCA transactions data were used to inform visual analysis for the four case study cities. RCA data collection relies on the accuracy of reported deals. RCA make every effort to check and triangulate information, but there may be issues with data accuracy in less transparent markets. Nevertheless, the dataset represents a robust view of major real estate deals in the period from 2007.

For each transaction, RCA record the address, buyer and seller name, details of joint venture acquisitions and the name of buyer and seller brokers where used. In the dataset used, there is limited information on the properties themselves, but the average cap rate (where recorded) indicates that the sales are of prime (class A) office assets. The data have been augmented by the research team adding the property postal address to permit the approximate city location to be shown in the visualization tool.

The results show how concentrated global office market investment is within the selected case study cities.

Key challenges were:

Because the central purpose of the research was to establish the relationship between good density and returns, cities that might have good density but lack returns data, are automatically excluded from the analysis. The analysis as a whole is thereby not representative of good density but of returns, which skews the results to the identification of correlations with returns in major real estate markets. From 200 cities with density data in the AoUE database, a sub-set of just 28 cities having CBRE returns data are included in the analyses. No Japanese cities are included in the CBRE database.

To assess whether missing data was influencing the results, the correlation between returns and good density indicators was calculated using the 17 cities with complete data. Results showed that the correlations were highly similar for urban extent density, built up area density and many other indicators (Table ii). However, tourism, green environment, low employment, and transparency correlations did change and therefore results should be considered with caution. The analyses do not establish causal relations between the good density indicators and the real estate investment metrics, however they do establish correlations. The correlations identified have been tested for significance (see Exhibits i – iii). Whereas rank correlations are used as the basis for the bar charts, the city scatter maps are based on actual values for indicators where data are available.

Table ii Correlations between returns and good density indicators when using only cities (*N* = 17) with complete data.

	Correlation with returns
Real investment capital flows	0.21
Business services	0.45
Financial services	0.59
Innovation	0.20
Green environment	0.02
Transparency	-0.07
Urban extent density 2016	0.72
Built up area density 2016	0.70
Open space ratio	-0.19
Walkability ratio 2016	-0.41
Tourism	0.56
Low unemployment	-0.20
Low crime	0.24

Table iii Correlations between capital flows and good density indicators when using only cities (*N* = 17) with complete data.

	Correlation with Real investment capital flows
Returns	0.21
Business services	0.72
Financial services	0.74
Innovation	0.74
Green environment	0.20
Transparency	0.40
Urban extent density 2016	-0.19
Built up area density 2016	-0.23
Open space ratio	0.03
Walkability ratio 2016	-0.22
Tourism	0.28
Low unemployment	0.16
Low crime	-0.16

D. Carbon emissions: Approach and challenges encountered

A review of relevant literature highlighted the critical importance of infrastructure development in defining, as opposed to simply modifying, urban climate, emissions and air quality that impact on environmental and human health. Integrated interdisciplinary research is needed to quantitatively assess interactions across scales leading to different outcomes.

In relation to CO_2 emissions specifically, the review also revealed that calculation is subject to different methodological approaches that lead to differences in data reported globally, and its interpretation. Consequently, although there is much evidence that increases in urban density are associated with decreases in local, direct *per capita* CO_2 emissions and energy consumption from motor vehicles and buildings, there is debate about the overall magnitude and exact causal mechanisms of this correlation.

General availability and quality of carbon emissions data

Different methods of CO_2 accounting and data collection reflect two distinctive conceptual approaches to the attribution of CO_2 emissions linked to the scale of analysis and the units of analysis used. Density reported for cities at a global level can therefore be misleading.

- Importance of scale

The most important urban form related variable controlling traffic emissions is likely to be the distance between places of residence and jobs and other activities (Ewing and Cervero, 2010). Emissions may therefore be displaced to urban locations with high through-flows of traffic and/or traffic congestion. Increasing urban density may also displace emissions away from urban areas towards less-regulated areas, resulting in an overall increase in emissions (Glaeser and Kahn, 2010; Echinique et al., 2012). Because of this, either consumption- or production-based approaches to emissions calculation may be used and this will be reflected in reported data.

- Importance of unit of analysis -

Typically, either *per area* or *per capita* emissions are reported. But, as population and built density increase, *per capita* local CO_2 emissions tend to decrease, whereas *per area* local emissions increase (Christen. 2014; Kennedy et al., 2015) affecting the data reported. Furthermore, smaller dwelling sizes associated with high population density tend to reduce per capita energy consumption, but evidence suggests that after a certain unit size, high-rise apartment buildings tend to become less energy/ CO_2 efficient than low-rise or semi-detached homes (Rickwood et al., 2008; Van der Laan, 2011). Other variations in the units of analysis used include *per unit area of living space* (Norman et al., 2006). The use of different units can lead to confusion in reporting practices and/or to mis-interpretation of results.

Findings on availability of carbon emissions data:

Due to the problems with inconsistent methods and reporting practices at the global level of analysis, after detailed exploration it was concluded that none of the sources available are of sufficient quality to be usable.

The intention therefore was to use CO2 satellite data to allow global analysis.[19] However the technology is not yet mature enough. Data sources were found to have large gaps, to cover a wide range of seasons, e.g. source vs sink variations, summer vs winter behaviour. Unfortunately, this means that this independent and consistent data for all cities was not usable. For example, even for London, satellite data are not usable (as they are often only partially available). In consequence, a small sample of eight cities shown to have relevance for the relationship between good density and real estate investment, were studied to scope the availability and comparability of their data to inform investigation at case study city level (Table iii).

Table iv Summary of CO_2 sources.

City	*Data Link*	*Notes*	*Period*
London	Municipal Inventory[1]	City- and borough level CO2e by sector and fuel type	2012
New York	Municipal Inventory[2]	City level CO_2e by sector and fuel type	2014
Shanghai	-Sugar et al.[3] -World Bank Report[4]	-Research paper, city level CO_2e & emissions factors -City level total and per capita CO_2e emissions (p. 67)	-2006 -2006
Brussels	-Municipal Inventory[5] -World Bank[4]	-City level CO_2e, by sector -City level total and per capita CO_2e emissions (p. 25)	-1990-2010 -2005
Berlin	-CDP[6] -World Bank[4]	-City level CO_2e using a consumption based approach -City level total and per capita CO_2e emissions, estimated from national level statistics (p. 68)	-2013 -2006
Warsaw	-CDP[6] -World Bank[4]	-City level total CO_2 CO_2e -City level total and per capita CO_2e emissions, estimated from national level statistics (p. 68)	-2011 -2006
Zürich	CDP[6]	City level total CO_2e	2013
Hong Kong	World Bank[4]	City level total and per capita CO_2e emissions, estimated from national level statistics (p. 68)	2006

Sources:

[19] The advantages of CO_2 observations from satellites are i) application of a consistent measurement technique across all locations and ii) observed concentrations represent an integrated response from all sources and sinks (including vegetation and soils) across multiple scales. The disadvantages are i) limited temporal coverage and ii) CO_2 concentrations by themselves are not a direct measurement of emissions. There are several techniques to derive emissions from concentrations, however, including analysis of vertical profile concentrations, inverse atmospheric modelling, or comparison with surrounding non-urban locations.

[1]Greater London Authority (2012) https://data.london.gov.uk/dataset/leggi2012, Accessed 13 Feb. 2017

[2] The City of New York (2014) http://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/NYC_GHG_Inventory_2014.pdf, Accessed 13 Feb. 2017

[3] Sugar, L., Kennedy, C. and Leman, E. "Greenhouse gas emissions from Chinese cities." *Journal of Industrial Ecology*, 16.4 (2012): 552-563. http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2012.00481.x/pdf, Accessed 13 Feb. 2017

[4] World Bank (2010) http://siteresources.worldbank.org/INTUWM/Resources/340232-1205330656272/CitiesandClimateChange.pdf, Accessed 14 Feb. 2017

[5] City of Brussels (2012) http://www.environment.brussels/state-environment/summary-report-2011-2012/climate/emissions-greenhouse-gases, Accessed 13 Feb. 2017

[6] CDP (2013) https://data.cdp.net/Cities/Citywide-GHG-Emissions-2013/qznk-mn6r/data, Accessed 13 Feb. 2017

Carbon data for case study cities

Data were finally collected for four case study cities - London, Zürich, Hong Kong and New York.

The data available for London allowed CO_2 emissions at borough level to be extracted to inform visual analysis in a landscape context: https://data.london.gov.uk/dataset/leggi2012 revealing sub-city variations associated in part with volume of traffic flow and/or congestion. Caveats to be aware of are that, first, London was the only city studied that had readily available data to illustrate CO_2 emissions across spatial scales and, second, as is the case for a number of other cities, the CO_2 emissions shown for London do not take into account the influence of vegetation. Furthermore, the data for Zürich are not compatible with those for the other three case study cities due to a different CO_2 accounting method being used in Zürich (see technical note below).

Despite concerns about the in-consistency of CO_2 reporting at the global level it was decided to also run an initial analysis of the relationship between CO_2 emissions and real estate investment, followed by an analysis of the relationship between CO_2 emissions and urban density for cities at the global level: urban extent and built up density, walkability and open space ratio.

With the caveat that data sources available at a global level are self-reported and unreliable for the varied reasons already explained, the source incorporated for the 'green environment' rank data, from Arcadis was used to provide direct insight into potential relationships between CO_2 emissions and urban form given the interesting positive and negative correlations revealed with real estate investment returns, CDP: https://data.cdp.net/Cities/Cities-2015-Map/ufw9-sh2k. Total city-wide emissions (metric tonnes CO2e) were used to calculate emissions/km^2/person (i.e. total emissions standardised by area and population).

Technical note – Understanding the Zürich anomaly

The methodology used in Zürich CO_2 emissions data calculation and reporting demonstrates the problem with different approaches and data used for different cities, and their inconsistency.

The 2000-Watt Society methodology (Marechal et al., 2005) used for Zürich is based on a concept of 'sustainable development' that uses two indicators: Primary energy demand and greenhouse gas emissions.

The methodology is based on the final energy demand. Primary energy factors and GHG emission coefficients are used according to the ecoinvent database (database with consistent and transparent, up-to-date Life Cycle Inventory (LCI) data – www.ecoinvent.org/database/). However, the grey energy of net imported other goods and services, is not included in the methodology as there are no specific data available. The methodology does not include emissions from non-energetic sources (e.g. landfills, waste water treatment).

Primary energy is defined as the total energy present in the original energy source, plus its grey energy. The energy that reaches the customer, after all conversion and transmission losses, is called final energy. In turn, only a part of this is actually used: the effective energy. The rest is lost as waste heat. The basis for all calculations is the final energy demand.

The basis of the methodology is the 'territorial principle'. It refers to the energy consumed in the city area and the emissions which occur there. The energy sources grey energy and grey emissions are also taken into account. The grey energy of net imported other goods and service is not included in the 2000 Watt Society methodology due to a lack of specific data. However, the aim is to separately calculate and indicate the grey energy of net imported other goods and services. All calculations in regard to primary energy demand and greenhouse gas emissions are made with the balancing program ECORegion (http://www.ecospeed.ch/).

This example illustrates the challenges for comparative analysis presented by inconsistent concepts and methods applied. The grey energy is not appropriate in this context as it mixes what occurs in the city with its cultural "footprint" (not to be confused with the source area footprint of a CO_2 sensor).

Technical note – Australian city anomaly

When visualising the distribution of CO_2 emissions per km^2 per person, it was apparent that Australian cities were outliers (Figure i). Why Australian cities appear as outliers on this metric is unclear but it is likely a consequence of the small land area and population within Australian cities. The correlation between CO_2 emissions per km^2 per person and good density metrics was consistent when Australian cities were removed from the analysis (Table v).

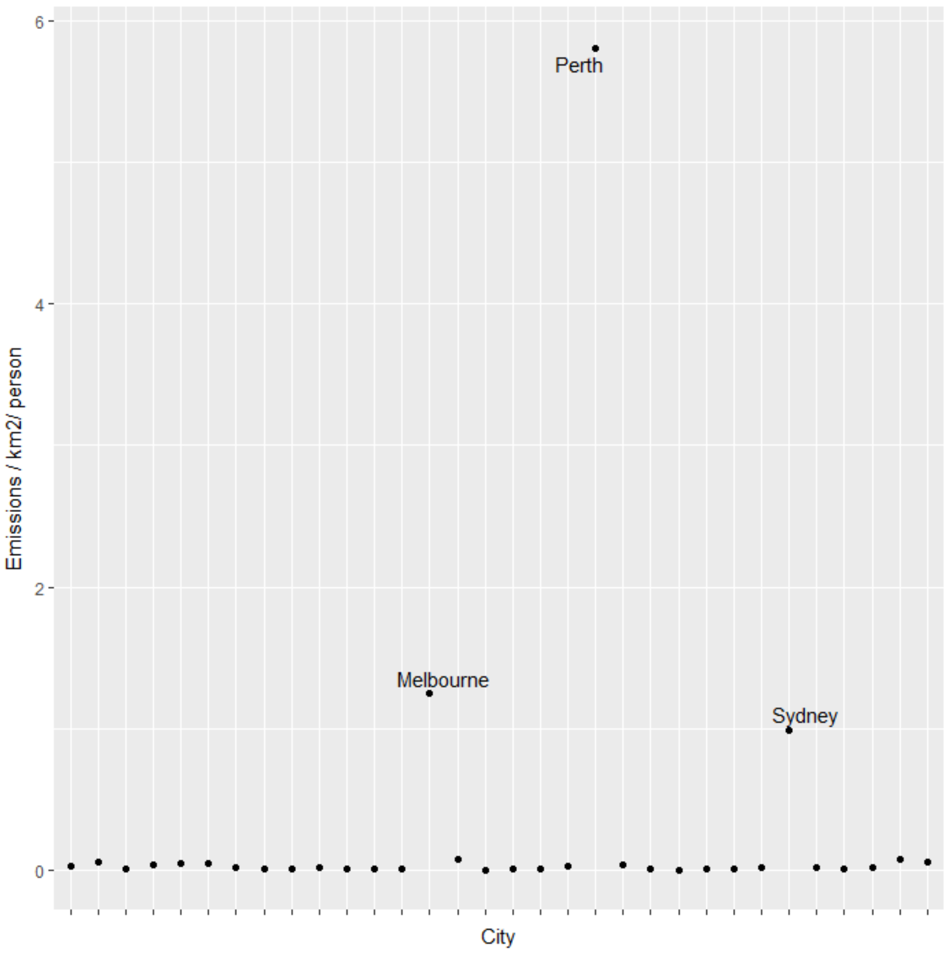

Figure i CO_2 emissions per km^2 per person for cities. The three Australian cities are clear outliers and have been labeled.

Table v Correlation between CO_2 emissions per km^2 per person and good density metrics excluding Australian cities.

Good density indicator	Correlation with CO_2 emissions per km^2 per person	*p*	*N*
Returns after 2008	0.16	0.40	29
Real estate investment flows	0.33	8.97E-02	28
Business services	0.17	0.37	29
Financial services	0.14	0.48	29
Innovation	0.25	0.20	28
Low unemployment	0.29	0.20	21
Low crime	0.25	0.21	27
Green environment	-0.02	0.91	27
Transparency	-0.52	3.68E-03	29
Urban extent density 2016	0.30	0.26	16
Built up area density 2016	0.35	0.18	16
Open space ratio	-0.31	0.24	16
Walkability ratio 2016	0.45	8.25E-02	16
Tourism	0.18	0.50	17

Key challenges were:

Additional to the challenges presented by a deficit of consistent data already discussed, there are important specific data gaps for assessing relationships between CO_2 emissions and urban density:

Transport emissions – Transportation which plays a critically important part in CO_2 displacement involving dense urban areas, may or not be included in assessment, dependent on the reporting procedures adopted by governments for different cities.

City boundaries – City boundaries may not be consistent with other definitions being used elsewhere in the analysis in this report.

Vegetation – Vegetation can offset some CO_2 emissions but this is not being taken into account for many, or most, analyses. This is important for comparative analysis, especially global analysis, because cities have different growing seasons (e.g. high latitude vs low latitude), vegetation amounts (e.g. London inner city vs residential London) etc., landscapes (soil and plant respiration) can also emit CO_2 and, again, this varies with climate (e.g. soil temperature). The role of green infrastructure is not being considered.

Data gaps – In addition to inconsistencies due to data all being self-reported, not all relevant data is necessarily available, for example, population, area, emissions.

C**alculation methods** are also inconsistent.

Bearing all challenges in mind, the database for global emissions was first checked for any city values that were significantly different from the mean for cities worldwide. Australian cities were omitted from subsequent correlation testing for this reason as their inclusion would have distorted the results for all other countries.

NOTE: The University of Reading Meteorology research team are working on a model to remove some of these problems to allow a consistent methodology to be used within a city. This is work that could be expanded in future.

E. Transport Infrastructure Costs: Approach and challenges encountered

Research focused on: (i) general availability and quality of urban transport infrastructure costs data in order to inform selection of case study cities and methodological development and (ii) public transport infrastructure cost and other data for four selected case study cities (London, Zürich, New York and Hong Kong).

General availability and quality of transport infrastructure costs data

Research on availability and quality of public transport infrastructure costs data consisted of a rapid review of known sources and other key sources resulting from key word searches. Due to time limitations a more comprehensive literature search of transport and other infrastructure (ICT, community services, green infrastructure, energy and water) was not undertaken. The transport infrastructures included were road, rail, bus rapid transit (BRT), metro/underground, tram/light rail, cycling and walking.

There are a large range of sources on the issue of transport infrastructure costs, from databases (largely for benchmarking costs and international comparisons) and related studies, to city transport authorities, academic studies and NGO websites and publications. Thus the challenge (at least in EU and USA) was not lack of data in general on these infrastructure costs but rather availability of comparable cost data per mode and appropriate level of detail at city level.

The most authoritative cost sources are city transportation authorities and related national and local websites on infrastructure issues. City transportation authorities in general provide information on budgets, planned and existing capital projects and a variety of other cost data. However, detailed data on specific infrastructure costs is sometimes missing or difficult to find per project or mode of transport (in some cases due to restricted public access including for commercial confidentiality reasons where private contractors are used). Thus it may be appropriate to make direct contact with selected city authorities for any further research.

The international databases reviewed are helpful in general reporting of typical cost ranges for different types of infrastructures but often lack specific city data (as they are commonly intended to guide planning through giving benchmark values), or have gaps in data or access restrictions. In the absence of specific city cost data they could potentially be used to make ballpark estimates (or indicative ranges) for transport infrastructure costs in combination with physical network data for case study cities. However, caveats would be needed regarding validity of such data transfer to study contexts.

It is common for the sources of detail on infrastructure cost to be given by specific mode (road, rail, BRT, etc.) although urban transport authorities and key urban operators may also publish consolidated costs data for the modes under their responsibility.

Comparability challenges can exist for infrastructure cost data between different modes of transport due to different traditions in cost definitions, accounting practices and reporting. Thus it is necessary to be clear and transparent where these differences exist, although in some reporting precise definitions are not made explicit.

There are also potential comparability issues due to differences in the precise definitions and accounting practices for reporting infrastructure costs between country contexts.

Findings on availability of infrastructure costs data per mode:

Roads: Indicative ranges of cost per km or per lane km for road infrastructure are available from a range of sources (e.g. ROCKS, AICD, HM Treasury)**.** There is a complex picture of different unit costs available as these relate to different: (i) types of road including urban roads, (ii) types of costs (new roads, renewal, routine maintenance and operational) and (iii) regions and countries. There is commonly a large dispersion in unit costs for comparable road work activities.

Rail: Indicative average costs per km for rail infrastructure in Europe and USA are available. As with roads there is a complex picture according to location, type of rail (high speed, commuter, light rail) and type of cost, with a large dispersion in unit costs for comparable rail network activities. Restricted access to key database for railway costs in Western European countries (Lasting Infrastructure Cost Benchmarking (LICB)).

Metro: Infrastructure costs for Metro can vary even more widely than overground rail depending on design factors and local conditions. The rapid review found reasonably good coverage of metro costs in most selected cities.

Tram and Light Rail Transit: As in the case of rail and metro there are quite large variations in unit costs for Tram and LRT for different locations. Average unit costs are available for EU countries and USA.

Bus Rapid Transport: Detailed global evidence of BRT system costs is available (e.g. BRTData and EMBARQ, 2013) although many gaps in data per city. Project costs vary significantly across systems depending on design factors and local conditions. Typical ranges for capital costs of BRT are given as $1m/km to 10m/km and for bus lanes as $1m/km to 5m/km (Rode et al, 2014).

Walking: Aggregate cost data on walking infrastructure can be more difficult to isolate than for other modes as it may be included as part of road costs (for pavements), specific walkway projects and cycle path projects. Some typical costs data are available.

Cycling: There are quite extensive general data available on urban cycling infrastructure in developed countries. Although quantitative details on costs can be limited and some cities have detailed infrastructure funding data, such as London. Typical cycle path capital costs are available.

A rapid review of general availability of public transport infrastructure cost sources for a small selection of candidate cities for case studies was also undertaken. The key findings were:

- The most readily available cost data are for key Western European and North American cities. London and New York have good general level of data for budgets and project costs and a transparent reporting culture.
- Total cost data for Warsaw were available per transport mode. Although slightly more difficult to track down and less detailed (than for London and New York) in the sources reviewed, there is general reporting of funding and contractual arrangements.
- From the rapid review, reporting of transport funding and cost data in Shanghai seems to be more limited.
- In terms of availability of cost data, Mumbai (and other Indian cities) seems to be a more promising choice for an developing economy case study.

It was concluded that the costs most apposite at the city scale and feasible to include are as follows:

- Renewal and maintenance cost and operating costs per transport mode.
- Per km costs by transport mode. If not available a ballpark range could be estimated given appropriate data availability on length of networks.
- Per resident or passenger costs by transport mode. If not available ballpark figures can be estimated based on population, ridership and infrastructure cost totals.

The rapid review found very limited specification of infrastructure costs in relation to urban form. If studies differentiate at all in infrastructure costs it is usually only between different sub categories (e.g. motorway/trunk road/local road) rather than in spatial terms or urban forms. There is plenty of evidence of variations in unit costs between different cities but in general this does not focus on analyzing this according to urban forms.

Public transport data for case study cities

As for CO_2 emissions, data were finally collected on public transport infrastructure for the four case study cities of London, Zürich, Hong Kong and New York. Key sources were city transport authorities and key operating company reports and websites, and other related reports. Key metrics researched per transport mode were passenger numbers, numbers of routes, operating costs and capital costs (renewal and maintenance). The organizational and funding context of public transport in the cities was also established along with statistics on public transport's share of the city's transport market. An estimation of operating expenditure per passenger for key public transport modes in each city was made to the extent feasible with available data (Table vi).

Table vi Summary of public transportation infrastructure costs.

City	Passengers per year (millions)	Share of Transport Market (%)	Operating Expenditure (Mill US$)	Capital Expenditure (Mill US$)	Operating Expenditure per passenger (US$)
London (1)	2666	37 (2015)	5,425	2910	2.03
Zürich (2)	327	65 (2005)	802	149	2.45
Hong Kong (3)	2521	81 (2014)	2,264	1229	0.65 (MTR Rail only)
New York (4)	2711	33 (2014)	15,215		5.61

(1) Source: TfL. London Passengers total only for TfL services. Operating and capital expenditure includes only TfL services (Underground, rail, bus services and other surface transport).
(2) Source: VBZ. Zürich data only includes VBZ services (bus, tram, trolleybus) and not S-Bahn Rail.
(3) Sources: MTRC, KBS, City Bus and Hong Kong Digest of Statistics. HK passenger totals do not include buses. Operating expenditure only includes MTR, KBS and City Bus. Capital Expenditure only includes MTR.
(4) Source: MTA. Passenger numbers and operating costs includes only MTA services.

Key challenges were:

- Variations between cities in the availability of data per transport mode. In some cases passenger numbers and costs were only available at an aggregated level across a number of transport modes or only for key operators. This meant that it was not always possible to get a comprehensive set of data that were directly comparable between cities.
- Issues of complexity and availability of data were encountered in some cases where there is contracting of city public transport services. This was especially the case for rail and bus services that are not operated or franchised by a city transport authority, such as in London where suburban rail is operated by a number of operators under franchise from DfT and infrastructure is managed by Network Rail (and costs are not reported at the city level by these entities).
- Comparability issues exist for operating and capital expenditures between cities in particular in the accounting of capital costs. More research would be needed to establish the precise basis of reported operating and capital expenditures for each city. However, it is likely that

cost definitions and accounting practices differ to some extent between cities. It is possible that some costs such as for maintenance and renewal are included as operating costs in some instances and capital costs in others. In the case of New York it seems likely that renewal and maintenance expenditures are included in the quoted operating costs as these are much higher than for the other cities (in total and per passenger) and no separate figures were found for these expenditures. Investment in major new infrastructure (new routes, stations, etc.) was excluded from our research at present because a snapshot of costs in one year or planning period was not considered meaningful in the context of city comparisons.

In consequence, it was only possible to report public transport costs at the city level. Further research and consultation would be necessary to establish whether costs can be estimated with greater granularity (e.g. per route/district/borough/fare zone).

Public transportation systems case study insights

London

Outline

Transport for London is responsible for managing a part of the city's rail networks including the London Underground, London Overground, Docklands Light Railway and TfL Rail, as well as bus, tram and river services. The responsibility for operation of TfL managed services varies between modes including wholly owned subsidiary companies (London Underground), private sector franchisees (other rail services, trams and most buses) and licensees (river services and some buses). Other (non- TfL) suburban rail services are part of the national rail network and are currently run by nine Train Operating Companies (TOCs) under franchise contracts awarded and managed by DfT[20] running on rail infrastructure managed by Network Rail. Public transport (Bus, tram, rail) constituted 37 percent of all journeys in 2015, an increase of 9 percent since 2000 (TfL, 2016b).

Cost Data

Operating and capital costs for TfL managed services are given in their Budget and Business Plan report (TfL 2016). Key points/caveats are:

- Total **operating costs** given in TfL accounts including Underground, Rail and Bus were £2832m in 2015/6. The total including "other surface transport" was £3,660m but note that while this will include other public transport modes (such as tram and ferry boat services) it may also include non public transport services (e.g. cycling networks and taxi licences).
- In the above total **bus operating costs** are given as £84m but this is likely to include only TfL management functions. A significant part of operating costs will be borne by franchised bus companies. We do not have these figures (though a total could be calculated if operating

[20] Plans to transfer responsibility for franchising all of London inner suburban rail services from the DfT to TfL were announced in 2016 (DfT/TfL, 2016) although currently there is some doubt about this transfer. https://www.ft.com/content/a7cbe84e-b1a7-11e6-9c37-5787335499a0

costs are available at the level of London services in the accounts of the various bus operating companies) but note that a significant portion of the "Bus contract costs and ticket commission" of £2,036m given in TfL accounts may be paid by contracted bus operating companies in operating costs.

- **Capital costs** including Underground, Rail (TfL managed) and Bus were given as £1618m in 2015/6. Including "other surface transport" the total was £1,963m but the same caveat regarding possible inclusion of some non public transport services applies here.
- **New capital investment** was £2,665m in 2015/6. A large part of this was for the major new investment in Crossrail (£1,535m in 2015/16) which TfL is responsible for commissioning jointly with the Department for Transport (DfT).
- There are difficulties in establishing operating costs for **national rail services** (i.e. non TfL services) in London due to: (i) the lack of reporting of costs at the level of Greater London since services are operated by Train Operating Companies (TOCs) to and from destinations beyond London borders and (ii) the number of TOCs operating suburban services in London. This is a significant omission given the large numbers of commuters using suburban rail services. *(I will keep looking for any available estimates)*
- Establishing total **capital costs for non TfL rail services** in London is also problematic. Renewal and maintenance for the national rail system rail is the responsibility of Network Rail but costs are not reported at London level but according to eight regions of which six connect to London (ORR, 2017).

Zürich

Outline

Zürcher Verkehrsverbund (ZVV) is the Canton of Zürich public transport authority responsible for strategic planning, coordination and financing public transport. It provides the tariff and ticketing system for public transport services but does not operate these services which are contracted to a number of transport companies. Key operators in the City of Zürich are Verkehrsbetriebe Zürich (VBZ) which operates trams, trolleybuses, buses, and funiculars and Zürich S-Bahn (rail system). The Zürich public transport system maintains a high market share with 65 per cent (*Moglestue 2005).*

Cost Data

Total operating and capital costs are given in ZVV[21] and VBZ sources[22] for 2015. Key points/caveats are:

- Total **operating costs** for transport companies in the Canton of Zürich calculated from ZVV sources are CHF 721.8m. This includes labour costs and operating charge of transport companies. The total operating charge for VBZ is given as CHF 516.5m.
- It is rather unclear whether the above total operating cost figure for ZVV includes S-Bahn as one of the transport companies as there is an additional cost item of "Compensation to SBB

[21] http://www.zvv.ch/zvv/en/about-us/zuercher-verkehrsverbund/figures-and-statistics/key-financial-figures.html
[22] https://www.stadt-zuerich.ch/vbz/en/index/vbz/facts_figures/finances.html

and others" given in the ZVV summary which may refer to S-Bahn operating costs. If so, the total operating cost would be CHF 794.4m.

- Zürich S Bahn covers the entire canton of Zürich and portions of neighbouring cantons. Thus costs data for S Bahn may not be only for the city of Zürich.*(To be clarified if possible)*
- Total capital costs of transport companies are given as CHF 147.3m. Again it is not clear whether this includes the S Bahn.

Hong Kong

Outline

The public transport system in Hong Kong includes Mass Transit Rail (MTR), light rail, tramways, furnicular, bus, minibus, ferry and escalators systems. Transport Department of the Government of Hong Kong is responsible for licensing of rail and bus operators in Hong Kong. A key operator is the MTR Corporation with a 48.5 percent share of franchised transport market in Hong Kong (operating the mass transit rail network and other rail and bus services). MTRC is an unusual example a provider of city public transport covering the full costs and making a profit, achieved by the use of a value-capture model (UNHabitat, 2013). The Kowloon Motor Bus Company (KBS) has a 24 per cent share of the transport market while a number of other companies also operate transport services (bus, tram, ferry, etc.). Public transport (Bus, tram, rail) constitutes 81 percent of all journeys (LTA, 2014).

Cost Data

The number of public transport operators makes establishing total operating and capital costs a complex task and thus totals given only include the key operators and are therefore underestimates. Cost totals have been calculated from data given in the financial reports for the main operators (MTRC 2015, KBS 2015, City Bus 2016). Key points/caveats are:

- The value of 17.5 billion HK$ for total **operating costs** in 2015/6 includes MTRC, KBS and City Bus Hong Kong transport operations only. Thus it does not include trams, ferries and escalators and some buses and minibuses.
- A figure of 9.5 billion HK$ has been calculated for **capital expenditure** based on MTRC Hong Kong operations only in 2015/6. Capital costs are not stated in bus operating company reports we have reviewed and it is likely that routine capital costs (maintenance and renewals) are included in the reported operating costs totals in these companies.

New York

Outline

The Metropolitan Transportation Authority (MTA) is responsible for operating most of New York City's transit systems including subway, other rail and buses. A few services are run by other operators (e.g. Staten Island Rail and Ferry) but most passenger and cost data are captured in the MTA operations. Public transport (Bus, tram, rail) constitutes 33 percent of all journeys (LTA, 2014).

Cost Data

Sources for cost total are MTA financial reports (MTA 2017) and summaries[23]. Key points/caveats are:

- The value of US$ 15.3 billion for **total operating costs** in year ending Dec 2015 includes MTA operations (subway, rail, bus) and Staten Island Railway.
- *We have yet to establish an annual figure for capital costs.* Note that a separate company "MTA Capital Construction" serves as the construction management company for MTA expansion projects and mobility projects. Projects includes major investments in transport infrastructure included hubs (e.g. The Fulton Centre).
- Further discussion of capital investment needs for public transit in New York can be found in the report by ASCE (2015) which concludes that: "upstate and suburban transit systems require $1 billion over the next five years to maintain infrastructure in a state of good repair and add capacity to address ridership demand. However, the anticipated funding will only cover 43% of transit infrastructure needs, leaving a $577 million funding gap".

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F. Significance heat charts

The ‘heat charts’ are a graphical representation of the research data with individual values in the matrix represented by colours.

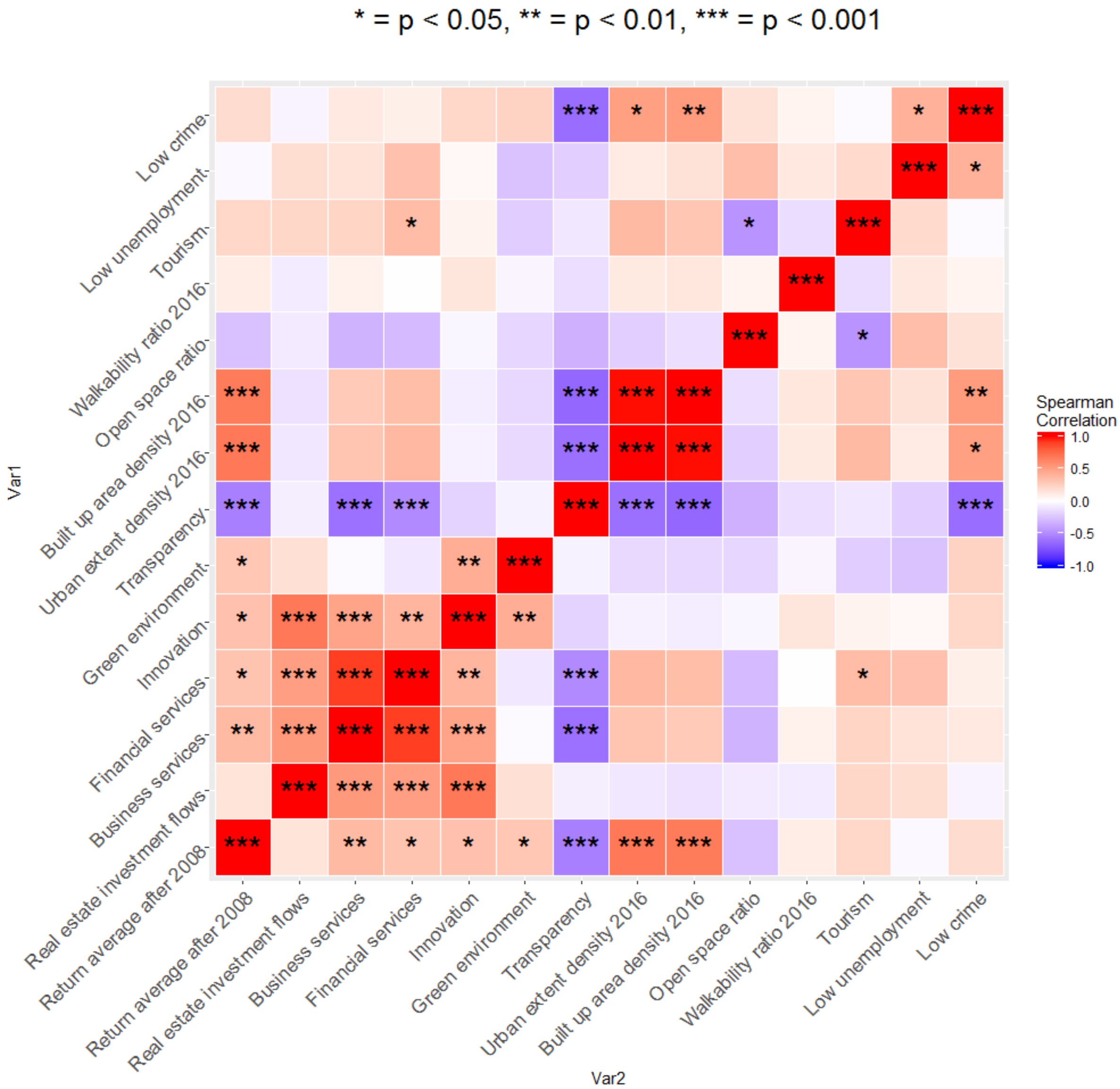

Exhibit i Spearman correlations for office investment returns, real estate investment flows and 12 good density indicators.

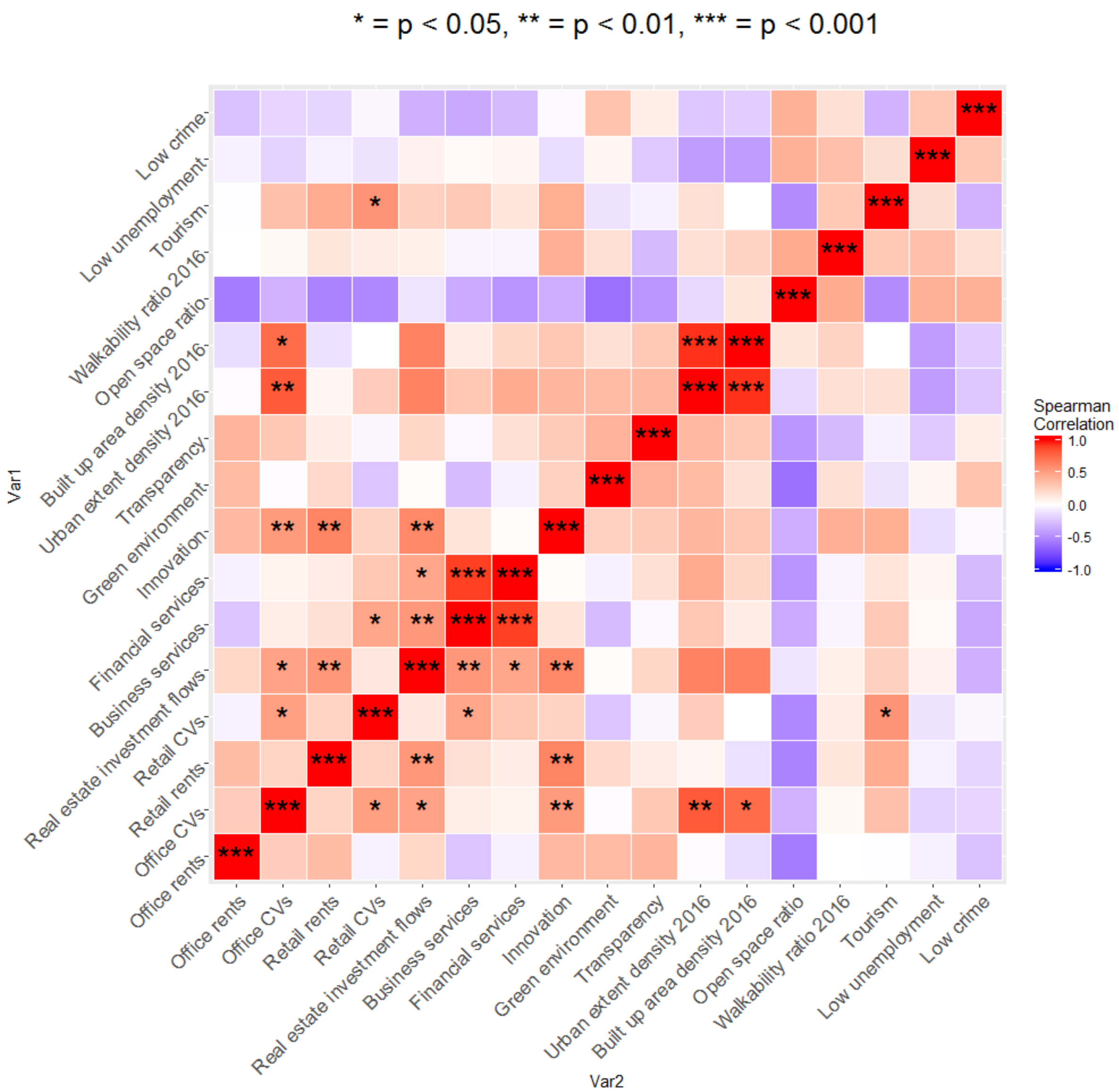

Exhibit ii Spearman correlations for European capital values and rents, real estate investment flows and 12 good density indicators.

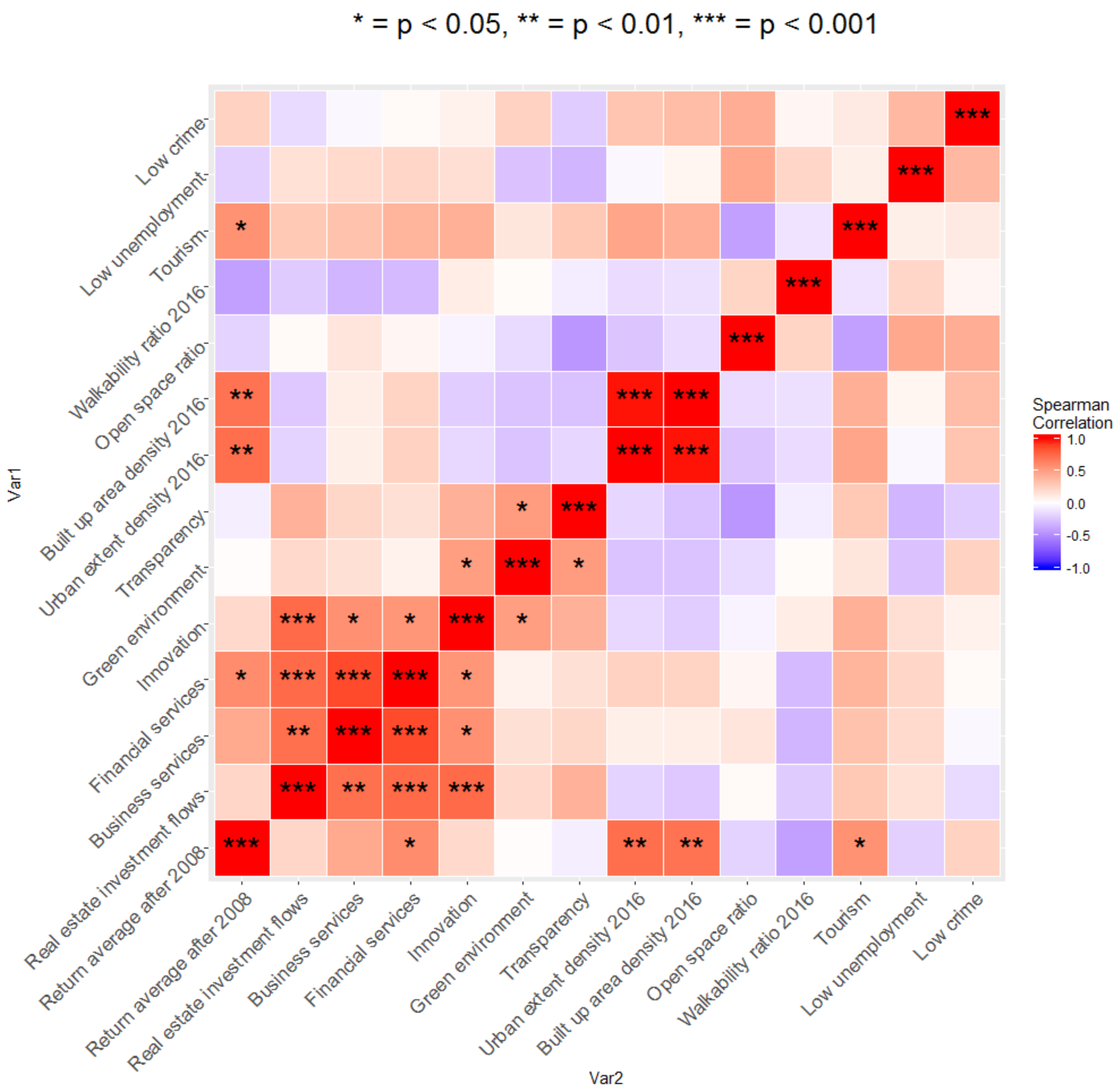

Exhibit iii Spearman correlations between returns, real estate investment flows and 12 good density indicators when only using cities with complete data.

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ANNEX II - Interview research key messages, ethics application documentation and questionnaire proformas

Key messages from Steering Group member interviews

For background information on the interview ethics application, information sheet, signed consent form and questionnaire proformas.

Research interest: Gain insights into future markets and marketable investments in relation to good density / sustainability for diversification. To reflect changing population demographics, employment, capital productivity, concentration, infrastructure, connectivity and economic growth, and their relationship to property value, rental levels, liquidity and risk profiles. To increase market knowledge, to identify marketable investment opportunities that meet different client expectations, and to feed into forecasting and an appraisal tool.

Scale focus: Cross-border global, city-region, micro and property scales.

Analytical focus: Capital market allocations and investment strategy on value, risk and returns for internal decision-making (global strategy, acquisitions, landscape level projects) and for marketing, investor advice (responsible investment), public authority discussions and wider public-private sector collaboration.

Geographical focus: Mature and developing markets: within Europe, prime markets, e.g. London, Paris, Brussels, Amsterdam, Berlin. In developing markets: China, India, South America and Eastern Europe, e.g. Poland.

Real estate sector focus: Offices (large cities / prime), retail and, if available, residential and non-traditional property uses, e.g. business processing.

Methodological focus: Robust commercial quantitative market data, subject to data volume, coverage, collection methodology and comparability. Quantitative urban form metrics where possible, and a qualitative element for intuitive interpretation incorporating findings from the international research reviewed to inform forecasting and underwriting, and sense check heuristic social network information.

Expectations:

Practical recommendations from a high-level report with a forward-looking, global prime A-class investment focus to consider a range influencing factors, including: What kinds of countries and sectors to invest in? Where is marketable and where is secure for investors? Why do certain cities have good density, e.g. population size, density threshold, land use linked to buildings, offices, balance of green space, transport infrastructure, traffic generation, carbon and environmental change, housing supply, location and affordability, amenities, cultural aspects, heritage, quality and design principles? At functional urban region, city and sub-city levels, how do the following contribute to real estate investment value and returns: economic growth, spatial structure, mixed-use, transport infrastructure, commuting, walkability, green space, contiguity of physical development? What would good density look like?

School of Real Estate and Planning Research Project Ethical Approval

Introduction

The University Research Ethics Committee has issued Guidance Notes outlining its Terms of Reference and procedures:

http://www.reading.ac.uk/internal/res/ResearchEthics/reas-REethicshomepage.aspx

In accordance with the Notes for Guidance, ethical propriety of all research relating to human subjects or human personal data must be assessed for undergraduate, masters, postgraduate and staff research projects. If project methods alter significantly subsequent to initial ethics clearance, then a new application form will need to be generated and approved.

Is it research?

It is not research if the activity is carried out solely for the purpose of teaching and learning, or if it constitutes Clinical or Social work practice or audit. With regard to the latter two categories, see Annex E in the Guidance Notes (PDF-299kb).
If the activity is not research, then it does not require ethical approval.

Is it research on human subjects, human samples or human personal data?

If the answer to this question is "yes" then the research requires ethical approval, subject to the following questions:

If it involves human data, are those data in the public domain? Do they relate to deceased persons?

If the answer to either of these questions is "yes", there is no need to obtain ethical approval; but ethical considerations may still be relevant.

If the answer to both these questions is "no", then ethical approval is needed.

Ethical concerns are usually strongest where data are gathered directly from the subject. If the project is funded by a Research Council or other external source then ethical clearance should be sought via the University Research Ethics Committee (see page 5).

The responsibility for ethical conduct of research in the School lies with the Head of School. Under the exceptions procedure outlined in the Notes for Guidance, REP's Head of School (HoS) can approve research project ethical applications (see Annex 1). Authority to sign off ethical approval forms lies with the HoS or nominated persons. Students should discuss their applications with their supervisors prior to submitting to the HoS for approval. If the supervisor is not available, students should contact their Programme Director.

Procedure

Ethical review should be obtained before data collection or recruitment is initiated. This includes feasibility or pilot studies.

This form should be completed by the student/member of academic staff as appropriate and submitted to the School Secretary.

- Ethics clearance must be obtained before the research project commences.
- There is an obligation on all students and academic staff to observe ethical procedures and practice, and raise any concerns or questions with the Head of School. If the Head of School is not available, please contact the Director of Research.
- Records will be maintained and audited as required by the University Research Ethics Committee.
- Completed Consent Forms must be retained by the School for a minimum period of five years from the date at which the project is completed. If ethical clearance is sought from a different School, a copy of the clearance must also be retained in REP.
- The storage of consent forms may be audited from time to time.
- This form is designed to conform to the University's requirements with respect to research ethics. Approval under this procedure does not confirm the academic validity of the proposed project.
- Student research project ethical applications must be referred to the dissertation/thesis supervisor in the first instance for advice; however, sign off must be done by the HoS. Research projects requiring ethical clearance undertaken in the absence of this form will not be marked.
- If in the course of the work the nature of the project changes (including research methods and questionnaire), advice should be sought from the academic supervisor / Course Director and, if required, a further application form for ethical clearance submitted.
- Similarly, if appropriate, changes in the nature of staff research projects (including research methods and questionnaire), must be considered for re-submission for ethical clearance.
- The following must be submitted with this form for approval:
    - The information sheet (see Annex 2a and 2b)
    - Consent form (Annex 3)
    - (Survey) methods
    - Questionnaires or surveys (if appropriate)
    - Focus group or interview questions (if appropriate)

- Please allow sufficient time when seeking ethics approval. The following timescales are an indication:
    - Head of School approval – 2 weeks
    - University's Research Ethics Committee – a minimum of 4 weeks

School of Real Estate and Planning Research Ethics Form

Title of Proposed Project:
Supporting Smart Urban Growth: Successful Investing in Density

Project Details:
The research is investigating how urbanisation can be made more sustainable through improved private and public sector real estate investment decision-making

Name & email address of principle researcher/student:
Professor Kathy Pain: k.pain@reading.ac.uk

Name and email address of supervisor (if applicable): NA

Date of commencement: August 15, 2016
Date of completion: January 31, 2017 (The application is being submitted now because the original project brief did not include collection of personal data.)

Project type (tick as appropriate):

*Staff research	✓	Masters	☐
Undergraduate	☐	Doctoral	☐
Other	☐……………………………….		

*Staff research projects should be signed off by the Director of Research or Head of School.

Brief Summary of Proposed Project and Research Methods

The research is investigating how urbanisation can be made more sustainable through improved private and public sector real estate investment decision-making. The approach is interdisciplinary and the geographical scope is global. A model will be delivered which will enable real estate investors to make informed investment decisions which will simultaneously improve their investment returns whilst also investing in sustainable urban density and urban form. This work is funded by industry investment via the Urban Land Institute in association with the New Climate Economy (NCE). Together these organisations lead the way on sustainable urban land use and the provision of robust evidence on actions which both increase prosperity and resilience, whilst at the same time reduce the risks of climate change.

There are two phases to the research: Phase I is a literature review of secondary sources – scholarly research papers and grey literature – and data sources. A new element of this research phase (not included in the original brief) is an interview survey with relevant industry experts. The survey will help to inform the research team on: (1) the ways in which the research will be used by industry and (2) relevant information and data sources. In Phase II, relevant data will be analysed and modelled.

Data Management

Research Data management is an important consideration within research ethics and is the sum of activities undertaken in relation to the **collection, processing, retention** and **disposal** of research data. Research data, by being well managed, can generate benefits for both the University and its researchers in terms of greater research impact, enhanced reputation, and increased return on investment. Further information on the University's Research Data Management Policy can be found here here.

	Yes	No
Have all aspects of Research Data Management been considered? See What is Research Data Management	✓	
Active data will be stored on a secure University drive (**NOT** on computer/laptop hard drives) Tools and Services	✓	
Have appropriate processes for the retention of data been considered? Tools and Services	✓	
Will the University of Reading Research Data archive be used?	✓	
For personal and sensitive data have measures been put in place to make data of long-term value accessible to the fullest extent that is consistent with any confidentiality requirements? Such measures might include using the initial consent process to secure broad consent for data sharing, and the use of anonymisation techniques, data aggregation, and editing of video or sound recordings to remove personal identifiers from data. The UK Data Archive has a comprehensive guide on consent and ethics	✓	
For sensitive data (e.g. industry data) appropriate arrangements for what can and cannot be done with the data, and who may or may not have access to the data, are defined by participation agreements or the terms of contract.	✓	
Where appropriate, arrangements for disposal of data have been made	✓	
Appropriate training and/or information resources have been accessed Training and General Information	✓	
PhD students have identified data management training (section C1 of the Learning Needs Analysis) and undertaken the necessary training through the Reading Researcher Development Programme (RRDP)	NA	
Postgraduate and Masters students in Planning have taken the Research Methods Module (to be replaced by Good Academic Content Course/Workshop in Autumn 2017)	NA	
Undergraduate Year 3 research module students have taken the Research Methods Module (to be replaced by Good Academic Content Course/Workshop in Autumn 2017)	NA	

Health and Safety

	Yes	No
Will the research be conducted away from an office environment or normal place of work?		✓
Will the research be conducted outside normal working hours? please note the details below and comment on how the personal safety and security of the researcher(s) has been safeguarded:		✓
If you have answered "yes" to either of the above questions, please detail the steps taken to ensure the personal safety and security of the researcher(s)		
Training needs in Health and Safety have been assessed	✓	
Where appropriate, PhD students have identified Health and Safety training (section C1 of Learning Needs Analysis) and undertaken the necessary training through the Reading Researcher Development Programme (RRDP)	NA	
Postgraduate and Masters students in Planning have taken the Research Methods Module (to be replaced by Good Academic Content Course/Workshop in Autumn 2017)	NA	
Undergraduate Year 3 research module students have taken the Research Methods Module (to be replaced by Good Academic Content Course/Workshop in Autumn 2017)	NA	

Checklist for Investigator

✓ I confirm that where appropriate a **consent form** and **information sheet** has been prepared in accordance with the checklist and will be made available to all participants. This contains details of the project, contact details for the principal researcher and advises subjects that their privacy will be protected and that their participation is voluntary and that they may withdraw at any time without reason.

✓ I confirm that **research instruments** (questionnaires, interview guides, etc) have been reviewed against the policies and criteria noted in The University Research Ethics Committee Notes for Guidance. Information obtained will be safeguarded and personal privacy and commercial confidentiality will be strictly observed in accordance with the University's Data Management Policy

✓ I confirm that where appropriate a copy of the **Consent Form** and details of the **Research Instruments/Protocols** are attached and submitted with this application. Arrangements have also been made for the storage of the forms for a minimum period of five years from the date of project completion.

NA For student research, I can confirm that I have consulted with my dissertation supervisor or Programme Director prior to submitting this form, and attended the necessary RRDP training courses.

Approval by HoS or nominee

☐ I have reviewed this application as **APPROVED** and confirm that it is consistent with the requirements of the University Research Ethics Committee procedures

☐ This proposal is **NOT APPROVED** and is returned to the applicant for further consideration / revision.

☐ This proposal is **NOT APPROVED** and will now be submitted to the University Research Ethics Committee

COMMENTS (e.g. where application has been refused):

……………………………………………………………………………………………..

Signed (Staff or Student Investigator):  **Date:** 15 Oct 2016………………

Signed (HoS or nominee): …………………………………………**Date:** …………..………

ANNEX 1

Exceptions

The HoS can approve Ethical Clearance applications with some exceptions. Please confirm whether your work falls within the exceptions process by answering the following:

	Yes/Agree	No
To the best of my knowledge the participants and subjects of the study are not patients or clients of the National Health Service (NHS) or social services.	✓	
Participants and subjects of the study have the capacity to give free and informed consent within the meaning of the Mental Capacity Act 2005 to the best of my knowledge.	✓	
Questions are not likely to be considered impertinent or to cause distress to any of the participants	✓	
The participants and subjects of the study are not involved in a special relationship with the investigator.	✓	
The personal safety of the researcher(s) has been considered and the research does not involve any element of risk to the researchers or participants	✓	

If you have answered “no” to any of the above, please speak to the Head of School, as the scope of the project falls outside the exceptions procedure, and the project will need to be referred to the University’s Research Ethics Committee.

If the work is to be funded by RCUK, then the project will also need to be referred to the University’s Research Ethics Committee. Other funders may also stipulate this as a requirement for funding, so please check with your funder.

If you have answered “yes”, please complete the form.

ANNEX 2A

Information Sheet: checklist and issues for inclusion (see suggested text Annex 2b)

The information sheet may be combined with the consent form if appropriate.

	Yes	No
Information Sheets and Consent Forms have been prepared in line with University guidelines for distribution to participants	✓	
The subject and/or parent is invited to sign a Consent Form. Where minors are subjects, consult the Guidance Notes	✓	
Copies of the Information Sheet and Consent Form are provided for retention by the subject/parent	✓	
Arrangements for the completed consent forms to be retained upon completion of the project have been made. Consent forms will be retained for a minimum of five years from the date at which the project is completed.	✓	
The information sheet is on headed notepaper and includes a contact name and telephone number.	✓	
A summary of the research to be undertaken and its purpose together with a full and clear account of what will be required of the subject.	✓	
The Information Sheet and Consent Form include the name and designation of a member of staff with responsibility for the project together with a contact address or telephone number. If any of the project investigators are students, this information must be included and their name provided.	✓	
A standard statement be included on the Information Sheet/Consent Form, indicating the process of ethical review at the University undergone by the project, as follows: "This project has been subject to ethical review, according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct"	✓	
How the participants have been selected is explained	✓	
If applicable, arrangements for expenses and other payments to participants	✓	
Arrangements to allow participants to withdraw at any stage if they so wish.	✓	
Arrangements to ensure the confidentiality, storage and security of material (including data and audio recordings) during and after the project, and for the disposal of material (see data management section below).	✓	
Arrangements for providing subjects with research results if they so wish	✓	

The arrangements for publishing the research results and, if confidentiality might be affected, for obtaining written consent of this have been considered.	✓	
Where appropriate, a statement to the effect that the results of the investigation are to contribute to the attainment of a qualification of this or any other University. Is such cases, the students involved must be named on the Information Sheet.	✓	

ANNEX 2B

Information Sheet – suggested text, see checklist (Annex 2a)

Title of Proposed Project:
Supporting Smart Urban Growth: Successful Investing in Density

Name, University postal and email address and contact number of principal researcher/student: Professor Kathy Pain, Real Estate & Planning, Henley Business School, University of Reading, Whiteknights. RG6 6UD
Email: k.pain@reading.ac.uk / Tel: 0044 (0)118 3786349

Name, University postal and email address and contact number of supervisor: Not applicable.

What is the purpose of the study?
The research is investigating how urbanisation can be made more sustainable through improved private and public sector real estate investment decision-making. The approach is interdisciplinary and the geographical scope is global. A model will be delivered which will enable real estate investors to make informed investment decisions which will simultaneously improve their investment returns whilst also investing in sustainable urban density and urban form. This work is funded by industry investment via the Urban Land Institute in association with the New Climate Economy (NCE). Together these organisations lead the way on sustainable urban land use and the provision of robust evidence on actions which both increase prosperity and resilience, whilst at the same time reduce the risks of climate change.

There are two phases to the research: Phase I is a literature review of secondary sources – scholarly research papers and grey literature – and data sources. A new element of this research phase (not included in the original brief) is an interview survey with relevant industry experts. The survey will help to inform the research team on: (1) the ways in which the research will be used by industry and (2) relevant information and data sources. In Phase II, relevant data will be analyzed and modelled.

As an industry expert closely associated with the project, your views are being sought to inform the research team on (1) and (2) above so that we will be able to develop analytical approaches and modelling techniques relevant for your business in Phase II of the project.

How long will it take?
Approximately 60 minutes interview either face-to-face or by Skype or telephone conference.

Who is doing this research and why?
The project is being undertaken for Urban Land Institute in association with the New Climate Economy (NCE). The researchers who will conduct the interviews are Professor Kathy Pain, Chair in Real Estate Development at the Henley Business School, University of Reading and Daniel Black (Research Contractor to the University of Reading).

Are there any exclusion criteria?
No.

Once I take part, can I change my mind?
Yes - After you have read this information and asked any questions you may have we will ask you to complete an Informed Consent Form, however if at any time, before, during or after the sessions you wish to withdraw from the study please just contact the main investigator. You can withdraw at any time, for any reason and you will not be asked to explain your reasons for withdrawing.

Will I be required to attend any sessions and where will these be?
The interview can either take place at your place of work, or by Skype or telephone conference, to be mutually convenient.

Is there anything I need to do before the session?
Complete the attached questionnaire and data survey proforma. In doing so, you may wish to consult with others.

Is there anything I need to bring with me?
No.

Who should I send the questionnaire back to?
The questionnaire and the data survey proforma should be emailed to Dr Ruth Pugh, Real Estate & Planning Research Manager, Henley Business School, University of Reading: r.pugh@reading.ac.uk

What will I be asked to do?
Participate in one approximately 60 minutes long interview.

What personal information will be required from me?
Information that is relevant to the attached questionnaire.

Are there any risks in participating?
No.

Will my taking part in this study be kept confidential?
Yes. The researchers will take notes during the interview and appropriate anonymization techniques will be applied. Data collected will be securely stored, analysed and disposed of according to University of Reading guidelines.

What will happen to the results of the study?

The project results will be published by Urban Land Institute.

What do I get for participating?

The project results will be published by Urban Land Institute.

If I have some more questions who should I contact?

Professor Kathy Pain: k.pain@reading.ac.uk

What if I am not happy with how the research was conducted?

The University has a policy relating to Research Misconduct. http://www.reading.ac.uk/internal/res/ResearchEthics/reas-REethicshomepage.aspx.

This project has been subject to ethical review, according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct.

ANNEX 3

School of Real Estate and Planning

Consent Form

1. I have read and had explained to me by …………………………………………….…

   the accompanying Information Sheet relating to the project on:

   ……………………………………………………………………………………….....

2. I have had explained to me the purposes of the project and what will be required of me, and any questions I have had have been answered to my satisfaction. I agree to the arrangements described in the Information Sheet in so far as they relate to my participation.

3. I understand that participation is entirely voluntary and that I have the right to withdraw from the project any time, and that this will be without detriment.

4. This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

5. I have received a copy of this Consent Form and of the accompanying Information Sheet.

   Name: ………………………………………………………………………………

   Date of birth: ……………………………………………………………………

   Signed: ………………………………………...………………………………

   Date: ……………………………………………………...………………………

Steering Group Data Survey Questionnaire

Supporting Smart Urban Growth: Successful Investing in Density

1) How will the results/findings from the project be used by you and/or your business/organisation?

2) What results/findings from the project are expected to be most important for you and/or your business/organisation?

3) Who will be the main beneficiaries from the results/findings?

4) Who within your business/organisation might provide access to additional potentially relevant information and/or data (contact name, country, role, email address)?

5) What other sources of additional potentially relevant information and/or data do you know of (company name + contact name, country, e-mail address if known)?

6) Would you or and/or another member of your business/organisation be willing to be contacted by the research team to discuss your interests in good density and urban form further (contact name, role, email address)?

Reply to be emailed to Dr Ruth Pugh together with the completed Data Survey Proforma: r.pugh@reading.ac.uk

Steering Group Data Survey Proforma

Supporting Smart Urban Growth: Successful Investing in Density

Completed proforma to be emailed to Dr Ruth Pugh together with the Data Survey Questionnaire: r.pugh@reading.ac.uk

Description of data, i.e. real estate investment returns, carbon emissions, infrastructure cost	Analytical scale (i.e. country, city, sub-city)	Geographical area (e.g. United States, Johannesburg)	Time series / date span (e.g. annual, January 2000-December 2016)	Relevance of data for urban density and/or urban form and/or urban growth (if known)	Data owner	Usage restrictions (if any)	Format (e.g. Excel)	Any other known dataset relevant to urban density and/or urban form and/or urban growth