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Size and complexity of hospitals matter for quality of care:

A spatial classification of NHS buildings

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Abstract

The relationship between quality of care and hospital environments has been established in previous research, which proved that environmental and configurational factors could affect health outcomes. However, the focus of these studies was on single cases and results were not always comparable. To fill this gap in knowledge, the aim of the paper is to classify NHS hospitals according to building properties and to study the relation between the physical environment and healthcare adopting a top-level approach. This was initiated by the recent quality of care inspections of NHS hospitals. The main arising question was to see whether spatial layout could be related to quality of care problems. Such a classification however was not straightforward because of the condition of the NHS estates. Almost each campus consists of a hotchpotch of buildings of different sizes, built in different years and adopting various typologies. Therefore, a classification based on the relation between different spatial elements was proposed and adopted.

Various data sets were used to gather the necessary information for a top-level classification. The Care Quality Commission and the NHS Hospital Estates and Facilities Statistics were the two main data sources. Information regarding quality of care and building metrics was obtained from these data sets. Details about the spatial configuration of the buildings were retrieved manually for a selected set of hospitals and their spatial properties were analysed. The presented results suggest that the quality of care is influenced by the size of the hospital campus and its complexity i.e. the number of distinctive buildings on site. Such a relationship is not surprising because smaller and less complex buildings are occupied by smaller and less separated organisations and thus the dimensions of the building enhance communication and flow of information between different teams. The results could give insights to future planning policies and new building developments on NHS hospital sites.

Keywords

Classification, quality of care, hospital buildings, space syntax, NHS.

1. Introduction

Several NHS Trusts have been under public investigation in recent years because of the failure to meet quality standards (Healthcare Commission, 2009; The Mid Staffordshire NHS Foundation Trust Inquiry, 2010; Keogh, 2013). It was concluded that poor management, number of nursing staff, inexperienced junior doctors and poor communication were amongst the reasons for the trusts to fail in meeting the criteria for excellence. Less or no attention was paid to the physical conditions of the buildings, their design and spatial configurations. However, it is suggested here that issues with health care quality could partly stem from physical space insofar as it mediates relationships among people and can be a contributing factor to poor communication. It was assumed that certain building types could provide better quality than others. To investigate this relationship further, hospital buildings were classified according to certain properties to define a number of typologies and test whether these criteria (such as built form) relate to quality of care issues.

The classification however was not straightforward. Buildings could be classified by form, function and space and each of these parameters entails certain difficulties or ambiguities.

Studies on the relationship between hospital environments and aspects, which contribute to quality of care are not a novelty. Various researches showed that environmental factors such as noise, light and air quality could influence well-being and healing of patients (Ulrich, 2004; 2008). The configurational properties of buildings could also affect health outcomes indirectly by impacting movement and interaction (Lu et al, 2009; Heo et al, 2009; Cai and Zimring, 2012; Koch and Steen, 2012a; Koch and Steen, 2012b; Sailer et al, 2013; Pachilova and Sailer, 2013). However, these studies focus on single cases or small comparative samples and do not allow inferences for the overall building stock of hospitals and the bigger problem of quality of care differences among them. Hence, the aim of this paper is to classify a large sample of hospital buildings based on building properties and to study the relation between physical environment and quality of care by adopting a top-level approach.

The paper starts with a brief history of NHS buildings and discusses possible ways to classify the hospitals highlighting the problem of classification. This discussion gives rise to initial research questions and hypotheses regarding potential spatial factors affecting quality of care. Next, data sources, units of analysis and sampling processes are described in further detail followed by the analysis and results of the study and further thoughts on classification. Conclusions, limitations and future work are discussed in the final section of the paper.

2. A brief history of the NHS estate and its present condition

The NHS is a public organisation, which delivers a large proportion of healthcare services. There are currently around 2300 NHS hospitals in the UK. To understand the present condition of its facilities, one must understand the changes, which took place since its establishment in 1948 (Francis et al., 1999; Walker, 2007).

The NHS was set up to provide free care with funds taken from government taxation in order to bring together hospital services, family doctors and other health services as part of an integrated system. During the 1950s, the NHS concentrated on rationalising the estate it inherited which consisted of a number of infectious diseases hospitals. These rapidly became redundant and unsuitable for modern acute care as immunisation against diseases became widespread. In the 1960s and 70s, a number of community health centres were built providing a range of services from a single location. Hospitals built during this period often consisted of two-storey, deep plan buildings containing outpatients, diagnostic and treatment facilities, with wards in tower blocks above. Healthcare architects and researchers continuously carried out studies and developed design briefs and ideas for future hospital designs. The desire to apply consistent standards throughout a large healthcare organisation, led to a systemised approach to design. Standard layouts for hospitals were developed in the 70s such as the Harness Hospital System and the Nucleus[1] project. More than 130 Nucleus schemes were built in England. However, the system's inflexibility meant that functional content and spatial requirements were compromised and its standardised nature did not allow much latitude for site-specific architectural responses. From the 1990s onwards, the private sector began to be involved in the implementation of large construction projects under the Private Funding Initiative (PFI) as the NHS often struggled to fund them. Nowadays, learning from existing projects and feeding knowledge back into the design process, evidence based design practice has further shaped the profile of the NHS estate. Databases of research into the relationship between design and healthcare outcomes have been compiled showing that environmental and configurational factors can have an impact on various patient outcomes (Ulrich, 2004; 2008). Healthcare architects have begun to pay more attention to factors which would: 1) influence patient and staff experience such as daylight, artworks, external views, air quality and noise levels, number and locations of sinks, walking distances, single or multi-bed rooms; 2) reduce medical errors such as low distraction and communication strategies; 3) have an operational efficiency such as separate flows and nursing unit configurations; 4) affect the financial performance of the building such as energy performing and floor to floor heights (Cama, 2009). This results in the introduction of design indicators to allow both designers and clients to score proposed designs before they are built (Lawson, 2007).

Advances in the practice of medicine, new ideas and philosophies in architecture, buildings and society, new technology, construction materials and systems, changes in funding and government have all shaped the NHS estate and led to its current state. The majority of hospitals consist of a campus of small and large buildings built in different periods, influenced by various ideas, serving different needs and hosting a large and complicated organisation. The aerial photo of King's Mill Hospital in **Figure 1** illustrates the various developments from podium and tower block to Post Nucleus, a later extension and a PFI development. Added to this are a number of temporary, single storey buildings on the site, which became more permanent as NHS funds became stretched. Similar scenarios are a familiar sight around the country.

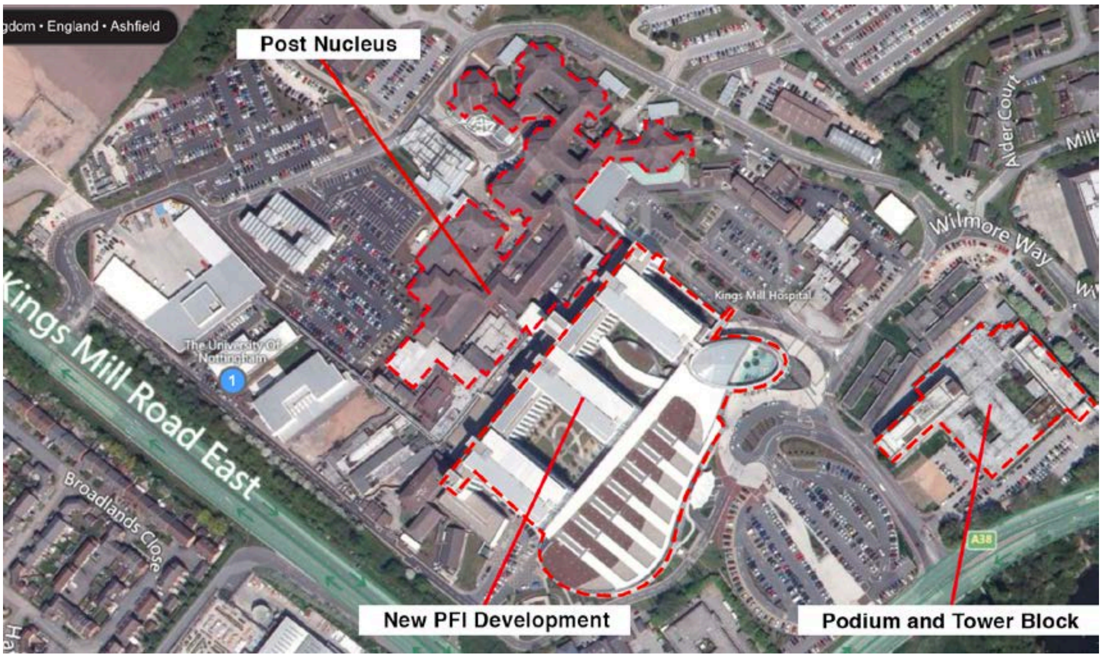

Figure 1: Aerial photo of King's Mill Hospital from Bing Maps.

[1] In a post nucleus hospital different functions were designed into a standard cruciform template of about 1,000sqm and joined together along a hospital street. Expansion of hospitals would progress in small stages with Nucleus templates added on as funds became available (Francis et al., 1999).

3. The Problem of classification

Classification is based on observing things, comparing and naming them accordingly. Labelling locates them in different classes and subclasses generally in a hierarchical structure. The members of a class are held to share a number of characteristics, which are significantly different from those shared by the members of another class (Markus, 1987). Within architecture, the two most commonly used typological classifications are either by morphology or by use (Forty, 2000). Steadman (2014) calls these 'built form types' versus 'activity type'.

Forms can be classified by geometrical properties, propositions, articulation, colour, ornamentation and surface treatment. Still the form of the buildings is the most difficult to bring into a classification analysis. Architectural historians placed buildings into a chronological stylistic class (Markus, 1987). However, as Markus (*ibid*, p.469) argues "*the great difficulty is to classify elements and their relations with respect to their formal, non-functional properties in the degree of generality necessary for any classification, yet in sufficient detail to distinguish between the forms of, say the Lloyds building and the Stuttgart Staatsgallerie*". As an example, the author lists categories such as 'high-tech' or 'postmodernist' which he argues are broad and offer little help in revealing the social forces or philosophic and scientific paradigms which underlie the design.

In terms of function, buildings can be categorised into certain types such as churches, airports, hospitals, etc. The function of a building could be judged from labelling and the location of furnishing in space. However, labelling would not necessary prescribe usage and some building types can serve several functions (Markus, 1993).

In addition to form and function, Markus (1987, p.468) proposed that buildings could be also classified by a "*third concrete experience (…) capable of empirical support*" namely space. Space is invisible and could be defined and made particular by observable characteristics, which relate both to function and form. With regards to the former, it describes "*who does what, where, with and controlled by whom*" (Markus,1987, p.469). As for the latter, what could give similarities to the form of a certain building type is a set of rules derived from the social practice housed in the building. The same set of rules will also govern the features of another local building of the same type (Markus, *ibid*). Thus society is embodied in its output i.e. the built environment in the same way genetic instructions are encoded in a biological system (Hillier and Hanson, 1984). The spatial reality is the 'phenotype' to be classified, by identifying the underlying social code i.e. the 'genotype' of the system, which has formed the spaces (ibid, 1984). An example of such a classification is the work of Hanson (1998) where 47 houses from the Banbury region were classified into 4 distinctive types based on their room arrangements and labeling. By studying the spatial patterns constructed out of depth and rings, Hanson described the instances of built reality i.e. the phenotypes to discover genotypical relations and identify different typologies.

Following this example, the spatial structure of a building can be analysed and categorised in terms of depth, the extent to which it is ringy or tree-like, how it defines the boundary between inside and outside, how it transforms people into visitors or inhabitants by assigning them different levels of access and allowing them various degree of control, how buildings regulate this interface between visitors and inhabitants by bringing people together or keeping them apart, how visitors and inhabitants can occupy different strategic locations on buildings either deep in the plan or shallow, thus defining elementary and reversed buildings (Hillier and Hanson, 1984). The complex spatial structures – the 'phenotypes', are built out of these elementary spatial gestures (Hanson, 1998).

In order to classify hospital buildings, several approaches were tested. The first one was Prasad et al's (2008) classification, where hospitals were split into various types according to built form illustrated in **Figure 2**. An initial selection of 73 buildings, which contained similar in size general hospitals with different quality ratings, was analysed in 2 and 3 dimensions, any edifices on site, which were not part of the general hospital were identified and excluded and afterwards the building type was defined. It was easy to identify the typology of some of the buildings. However 70% of the hospitals consisted of many buildings blocks of different types, sometimes interconnected, sometimes not, built in various periods thus belonging to different classes and categories. Such buildings fell into Prasad's category 'campuses'. A second attempt to classify the hospitals was made, where hybrids between two or more categories were identified. However, it was felt that the classification was too subjective to be used.

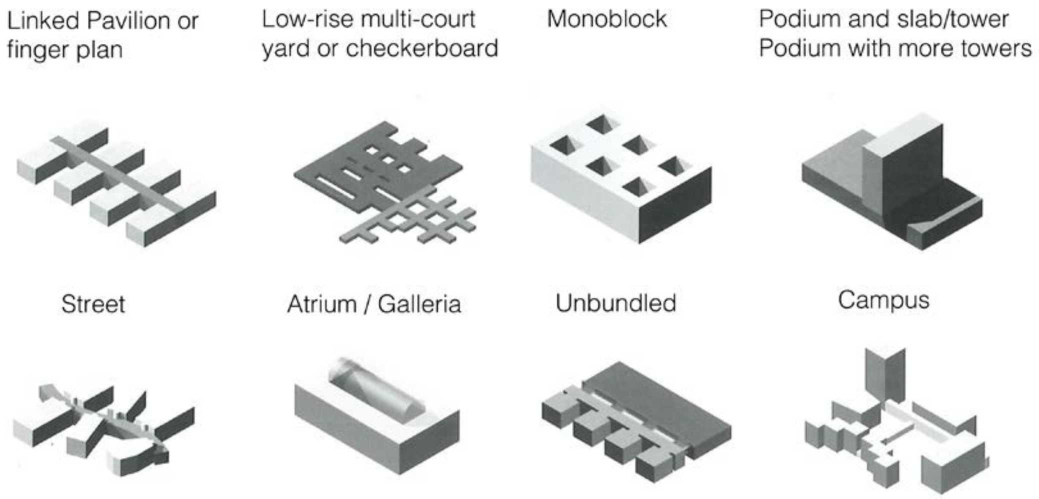

Figure 2: Classification of hospital types based on built forms (Source: Prasad et al 2008, p. ix-x)

A second possible approach is Steadman and Mitchell's (2010) scientific method for plotting plans of rectangular built forms. For the classification, the authors used an archetypal building, which was defined as a large and complex form, from which a great number of different simpler built forms can be generated using a method of subtraction or cutting (**Figure 3**). Steadman et al. counted and catalogued all possible forms that can be made from the archetype. Plans of five generic shapes were produced, which were rectangular blocks, complete courts, L, T and U shapes. This was done through a method of assigning a code to each form and then listing all codes in order. Every coded shape can exist in many dimensions but the basic underlying configuration, signified by the code, remains unchanged throughout. What this method of representation does is to separate consideration of shape from consideration of size. The forms were then plotted on an archetypal morphospace, which represented a map of all possible forms (Steadman, 2014). However, as pointed out by Steadman (ibid), the archetypal building has its limitations. It describes plans where all the ranges are straight and all courtyards are aligned in rows while many buildings may have ranges and wings that are cranked and courtyards of different sizes that are not aligned. Hence, the attempt to adopt this method was unsuccessful because of the complexity of the campuses.

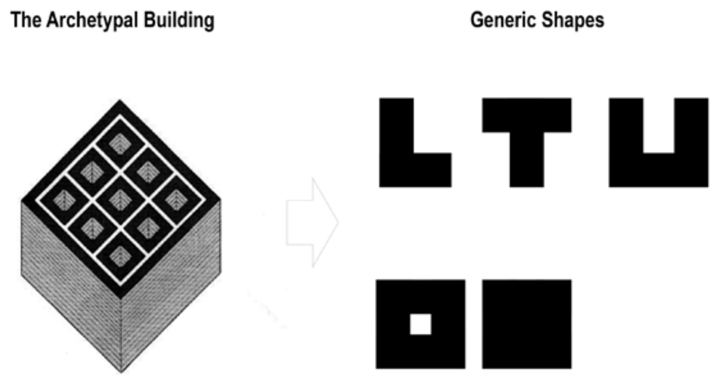

Figure 3a-b: Archetypal building consisting of three-by-three courts made up of three strips - daylight, artificial light and daylight (left); plans of five generic shapes produced, i.e. rectangular blocks, complete courts, L, T and U shapes (right). (Source 3a: Steadman et al 2010, p. 199)

4. Research questions

Following the above discussion on quality of care and the problem of classification, the following research questions arose: how can hospital buildings be classified in order to derive spatial properties matching quality of care ratings given to the whole site? Which classification strategies are feasible for a large data set given available data? Which spatial properties could potentially influence quality of care?

Based on these questions, the following hypotheses were formulated:

- H1: Newer hospitals perform better than older ones.

This is based on the assumption that a new building with an improved and purpose-built layout eases communication flow and current work processes. It could also be the case that a new building instils a sense of pride in staff that would in turn improve motivation and good work. Recent research (Williams et al, 2014) has highlighted that the impact of a new building on social outcomes is not straight forward in the case of schools, still is interesting to test in the case of hospitals.

Size and overall layout features in the following set of hypotheses:

- H2: Smaller hospitals perform better than bigger ones.
- H3: The less complex the hospital site is, the better the quality of care.
- H4: The more compact a hospital is, the better the quality of care.
- H5: The more connected the campus is, the better the quality of care.
- H6: The more integrated the campus is, the better the quality of care.

It could be argued, that organisations located in smaller, less complex and compact buildings perform better than larger ones as a consequence of greater integration of the organisation and thus better communication between departments and stronger management. Similarly, higher visibility and accessibility of the environment would lead to greater awareness of what is going on in the organisation and better flow of information, which would influence healthcare in a positive way.

It was assumed that hospitals located in more central areas have easy access to other amenities and potentially attract more qualified, talented and motivated staff, which could lead to higher quality of care, better decision-making and better communication and flow of information. Therefore it was hypothesized that:

- H7: Centrally located hospitals perform better.

Private financial initiatives (PFI) were developed to allow the construction of large projects, which would otherwise be impossible. In a recent study (Ive, 2010) it was concluded that PFI hospitals tend to have higher performance in aspects of patient environment, cleanliness and catering at seemingly no higher costs. Hence it was hypothesized that the investment factor could also improve working conditions and quality of care:

- H8: Hospitals, partially funded by the private sector (campuses with a PFI hospital on site) perform better than only publicly or governmentally funded hospitals.

Some universities operate their own hospitals, which provides training to medical students and directly involves latest research insights. It was suggested that this could have a positive impact on the provided care. Thus it is suggested that:

- H9: University hospitals perform better than non-university hospitals.

In the following, methodology and data sources for the testing of the hypotheses will be introduced.

5. Methodology

Data Sources

One of the main data sources for the study was the online NHS Hospital Estates and Facilities Statistics (HEFS) data[2], which provides site specific measurements of various aspects of hospitals specification and operational performance over the fiscal year. The size of the properties, number of beds, number of wards and building age profiles were obtained from these datasets.

The other main data source was quality of care data available online from the Care Quality Commission (CQC) website[3]. The CQC is an independent health and adult social care regulator. Its inspection teams are led by an experienced CQC manager and include experts such as professional or clinical staff, experts by experience, people who use services and carers. The CQC looks at whether services are safe, effective, caring, responsive to people's needs, well-led and encourage them to improve. Since it was established in 2008, the CQC used a 3-level rating system, which was changed in October 2014, when the regulator moved to a new inspection model and rated services using four levels. By January 2015, 167 institutions listed under 'hospitals' (excluding providers) were inspected with the new system. For comparison, 1955 hospitals[4] were investigated and rated according to the older system in the period from October 2008 until March 2014.

The 2011 rural-urban classification (RUC2011) for small area geographies (Bibby and Brindley, 2013) was used to find information about the location of the hospitals. A full list of PFI contracts was obtained and downloaded from The Guardian data blog[5]. However, this list contained names as per project not per hospital and additional information was sought from different sources. The remaining information about affiliation (university hospital or not) was retrieved manually from various online[6] references.

Units of analysis

Old CQC Rating: The old inspection model used a 3-level rating system to evaluate healthcare providers. The rates were labelled as 'all standards met', 'requires improvement' and 'enforcement action'. When at least one standard in the area was not met at inspection, the CQC either required improvement or took enforcement actions if the service was performing badly.

New CQC Rating: The new inspection model uses the following four levels: 'outstanding', 'good', 'requires improvement' and 'inadequate'. A service is rated as 'outstanding' when its performance is exceptionally well. The other three rates were as described above.

Location: The urban categories are: major and minor conurbation, city and town in a non-sparse and a sparse setting. The rural categories are: town and fringe in a non-sparse and a sparse setting; village in a non-sparse and a sparse setting; hamlets and isolated dwellings in a non-sparse and a sparse setting.

Occupied floor area: This is the total internal floor area of all buildings or premises, which are in operational use and required for the purpose of delivering the function/activities of the organisation.

Number of buildings: Total number of distinctive buildings, excluding unused edifices or buildings with unrelated function.

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[2] The latest information for the year 2013/2014 was downloaded from http://hefs.hscic.gov.uk/DataFiles.asp and http://hefs.hscic.gov.uk/PLACE.asp

[3] http://www.cqc.org.uk/search/services/hospitals/?sort=default&distance=15&mode=html

[4] In this paper, the term hospital was used for simplicity. While the vast majority of the facilities in the dataset were hospitals, there were some treatment centres.

[5] http://www.theguardian.com/news/datablog/2012/jul/05/pfi-contracts-list#data

[6] These were the official websites of the hospitals as well as Wikipedia.

Compactness of the floor shape: This measure was calculated as proposed by Steadman (2014, p. 194) by taking the perimeter of a square of equal area to the given plan and dividing it by the actual perimeter of the plan. Lower values mean less compact shape. The measure can be applied to any closed shapes or group of separate shapes thus also measuring the effect of ‘fragmentation’.

Average age of building stock: The average age of buildings weighted by the area each building is taking up.

Additionally, the following metrics were used: ‘*number of wards’, ‘number of beds’, ‘funding’* and *‘affiliation’.*

Amongst the measures used by the Space Syntax community to describe configurational relations, this paper uses connectivity, mean depth and integration (Hillier and Hanson, 1984). The spatial properties of the hospitals were calculated by drawing the outlines of the buildings from Google maps, Google Earth and Bing maps depending on which of these engines had the most recent satellite imagery. The outlines were analysed in depthmapX (Varoudis, 2012).

Sampling process

The following process was used to analyse the data sets:

- The old rating data was combined with the information from the NHS Properties. Basic statistical information about the combined data set is presented in (**Table 1**).
- The new rating data was also combined with the NHS Properties data and basic statistical information is presented in (**Table 2**).
- Information about the number of buildings, location, affiliation and funding was retrieved manually for the new rating data set (**Table 2**).
- The outlines of 20 campuses were drawn. Hospitals similar in size were selected of which 9 were rated as ‘good’ or ‘outstanding’ and 6 were rated as ‘required improvement’. As the data set included only 5 hospitals rated as ‘inadequate’, they were all included in the analysis. The outlines of the buidlings were then analysed in depthmapX and their level of compactness calculated (**Table 4**).

OLD RATING SYSTEM		CQC data set combined with NHS properties
All Hospitals		931
Old ratings	Met Quality Standards	814 (87.4%)
	Requires Improvement	115 (12.4%)
	Enforcement action	2 (0.2%)
Area	Max Floor Size [sqm]	227,000
	Ave Floor Size [sqm]	27,000
	Min Floor Size [sqm]	105
Wards	Ave No Wards	8
Beds	Ave No Beds	166
Type	General Acute	289 (31%)
	Community	167 (18%)
	Short-term	150 (16%)
	Long stay	92(10%)
	Specialist	97(10%)
	Others	136(15%)

Table 1: Basic statistics for old rating database

		CQC data set combined with NHS properties
All Hospitals		85
New ratings	Outstanding	1 (1.1%)
	Good	22 (25.9%)
	Requires Improvement	57 (67%)
	Enforcement action	5 (6%)
Area	Max Floor Size [sqm]	227,000
	Ave Floor Size [sqm]	62,000
	Min Floor Size [sqm]	1,800
Wards	Ave No Wards	18
Beds	Ave No Beds	397
Type	General Acute	64 (75%)
	Community	4 (5%)
	Short-term	3 (4%)
	Specialist	5(6%)
	Others	9 (10%)
Age	Ave Age [years]	30
No Buildings	Ave No Buildings	5
Location	Urban major conurbation	60 (71%)
	Urban city and town	21 (24.8%)
	Urban city and town in a sparse setting	2 (1.4%)
	Rural town and fringe	1 (1.4%)
	Rural village	1 (1.4%)
Affiliation	University	41 (48%)
	Non-university	44 (52%)
Funding	Public-private (PFI)	19 (22%)
	Public	63 (74%)
	Government	3 (4%)

Table 2: Basic statistics for new rating database

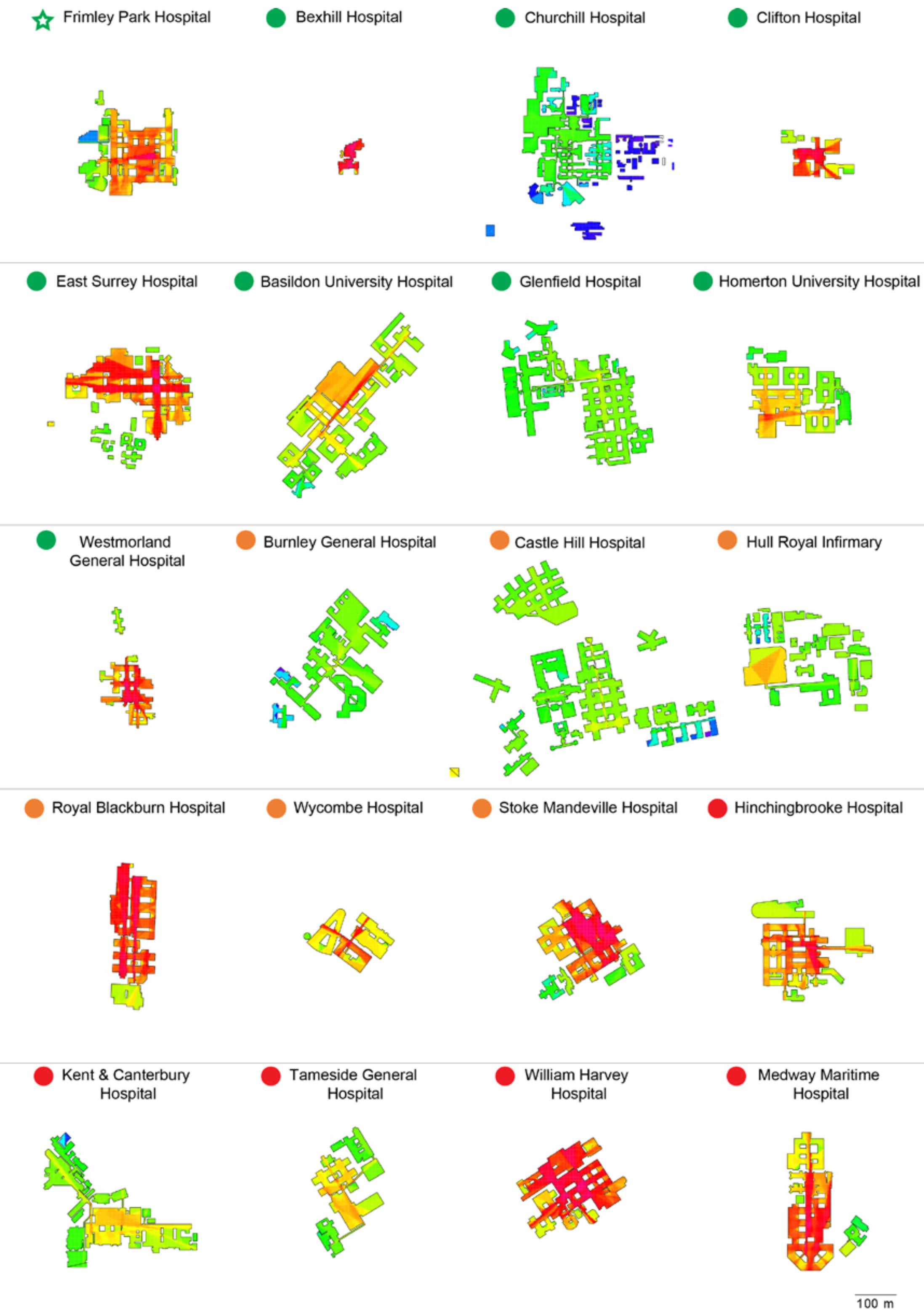

Figure 4: Global integration of 20 selected NHS hospitals calculated based on their outlines. Legend: ★ Excellent; ● Good; ● Requires improvement; ● Inadequate. Hospitals are in 1:100 scale. The buildings are on the same colour scale.

6. Quality of care and the impact of building metrics

Data quality

From the data publicly available for comparative analysis of care quality, the one provided by the CQC was the only source containing information about individual hospitals. All other available data sets provided information on a trust level, aggregating results for hospitals under each trust. However, the CQC data included repeated entries, which had to be excluded. Another issue was the uncertainty of the matching of the old and new rating system and to which degree they overlapped. It was assumed that meeting standards was equal to outstanding / good, requires improvement to requires improvement and enforcement action to inadequate.

Old Rating System

It was tested whether significant differences in size, number of wards, number of beds and average age of buildings could be found between the different care quality ratings using a one-way ANOVA test (**Table 3**). The area size (p<.0005), number of wards (p<.0005) and number of beds (p<.0005) were highly significantly different for the different levels. This indicated that those hospitals, which performed better, were smaller in size, had fewer wards and fewer beds, compared to the weak performers, which were much larger hospitals. No statistically significant differences were found for the average age of buildings (p=0.635) meaning that old buildings could perform as good or bad as new ones.

Area Size	Mean	No	F	Sig.
Met standards	25,492	814		
Requires improvement	38,368	115	10.029	**0.000**
Enforcement action	113,897	2		
No Wards	Mean	No	F	Sig.
Met standards	7	814		
Requires improvement	12	115	8.011	**0.000**
Enforcement action	14	2		
No Beds	Mean	No	F	Sig.
Met standards	150	814		
Requires improvement	254	115	9.594	**0.000**
Enforcement action	367	2		
Ave Age	Mean	No	F	Sig.
Met standards	33.5	814		
Requires improvement	31.6	115	0.454	0.635
Enforcement action	31.9	2		

Table 3: One-way ANOVA test between the old rating system and size, number of wards and beds.

New Rating System

Statistically significant differences were found between the area size (p=0.012); number of wards (p=0.023); number of beds (p=0.040); number of buildings (p=0.010) and the new rating system (**Table 4**). Again, good hospitals were significantly smaller in size and were made up of fewer separate buildings. However, in contrast to the old rating system, the worst performing hospitals were slightly smaller in size than those just requiring improvement, which is most likely caused by the small sample size and one particular outlier. It could be argued that with more data points in this category similar results to the old rating system would show. There were no statistically significant differences between the average age of buildings (p=0.870) and quality of care, thus newer hospitals did not necessary performed better than old ones. Results from chi-square test showed that the location (p=0.952), affiliation (p=0.630) and funding (p=0.447) of the hospitals did not affect quality of care (**Table 5**).

Area Size	Mean	No	F	Sig.
Good	38,918	23	**4.633**	**0.012**
Requires improvement	71,642	57		
Inadequate	62,244	5		
No Wards	Mean	No	F	Sig.
Good	10	23	**3.939**	**0.023**
Requires improvement	19	57		
Inadequate	17	5		
No Beds	Mean	No	F	Sig.
Good	232	23	**3.339**	**0.040**
Requires improvement	417	57		
Inadequate	378	5		
No Buildings	Mean	No	F	Sig.
Good	4	23	**4.925**	**0.010**
Requires improvement	6	57		
Inadequate	5	5		
Ave Age of Buildings	Mean	No	F	Sig.
Good	29	23	0.140	0.870
Requires improvement	30	57		
Inadequate	33	5		

Table 4: One-way ANOVA test between the new rating system and size, number of wards and beds, complexity and average building age.

	Sig.
Location	0.952
Affiliation	0.630
Funding	0.447

Table 5: Chi-square test between the new rating system and location, affiliation and funding.

Results from one-way ANOVA test for selected spatial properties showed no statistically significant difference amongst the three healthcare quality categories (**Table 6**). The closest measure was mean depth normalized by the size of the hospital (p=0.136) and it was assumed that if more cases were included in the data set this could show significant differences.

The conclusions from the analysis in this section were used to reflect on the stated hypotheses. **Table 7** below summarises the results. The size and complexity of the hospitals had an effect on quality of care, while the age, compactness of the site, location, affiliation, funding as well as the spatial properties of the campus did not show a strong relation to healthcare. It is suggested that using real floor plans of buildings including all floor levels rather than outlines drawn from an online mapping service application would be more appropriate and accurate for calculating spatial properties where the level of precision is important (**Table 4**). In addition, analysing wards' configuration rather than the whole campus might appear to be more relevant and susceptible to classification. Other types of location e.g. spatial metrics such as integration and choice derived from the space syntax map of East and South East of England (Hillier and Serra, 2014) as well as a Manhattan distance from the nearest large urban centre could be tested as they will provide numerical rather than categorical values.

Compactness	Mean	No	F	Sig.
Good	0.277	9	0.191	0.828
Requires improvement	0.299	6		
Inadequate	0.310	5		
Connectivity	Mean	No	F	Sig.
Good	626	9	0.889	0.429
Requires improvement	651	6		
Inadequate	807	5		
Integration	Mean	No	F	Sig.
Good	5.56	9	0.256	0.777
Requires improvement	4.85	6		
Inadequate	5.59	5		
Mean Depth	Mean	No	F	Sig.
Good	3.42	9	0.169	0.846
Requires improvement	3.45	6		
Inadequate	3.09	5		
Connectivity normalised by size	Mean	No	F	Sig.
Good	0.0294	9	1.12	0.349
Requires improvement	0.0089	6		
Inadequate	0.0132	5		
Integration normalised by size	Mean	No	F	Sig.
Good	0.000409	9	1.36	0.283
Requires improvement	0.000068	6		
Inadequate	0.000092	5		
Mean depth normalised by size	Mean	No	F	Sig.
Good	0.000131	9	2.25	0.136
Requires improvement	0.000047	6		
Inadequate	0.000050	5		
Connectivity normalised by No Beds	Mean	No	F	Sig.
Good	132	9	0.673	0.523
Requires improvement	33	6		
Inadequate	179	5		
Integration normalised by No Beds	Mean	No	F	Sig.
Good	1.68	9	0.54	0.593
Requires improvement	0.27	6		
Inadequate	1.36	5		
Mean depth normalised by No Beds	Mean	No	F	Sig.
Good	0.59	9	0.74	0.492
Requires improvement	0.19	6		
Inadequate	0.72	5		
Connectivity normalised by No Wards	Mean	No	F	Sig.
Good	3.99	9	1.21	0.323
Requires improvement	1.77	6		
Inadequate	11.88	5		
Integration normalised by No Wards	Mean	No	F	Sig.
Good	0.056	9	0.77	0.478
Requires improvement	0.015	6		
Inadequate	0.091	5		
Mean depth normalised by No Wards	Mean	No	F	Sig.
Good	0.021	9	0.96	0.402
Requires improvement	0.010	6		
Inadequate	0.048	5		

Table 6: One-way ANOVA test between the new rating system and spatial properties

7. Hypothesis

	Supported	Not supported
H1: Newer hospitals perform better than older ones.		✔
H2: Smaller hospitals perform better than bigger ones.	✔	
H3: The less complex the hospital is, the better the healthcare.	✔	
H4: The more compact the hospital is, the better the healthcare.		✔
H5: The more connected the campus is, the better the healthcare.		✔
H6: The more integrated the campus is, the better the healthcare.		✔
H7: Centrally located hospitals perform better.		✔
H8: Partially PFI hospitals perform better than only public or governmental hosptials.		✔
H9: University hospitals perform better than non-university ones.		✔

Table 7: List of hypothesis and results

8. Further reflections on the problem of classification

Classification of hospitals based on morphological properties is difficult because similar to species which are not *"discrete populations fixed in form and capable only of creation and extinction but also mutation"* (Peponis, 1982, p. 23), buildings change and evolve too. In addition, as Bernstein (1971) argued, classification does not necessarily refer to what is classified, but to the boundary strengths between what is classified. Thus, two types of classification could be distinguished – strong and weak classification. Traditionally, hospitals buildings could be strongly classified into a certain category. However, after the changes, which took place since the establishment of the NHS, hospitals could no longer be easily classified as they grew, diversified and formed campuses. Thus a change from a strong to a weaker classification can be observed.

It was proposed to classify buildings based on relations. This is not a new concept and came out of the debates about *continuita*[7] where typology was a means of describing the relationship between buildings and the city and it was a way to show that *"an 'architectural event' was not just four walls and a roof, but something that existed only as part of the general urban phenomenon, considering both spatially, socially and historically."* (Forty, 2000, p. 308). Certain building forms and street patterns persisted throughout the history of cities regardless of the various uses to which they were put, and this could be taken as manifestations of 'type' (Rossi, 1982). These forms and patterns are a product of social forces and processes which Hillier and Hanson (1984) describe as the 'genotype' of space. An attempt to uncover the 'genetic properties' of hospital buildings and define typologies was made in this paper. However, further work is required for such a classification.

[7] from Italian meaning 'continuity'

9. Conclusions and further research

The aim of this paper was to classify hospitals and to investigate a possible relationship between quality of care and selected spatial metrics. The presented results suggest that the delivery of healthcare is influenced by the size of the hospital campus and its complexity. Such a relationship is likely and makes sense because smaller buildings, which consist of fewer separated buildings i.e. less complex, host smaller organisations which have better connections between different teams. This leads to better inter-departmental communication and thus better care. No significant difference in quality of care outcomes was found regarding age, compactness of the site, location, affiliation, funding as well as the spatial properties of the buildings. These results could give insights to future planning policies and new building developments on NHS hospital sites.

Several issues made the analysis difficult and it is considered that overcoming these limitations might affect results. Firstly, a more fine-grained numeric rating system for quality of care rather than a categorical ranking with few categories might deliver a clearer picture. For instance, the commission assesses 5 different areas giving rates from 'outstanding' to 'inadequate' and then an overall rating. Thus, a hospital rated with 3 'good' and 2 'requires improvement' judgements would have the same rating as a hospital rated with 4 'good' and 1 'inadequate'. Secondly, as some of the information was retrieved manually, the task of gathering data on thousands of instances was impossible. Details were collected only for selected cases, which made the statistical analysis error prone and weaker. Thirdly, the spatial properties of the hospitals were calculated using outlines drawn from online mapping applications, which affected the precision of results. Moreover, some of the inherent properties of multi-level hospital buildings were hidden by the outlines.

On the one hand further research should focus on the need to prove and study the detailed mechanism behind the relationship between building size and complexity, communication and quality of care with a more in-depth understanding of single cases. On the other hand, a bigger and more complete and fine-grained data set would help to understand the top-level relationship.

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